

New Scientist

WEEKLY 9 December 2017

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as well as your brain

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CASEY KELBAUGH/REDFUXANT/VEVINE

Don't drop the ball now

The biosphere is still in decline, but we must not give up hope

"HUMAN beings and the natural world are on a collision course. Human activities inflict harsh and often irreversible damage on the environment and on critical resources. If not checked, many of our current practices put at serious risk the future that we wish for human society and the plant and animal kingdoms, and may so alter the living world that it will be unable to sustain life in the manner that we know. Fundamental changes are urgent if we are to avoid the collision our present course will bring about."

Hazard a guess as to when those words were written. Last month? Or 25 years ago?

The answer is "both". The *World Scientists' Warning to Humanity* was originally issued in November 1992, backed by more than 1700 signatories including most of the science Nobel prizewinners alive at the time. It was reissued last month, this time with the backing of 15,364 scientists – and an even blunter message. "Humanity has failed to make sufficient progress in generally solving these foreseen environmental challenges, and alarmingly, most of them are getting far worse."

So has nothing really changed?

Has 25 years of effort been wasted? Maybe things could have been even worse, but it is clearly not mission accomplished.

Perhaps it was always *Mission: Impossible*. Warnings from experts often fall on deaf ears, or worse are counterproductive. In these febrile, populist times they are easily dismissed as the sanctimonious preaching of an out-of-touch elite. The world appears to be in no mood to listen.

This puts scientists of all kinds – but especially environmental ones – on the horns of a dilemma.

"Despite all the problems, there is remarkable optimism that the message is getting through"

Documenting the decline of the biosphere is their day job, and many feel it is their duty to warn the world. But they also know their message will be met by widespread fatigue, cynicism or outright denial.

Meanwhile, the news from the coal face gets worse. Climate change – identified as "especially troubling" in the second warning – appears to be significantly worse than we thought (see page 9).

Even seemingly innocuous local actions can have global impacts. One of the natural world's great spectacles, the migration of mammals across Africa, is being killed by fences erected by cattle farmers (see page 32).

But despite these problems, there is remarkable and resilient optimism among scientists that their message is getting through. Progress has been made on the ozone layer, on deforestation and on renewable energy. The Paris Agreement is far from perfect but is more ambitious than anyone could have hoped for 25 years ago, says Peter Frumhoff, chief climate scientist at the Union of Concerned Scientists. None of this would have been achieved without the drumbeat of evidence-based warnings coming from the world of science.

Admittedly, it is hard to believe that in another 25 years scientists won't be issuing another warning. Humanity's problems run deep; our collective ability to tune out news we don't want to hear is one of them. But if scientists – and science magazines – give up trying to break through, we might as well pack up and go home now. ■





MATTHEW SCOTT LUSKIN

Nowhere to live

Last tiger strongholds

SUMATRAN tigers are running out of places to live. Their population fell by 16.6 per cent from 2000 to 2012, and the survivors live in shrinking forests.

"We're really at a tipping point," says Matthew Luskin at Nanyang Technological University in Singapore.

The Sumatran tiger (*Panthera tigris sumatrae*) only lives on Sumatra, Indonesia. It is critically endangered.

Luskin and his colleagues tracked tigers there using cameras to estimate how many are left. They focused on females able to breed. Populations with at least 25 breeding females are best, to avoid inbreeding.

There are now only two such viable populations, down from the 12 that were thought to have existed 70 years ago (*Nature Communications*, doi.org/cg2t).

The decline is driven by rapid loss of habitat. Indonesia has the fastest deforestation rate of any country: it lost 37 per cent of its primary forest between 2000 and 2012.

In the past 20 years, there has been a big effort to save the tigers. On one measure, it has worked. Tiger population density rose 4.9 per cent annually between 2000 and 2012.

But "while anti-poaching efforts have been successful", says Luskin, "at the same time, so much forest has been lost that it has offset those commendable conservation gains".

We must protect the two viable populations, says Joe Walston at the Wildlife Conservation Society in New York. Tigers there could ultimately restore other populations. "This is a very clear call to arms."

Euthanasia bill

VICTORIA has become the first state in Australia to legalise euthanasia. The state's parliament passed the Voluntary Assisted Dying Bill last week after more than 100 hours of debate.

"This will give people in Victoria the compassion and dignity they deserve at the end of their lives"

From June 2019, terminally ill people in Victoria who are over the age of 18 will be able to request a lethal drug to end their lives. A medical assessment will be required to confirm that they are expected to live for less than six months. If someone's request is approved, they will have to administer the drug themselves, unless they are physically unable to do so.

The legislation includes 68 safeguards to prevent foul play, such as criminal offences to stop vulnerable people from being coerced into ending their lives.

The move gives Victorians "the compassion and dignity

they deserve at the end of their lives", says Daniel Andrews, the premier of Victoria.

An 18-month period will now kick off to work out the details of implementing the legislation, including the type of drug that will be prescribed.

Other states and territories in Australia will be watching Victoria closely. A similar bill failed to pass the New South Wales parliament by a single vote last month.

Euthanasia or assisted suicide is already legal in several places, including Germany and some US states.

Voyager reborn

IT'S alive! By firing thrusters that have been gathering dust for almost four decades, NASA has extended the lifetime of the Voyager 1 mission by a few years.

The interstellar probe is 13 billion miles away and moving faster than 17 kilometres per second, but it still manages to send messages back to Earth. To do that, it needs to keep its antenna pointed towards us.

After 40 years in space, the thrusters that orient the spacecraft and keep its antenna

aiming in the right direction have started to break down.

NASA engineers decided to try firing the craft's backup thrusters, which have been dormant for 37 years. After initiating a test of them, engineers had to wait 19 hours and 35 minutes to get a signal from Voyager 1 just past our solar system. The long shot worked, and the team plans to fully switch over to the backup thrusters in 2020.

By swapping the thrusters, Voyager 1 may be able to keep sending us messages for a little while longer, until around 2025.

Ivory non-ban

JAPAN has ducked tough measures to clamp down on domestic ivory sales. The move could undermine the effort to halt the ivory trade.

Elephants are poached for ivory, which is sold in Asian countries. The trade threatens their survival.

The standing committee of the Convention on International Trade in Endangered Species met last week in Geneva, Switzerland. Countries lobbied for Japan to launch a national ivory action



ISSEIKATO/REUTERS

Hankering for a hanko

plan. This would have forced it to take firm steps, like banning the domestic trade in antique ivory.

However, Japan sidestepped the proposal. "It's let Japan off the hook," says Matthew Collis at the International Fund for Animal Welfare. In contrast, China aims to close all loopholes by year's end.

Animal welfare groups fear the failure to limit ivory sales in Japan could offset the benefits of bans elsewhere. They say criminals could sell illegal ivory objects by passing them off as antiques.

Antique ivory is sold in Japan in the form of chopsticks, figurines and letter stamps called hanko.

Missile launched

ON 28 November, North Korea launched an intercontinental ballistic missile towards Japan. It was the latest in a series of more than 20 test missile launches this year and the third aimed in the direction of Japan since August.

Before splashing down in the Sea of Japan, the missile covered about 960 kilometres in 50 minutes, reaching an altitude of 4475 kilometres – about 10 times as high as the orbit of the International Space Station.

"If these numbers are correct, then if flown on a standard trajectory rather than this lofted trajectory, this missile would have a range of more than 13,000 kilometres," wrote David Wright, a US missile scientist at the Union of Concerned Scientists in Cambridge, Massachusetts, in an online post. "Such a missile would have more than enough range to reach Washington, DC."

In response, the South Korean military performed a "precision missile-firing drill", according to the South Korean news agency Yonhap. Japanese prime minister Shinzo Abe called an emergency meeting of his cabinet.

President Trump responded by tweeting the next day, "Additional major sanctions will be imposed on North Korea today."

NHS culls drugs

AN UPDATE to National Health Service guidelines means patients in England are set to lose access to a raft of prescription drugs. Some headlines have decried this, but the 18 drugs that have been listed under "do not prescribe" are now considered to be either too expensive, ineffective or dangerous.

One is doxazosin, which is used to treat prostate enlargement. The slow-release form of the drug costs about six times as much as the form that works immediately, but there is no evidence that there

are any additional benefits to taking it. The NHS currently spends £7.7 million prescribing slow-release doxazosin, so will save a lot of money by swapping to the cheaper version of the drug.

The guidelines list 17 other examples of drugs that should no longer be prescribed for similar reasons.

Among the drugs listed are homeopathic treatments – highly diluted substances that are no more likely than a sugary sweet to cure your ills. The NHS spends more than £92,000 a year on homeopathy, despite a wealth of research dismissing it.

World's richest science awards

THE richest prizes in science, the Breakthrough Awards, were presented at a star-studded ceremony in California on Sunday.

Seven prizes, each worth \$3 million, were awarded across three categories: fundamental physics, life sciences and mathematics.

In physics, the award was divided between the 27 members of the team that mapped the temperature of the cosmic microwave background using NASA's WMAP satellite. The pattern of hot and cold spots seen in this radiation leftover from the big bang 13.7 billion years ago has advanced our understanding of the origins and evolution of the universe and transformed cosmology

into a precision science.

Christopher Hacon at the University of Utah and James McKernan at the University of California, San Diego, share the prize in mathematics for their contributions to algebraic geometry.

Five prizes were given to researchers working in the life sciences, including to Don Cleveland at the University of California, San Diego, for his insights into diseases of the brain and nervous system. Seven prizes worth \$100,000 each went to early career scientists.

The Breakthrough prize was founded in 2012 by Silicon Valley entrepreneurs Mark Zuckerberg, Priscilla Chan, Anne Wojcicki, Yuri and Julia Milner and Sergey Brin.



Star-studded ceremony

60 SECONDS

Musk's hot wheels

Elon Musk has announced that the first flight of SpaceX's Falcon Heavy rocket will carry his car to Mars. The Tesla Roadster "will be in deep space for a billion years or so if it doesn't blow up on ascent," he said. Falcon Heavy is set to launch in January and will be the most powerful launch vehicle since the Saturn V rocket that took astronauts to the moon.

City rats don't mix

A study of the DNA in brown rats living on New York's Manhattan island found a distinct difference between rodents from uptown and those from downtown (*Molecular Ecology*, doi.org/cgz7). The middle of Manhattan doesn't have as many habitable spaces for rats, which may be why that is the dividing line between the two populations.

Mirrored vision

The scallops have eyes – 200, in fact, each the size of a poppy seed. As if that wasn't enough, each one has two retinas, one that sees dimmer light from peripheral vision, and the other tuned to bright light (*Science*, doi.org/cgz8). A miniature mirror behind the retinas works a bit like a telescope to direct each type of light.

Cats on the blockchain

More than 15 per cent of the traffic on Ethereum, one of the biggest blockchain platforms, is from people playing *CryptoKitties*, a game where you collect cartoon cats. Each transaction to breed or trade kittens is completed using Ethereum's blockchain. One cat sold for the equivalent of \$118,000.

HIV transmission halted

Antigua and Barbuda, Bermuda and four places in the Caribbean have eliminated mother-to-child transmission of syphilis and HIV, the World Health Organization certified last week. They join Cuba, Thailand and Belarus on the list of countries to achieve this so far.

Welcome to the limb lab

The daring experiment to keep organs alive on shelves for days

Clare Wilson

I'M GREETED by the sight of several litres of pig's blood being poured into bags on a hospital drip-stand. The red splashes on the wall and the stainless steel counters make the place feel like a butcher's shop, but it is something altogether different. This is James Fildes's workshop, where he is trying to reanimate detached body parts.

Based at the University of Manchester, UK, Fildes is mainly working with pig legs and organs sourced from a local abattoir. But he is also experimenting with human organs deemed unsuitable for transplants, when they are available. The body parts are hooked up to a blood supply, which nourishes them with food and oxygen. It may sound gruesome, but this work could make more organs available for transplant, lead to new ways to treat cancer, and allow more limbs to be reattached after accidents.

The standard way of preserving a limb or organ for transplant is to put it in an ice box, similar to the kind of cooler you might use to keep beers cold. But after a few hours in cold storage, the tissue begins to deteriorate.

Some hospitals perfuse organs with blood for a few hours. Doing this gives doctors the time to check if the organ is healthy enough for transplant, or provides a longer window to transport it across the country and get a suitable recipient ready for surgery.

But Fildes's team wants to keep body parts alive for much longer. The group's record so far is keeping kidneys going for 24 hours. The team hopes to soon keep a limb alive for two days, hooking it up to kidneys that will keep its perfusion fluid clean.

There could be several advantages to letting a limb sit on a shelf for a day or two. When an organ that has been on ice is put straight into a patient, the shock of oxygen returning to it can cause inflammation. This may

"Surgeons had to throw one man's hand in a bin. If he'd been less injured, it could have been reattached"

trigger the recipient's immune system to reject the organ.

But Fildes has found that perfusing an organ with warm blood in the lab for long enough – perhaps about 6 hours – allows this inflammation to pass. "You get it out of the way before you

transplant," he says. This may reduce the risk of rejection.

People who lose limbs in accidents may also benefit. Immediately after a bad crash or a bomb blast, for example, people are often too ill to have parts reattached. The window in which it can be done is lost.

Plastic surgeon Kavit Amin of Manchester University NHS Foundation Trust has seen this happen with survivors of motorbike crashes. One example was a man in his 20s, who lost his hand. "We had to throw it in the bin. And it was such a clean cut."

But being able to keep a limb perfused with blood for several days while its owner is in intensive care could let them

get well enough for reattachment at a later date.

When Amin lugs in the first pig leg of the day – complete with skin and hair – it is reminiscent of something I might have for my Sunday lunch (excluding the trotter). But that impression vanishes when the leg is hooked up to the system. A short tube that had been sewn into the main artery is now connected to a blood supply.

Coming back to life

Soon the limb starts to look more alive: the skin flushes pink as circulation returns, and the muscles begin to twitch. Nearby, two kidneys are starting to produce urine. I can't see any today, but Fildes says hooked-up hearts beat in the workshop for hours at a time.

If the team is successful, its techniques could open up other new medical approaches. A doctor may be able to cut off a limb that harbours an aggressive cancer, blast it with an otherwise lethal dose of chemotherapy, and sew it back on later, for example.

Or injured limbs could be reconstructed without having to keep a patient under anaesthetic. "If you had a really mangled hand and it was in lots of different parts, you may want to fix it on the machine, and only then put it back on the patient," says Jason Wong, a plastic surgeon at Wythenshawe Hospital in Manchester.

Fildes can envisage his equipment one day being turned into a device portable enough for the battlefield. It will need some refinement, though – the current version is springing leaks and the lab floor is starting to resemble a bloody crime scene. ■



SAM WONG

Flushing and twitching

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Early Earth got an injection of heavy metal

LEFTOVERS from the moon's formation may have tunneled to Earth's core, and make up far more of our planet than we once thought.

Four-and-a-half billion years ago, when Earth had barely cooled off from its initial formation, a world the size of Mars collided with Earth and sent debris mostly from the mantle into space. This formed the moon. For the next few hundred million years after that other large bodies kept smacking into Earth. Some of those were so large they had their own iron cores.

Using known models of impacts Simone Marchi at the Southwest Research Institute in Boulder and his team simulated the after-effects of these large impacts and found that much of the time, the core material of the body smashing into the planet was either flung into space or tunneled straight to the Earth's core (*Nature Geoscience*, doi.org/cgzx). Not much ended up in the mantle.

According to earlier estimates, about 0.5 per cent of our planet's mass came from swallowing parts of planetesimals just after the "big splash" that formed the moon. Marchi's team at SWRI and colleagues at the University of Maryland have now upped that percentage to between 1 and 2.5 per cent.

That may not sound like much, but it helps explain something odd about the mantle, the part of Earth's interior between the crust and the core. Earth's mantle has a lot of siderophile elements, metals with a chemical affinity for iron, but they're not evenly spread out. The core of the impactor did not mix well with Earth's mantle and a lot reached our core.

Erik Asphaug at Arizona State University in Tucson says Marchi's model - good as it is - won't be the last word. "I'm not ready to hang my hat on any of these models", as there are assumptions built into the simulations about the behaviour of iron cores that might not be completely correct, he says. Jesse Emspak ■



Earth is toast

We will get roasting with shock rise in warming

CHILDREN born now could live to witness the planet warming more than 4°C, even if we cut greenhouse emissions by a fair amount. That's one of the terrifying implications of a study that adds to the growing evidence that the "official" projections underestimate future warming.

"Basically, it shows between 10 and 20 per cent more warming than previously reported," says Patrick Brown of Stanford University in California.

The biggest problem for global warming forecasts is that we don't know how much more carbon dioxide and other climate-altering stuff will be released. Even if we assume greenhouse gases reach a specific level, climate models still produce a wide range of results.

To narrow that range, Brown and Ken Caldeira, also at Stanford, tried to pick the climate models whose projections to date best match real-world data.

They chose several measures: for instance, how much heat is escaping from the top of Earth's atmosphere. This is a direct measure of how much the total heat content of the sea, air and

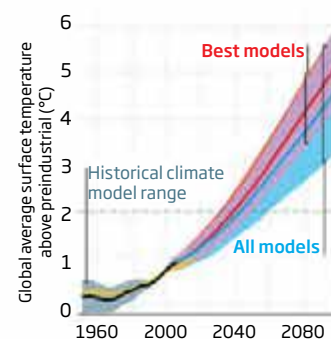
land surface is changing. Models that handle this well should be better at forecasting long-term temperature change.

"Warming is fundamentally a result of these radiation changes," says Brown.

Brown also looked at how well models predict monthly shifts in temperature. The idea here is that such changes in regions like the tropics are determined by clouds. Because clouds respond strongly to changes in temperature, models that are good at predicting

More warming projected

The models that best simulate the current climate are the ones that forecast higher temperatures



SOURCE: NATURE 2007

these short-term changes should also be good over the long term.

Once Brown had picked the best-performing models, he found they tend to project more warming (*Nature*, DOI: 10.1038/nature24672). "The

"It is now completely clear that our best models predict more warming than the average model"

models that warm the most are also the ones doing the best right now," he says.

For instance, for a scenario called RCP8.5 in which emissions continue unabated, the models used by the Intergovernmental Panel on Climate Change project an average of 4.3°C warming by 2081 to 2100, plus or minus 0.7°C. But the best-performing models project 4.8°C, plus or minus 0.4°C.

For a scenario that assumes more action is taken to combat climate change, called RCP6, the IPCC models project 2.8°C on average, compared with 3.2°C for the best models. The world is currently on a course somewhere between these two scenarios.

"It is now completely clear that our best models predict more warming than the average model," says Steven Sherwood of the University of New South Wales in Australia. In 2014, he drew this conclusion by a different method.

Clouds are key to these models' stronger warming response, says Kate Marvel at Columbia University in New York. "They project that clouds will block less sunlight in the future," she says.

Still, even the best-performing models may be wrong, Brown says. They may even underestimate warming.

For instance, models tend to assume soils will take up more carbon as the planet heats up. But a recent study found that soils will release a lot of carbon.

"There's a lot we don't know, but that doesn't mean everything's going to be OK," says Marvel. Michael Le Page ■

The body language of a natural boss

Helen Thomson

WITHOUT realising, we can tell who is likely to become a leader, automatically giving them more of our attention.

When a group of people who don't know each other meet for the first time, leaders naturally emerge – it helps us solve many social challenges. We use signals like charismatic behaviour and vocal cues to infer leadership qualities. But Fabiola Gerpott at Vrije University Amsterdam in the Netherlands and her team wondered whether such signals triggered more automatic changes in who we pay attention to.

They filmed meetings held by teams who had never met before over a period of seven weeks. At the end of this time, independent mentors rated each team member on whether they had emerged as a leader or follower. The researchers then edited the videos into 42 soundless clips, and showed them to 18 new people.

As the volunteers watched the videos, the researchers measured where they were looking, and for how long. They found that the volunteers looked more often,

and for longer, at people who went on to become leaders within the group, on average.

"This is not something we would be consciously aware of," says Gerpott. She says it may be evolutionarily useful. "In the past it might have been very helpful to recognise very quickly who was the person you should follow."

To find out how the leaders were able to trigger changes in others' attention, the team analysed how the people behaved.

They found that emerging leaders used active gestures more often, such as constantly moving their bodies and large hand movements. They also had passive facial expressions less frequently, such as yawning or staring blankly. Smiling made no difference – both followers and leaders used positive facial expressions an equal amount (*The Leadership Quarterly*, doi.org/cgzs).

"To make yourself stand out as a leader you need to use more active body language, and make sure you are not being passive in your facial expressions when others are talking," says Gerpott. "Try to engage non-verbally in the discussion. Being present with your whole body and

expressions can help you be perceived as a leader."

Simon Ho at the University of British Columbia, Canada, recently found that vocal pitch can signal if someone intends to dominate or submit to another person. Gerpott's team is now studying how vocal cues and body language may work together to signal leadership.

Gerpott's unpublished data suggests that talking a lot helps to signal leadership, but what a person says becomes more important over time.

"Initially talking a lot and being present in the discussion is important, but as the discussion develops it's more about what you say," says Gerpott. "Being a solution-orientated person who doesn't focus on problems is what seems to pick you out as a leader."

The team's results also suggest women face additional obstacles in becoming leaders. In situations where women went on to emerge as leaders, people spent slightly less time looking at them than they did at men who went on to become leaders in other scenarios.

"If we confirm that there's a preference for male emergent leaders then that could explain why more men end up in leadership roles," says Gerpott. "Perhaps it's easier for men to emerge as leaders because of this automatic bias that we have to focus our attention on them." ■



PLAINPICTURE/CAVANI IMAGES

Born leader

Alien life could be shielded by seas or smog

THOUGH they seem inhospitable, red and white dwarf stars could host planets with life forms.

These stars have narrow habitable zones – the areas around them where planets could have liquid water – yet their prevalence makes them tempting targets in the search for life. Any planet in such a star's habitable zone is close enough to be tidally

locked into a perpetually blazing dayside and frigid eternal nightside or, worse, shredded by tidal forces.

"If you park a planet in a habitable zone around a white dwarf, it will stay there for a very, very long time – potentially enough time for life to manifest. The problem is getting [the planet] there," says Jason Nordhaus at Rochester Institute of Technology, New York.

A white dwarf forms when a star puffs into a red giant, destroying nearby planets before collapsing. Any planet with life must have formed from the rubble or been nudged in

from further out. A migrating planet would need to shed enormous energy to get close to its star, but doing so could make it burn into an ember.

Red dwarfs are another option. These create stable systems where life might evolve. But they also hurl violent radiation flares, while their powerful solar winds strip protective atmospheres. Magnetic fields could protect a planet from solar winds.

"Hydrocarbon vapour clouds absorb radiation. It's not an ozone layer, it's a smog shield"

Alternatively, a thick haze like the one on primordial Earth or now swathing Saturn's moon Titan might survive the solar flares, says a team led by Matt Tilley at the University of Washington (arxiv.org/abs/1711.08484).

"Floating droplets of hydrocarbon vapour clouds are really efficient at absorbing ultraviolet radiation," says Jaymie Matthews at the University of British Columbia, Canada. "It's not an ozone layer, it's a smog shield."

Even without an atmosphere, oceans could survive under ice. Deep enough oceans could also shield life, says Matthews. Mika McKinnon ■

Bionic ovary fine-tunes menopause

WHAT'S the best way to relieve the symptoms of menopause? An artificial ovary may be the answer.

Many women experiencing menopause struggle with weight gain and a loss of bone density. Hormonal replacement therapies can help, but getting the doses wrong can raise the risk of heart disease or breast cancer.

Emmanuel Opara at Wake Forest School of Medicine in North Carolina thinks this is because HRT is too simple; it only supplies oestrogen, progesterone or testosterone, or a combination of these. His team has created capsules of ovarian tissue that, once implanted, can supply the full range of ovarian hormones.

The capsules are about half a millimetre wide and are made of layers of ovarian cells that mimic the structure of an ovarian follicle. To see if they work, the team implanted them into rats that have had their ovaries removed – a process that mimics menopause.

Removing the ovaries led to a drop in oestrogen and progesterone, but soaring levels of other hormones. Giving rats HRT boosted oestrogen and progesterone, but didn't bring these other hormones down. However, rats with a bioengineered follicle had more normal levels across the range of ovarian hormones (*Nature Communications*, DOI: 10.1038/s41467-017-01851-3).

This seemed to benefit their health. Both groups of rats gained less fat and lost less bone mass, but the effect was stronger in those given follicles. Opara thinks these results suggest a similar implant could help women.

"This research is a significant step towards creating a bio-ovary for management of the menopause," says Susan Davis of Monash University in Australia. But she says it may be hard to create capsules that suit each woman's individual hormone levels.

Women may also be unwilling to undergo surgery. Jessica Hamzelou ■



LAURIE CAMPBELL/NATUREPIL.COM

Live birth is so 2 million years ago

Lizards do evolutionary U-turn over babies

WHICH came first, the lizard or the egg? In at least one species, we have an answer: the lizard first gave birth to live young and only later re-evolved the ability to lay eggs. It's a rare example of a complex lost trait re-emerging in a species.

The common lizard is found across Eurasia from Ireland to Japan. Its name *Zootoca vivipara* means "live-bearing" in both Greek and Latin, and as you might expect, it gives birth to its young.

But there are exceptions. Two small populations on the edge of the lizard's range lay eggs. One of these subspecies is found near the border between Spain and France, the other in the southern Alps.

Biologists had assumed these subspecies were remnants of an egg-laying ancestral population from which the live-bearers evolved – something that seems to have happened over 100 times in reptiles. But genetic data from the lizards did not fit this simple story.

One suggestion was that live-bearing evolved twice. Another

was that egg-laying reappeared in one group, but this was thought to be unlikely.

"There is not really any consensus," says Kathryn Elmer of the University of Edinburgh, UK. So her team collected 76 lizards from around Europe and carried out thorough genetic studies, looking at over 200,000

"Evolution often changes direction, but rarely long enough for a complex trait to reappear"

sites in the genome. They used this data to build a detailed family tree of common lizards.

The tree shows the egg-laying lizards in the southern Alps are a remnant of the ancestral group. Live-bearing lizards evolved once from this ancestral population and split into several groups. In one group, egg-laying reappeared, creating the Spanish population (*bioRxiv*, doi.org/cgx8).

"I consider this strong evidence of regaining egg-laying," says April Wright of Southeastern

Louisiana University. In 2015 she found hints of three other cases of egg-laying re-emerging in lizards.

We don't know how or why common lizards began to lay eggs again. It must have happened recently, as these lizards only became live-bearing around 2 million years ago. Perhaps the genetic program used in egg-laying lay dormant for that time, then was reactivated.

However, snakes called sand boas may have re-evolved egg-laying after 60 million years. The old program probably didn't last this long, so sand boas may have evolved this trait from scratch.

It is becoming clear that evolution often changes direction. On one Galapagos island, finches evolved thicker beaks during a dry period when small seeds were rare, then swapped to thin beaks when the climate became wetter.

But it is a different matter for evolution to go into reverse long enough for a trait as complex as egg-laying to reappear. "I think it's quite uncommon," says Elmer.

It does happen, though, contrary to a claim by 19th-century biologist Louis Dollo. His hypothesis, that such reversions are impossible, is wrongly called Dollo's law. Michael Le Page ■

Wayfarers of the ancient world

Joshua Rapp Learn

ARCHAEOLOGISTS have used drones and a cold war spy boat to identify three shipwrecks on the Mediterranean seabed. One holds artefacts dating back over 2000 years, hinting at a vast network of trade during the rise of ancient Greek city states like Athens.

"If our dates are correct, this is just as Alexander the Great is beginning his conquest," says team leader Ben Ballard at the Ocean Exploration Trust (OET), whose father Robert discovered the wreck of the Titanic.

In 2010 and 2012, Ben Ballard and his colleagues explored the Eratosthenes seamount, an underwater plateau south of Cyprus, on expeditions supported by the OET. They scanned the seamount using OET's Nautilus vessel, which was originally a spy boat built by East Germany in the 1970s, plus other technology such as underwater drones.

In 2010, the team found two shipwrecks and 70 artefacts. When they returned in 2012, they discovered a third shipwreck and 149 further artefacts. Two wrecks were Ottoman vessels from the

19th century. The third dates to the 4th century BC, the time of Alexander the Great. The team has now described their finds (*Deep Sea Research Part II*, doi.org/cgx2).

Eratosthenes seamount is an ideal preservation site because of its depth. At 600 to 800 metres down it is deep enough not to be disturbed by trawlers, but shallow enough to be accessible – unlike most of the Mediterranean, which averages 2100 to 2600 metres deep. It is also far from the coast,

so artefacts haven't been buried by sediment flowing off the land.

"Deep water has an advantage in that it hasn't been looted, it hasn't been trawled," says archaeologist Jon Henderson at the University of Nottingham, UK.

Ballard says the Mediterranean seabed probably holds thousands of wrecks from the last few millennia. Still, individual boats are hard to find. In order to discover them, the researchers followed ancient trash trails.

Ancient mariners often cast large clay jars called amphorae into the sea after using up contents like wine. So many were dumped that they can be followed like a breadcrumb trail.

Based on the jars' styles, the

team dated them from 800 BC onwards. They came from all around the Mediterranean, including Egypt, Greece and Phoenician cities in the area of what is now Lebanon.

The finds are evidence for trading across the Mediterranean by 350 BC. "This is at the time of the rise of the Greek city states," says Ballard. "You have thriving trade between Greece, between Asia Minor and Egypt, you have the copper mines in Cyprus."

Some of the amphorae come from the Greek island of Chios, which at the time was noted for its excellent wine. Some ancient sailors, it seems, were drinking the good stuff. "It shows there was a taste for expensive goods even back then," says Henderson.

One piece may date from as long ago as 1500 BC – the time of the Mycenaean Greek civilisation, which legend says fought the Trojan war. It came from Canaan, so its presence suggests there was widespread trading even then.

It may also be significant that the ships ranged so far out to sea. Many scholars have assumed that ancient mariners feared the open sea and so clung to the coast. But Ballard says it is clear some took shortcuts across deeper waters.

Henderson says archaeologists talk a lot about agricultural and industrial revolutions, but not enough about the seafaring revolution and its significance. ■



Their trash is our treasure

Eyes linger longer on ultra-macho monkeys

FEMALE monkeys spend more time staring at males with masculine faces. But it's unclear why their gaze lingers.

Faces often vary between male and female members of a species. Human males often have heavier brows, squarer jaws and deeper-set eyes. It may be that facial masculinity signals mate quality, but nobody knows.

To find out, Kevin Rosenfield, then

at Roehampton University in the UK, and his colleagues studied rhesus macaques in Puerto Rico. Each female was shown two photos of male faces, one with a bigger jaw, longer nose and smaller eyes.

When the two faces had similar levels of masculinity, the females spent equal time observing them. But when the differences were obvious, they spent an average of 1.9 seconds staring at the more masculine face, and 1.5 seconds looking at the less masculine one (*bioRxiv*, doi.org/cgxz).

There are several possible reasons, says Rosenfield, now at Pennsylvania

State University. Females may have been attracted to masculine faces, perhaps linking them with better genes, or scared because they associated them with aggression.

In humans, masculine faces and high levels of testosterone are linked. This dampens the immune system, so too much might be bad. However, maybe only high-quality males can tolerate excess testosterone and

"It's like a guy saying, 'Look at me ladies, I'm such a high-quality male that I can waste money on a Ferrari'"

waste energy on masculine features.

"It's a bit like a guy saying, 'Look at me ladies, I'm such a high-quality male that I can waste money on buying a Ferrari and I'm still fine,'" says Ian Stephen at Macquarie University in Sydney, Australia.

Alternatively, females may choose macho males because they are better at competing for food and fending off attacks, says Barnaby Dixon at the University of Queensland. This fits with human studies suggesting that women tend to be more attracted to macho men in societies where crime and violence are rife. Alice Klein ■

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City ruins can tug at purse strings

Timothy Revell

CAN you imagine what it is like living in Raqqa, Syria? Using AI to help you do so could be just what's needed to boost donations to overseas aid charities.

Only a few years ago, Raqqa was filled with impressive buildings and had more than 200,000 residents. Now, around 80 per cent of the city is uninhabitable, according to the United Nations. A combination of civil war and the battle against Islamic State has damaged it beyond recognition.

Such destruction is difficult for us to really imagine. This problem often leads to fewer people contributing to fundraising campaigns as they put such issues out of their minds. That is why UNICEF has teamed up with the Massachusetts Institute of Technology Media Lab to use artificial intelligence to bring things closer to home.

Using a technique called style transfer, the team created pictures of cities around the

world as if they had gone through the war in Syria. Their algorithm uses AI to learn from images what destruction of Syrian towns looks like and then transfers it to pictures of London, New York and elsewhere.

The results are striking. Piles of rubble amass in the streets and windows are blasted out. But will the images raise more money?

"Making things visual, salient and immediate are all powerful influences on thinking, emotions and behaviour," says Susan Michie at University College London, who isn't involved with the project. "I can see that this is likely to have the desired effect."

Before the website was launched, the team ran an experiment on the crowdsourcing platform Amazon Mechanical Turk. This involved 1000 paid participants looking at either real before-and-after images of a Syrian district or simulated before-and-after images of a war-wrecked US neighbourhood.

They were asked to imagine



Bringing war closer to home

what it would be like for such a disaster to happen in their backyard, and then asked if they would donate some of their payment to charities providing humanitarian aid in Syria.

The simulated images managed to raise 96 per cent as much in donations as the real images. Though this is slightly less, the team hope that refinements will vastly increase overall donations.

"It means we are doing almost as good. We will continue to test how to get the biggest effect," says Pinar Yanardag at MIT.

In the future, the team will also produce images relating to floods, wildfires and other disasters. "With things like climate change, we want to teleport people to the future so they realise that we should do something now," says Manuel Cebrian at MIT. ■

Inching closer to real quantum computers

WE ARE two qubits closer to useful quantum computers. That might not sound like much, but the quantum computing arms race playing out could eventually deliver the biggest breakthrough in technology since the advent of the computer itself.

In July, a quantum simulator with 51 quantum bits, or qubits, was announced. Now, a team led by Christopher Monroe at the Joint Quantum Institute in Maryland has gone two better. The latest 53-qubit device, made from a chain of 53

charged atoms, or ions, trapped in electric fields, has run scientific simulations that don't seem to be possible with everyday computers (*Nature*, doi.org/cgwr).

"This is real quantum hardware. This can be turned into a quantum computer without much changing," says Monroe.

Mikhail Lukin at Harvard University, whose group was behind the 51-qubit simulator, points out that "there's nothing special about 51 atoms or 53 atoms". He says his team chose their goal simply to outdo a 50-qubit device developed by IBM, though its capabilities are unclear.

Lukin offers three desirable traits for quantum computers. More qubits would mean computations on a larger

scale. Better coherence, or lack of disruption of quantum states, would mean more trustworthy results. And the ability to run more than one program, instead of having to build a specific computer for each task, would make them more useful in the real world. Ideally, we want all three.

Both teams' devices could go bigger, says Lukin. "Both simulators can certainly scale to about 100 qubits."

Daniel Lidar at the University of Southern California agrees, but points out this will require arranging atoms in a 2D grid, as the performance of

a chain of ions degrades as it gets longer. That arrangement is tricky to achieve, because it requires precise control of the ion positions. It may even require specially designed ions that can quench motion.

The choice of atoms each team used also affects size and coherence: Monroe's group used ions, whereas Lukin's used neutral atoms. "It's easier to have a larger array of neutral atoms, since they won't repel, and each can be trapped more easily," says Lukin. On the other hand, ion traps are more coherent, resulting in lower error rates in computation.

Monroe's team thinks their device could also be tweaked to run multiple programs, something no other device has managed so far. Mark Kim ■

"This is real quantum hardware that can become a quantum computer without much changing"

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Gotta check that phone

Tech addiction's chemical cocktail

Timothy Revell

IF YOU'RE glued to your phone, a chemical imbalance in your brain may be to blame. It seems that people who struggle with so-called tech addiction have more of a chemical that slows down brain signals, and less of a chemical that excites neurons. This difference may be why some people tip over into internet obsession.

Hyung Suk Seo at Korea University in Seoul and his team have scanned the brains of 19 teenagers who answered in surveys that their tech usage is detrimental to their lives, and compared the results with 19 others of similar age who said they had no problems with tech. The scan the team used can detect the levels of brain signalling chemicals called neurotransmitters.

Of the 19 tech addicts they examined, 12 undertook a course of cognitive behavioural therapy (CBT) designed to reduce the amount of time spent using technology. These participants then underwent a second scan.

The initial scans showed that those who were addicted had more of a neurotransmitter called GABA, which slows signals and is thought to help regulate anxiety, but less of the chemical glutamate, which causes neurons to become electrically excited. However, the relative amounts of GABA and glutamate converged towards more normal levels after CBT. These results were presented

"The rewards might not be as strong as in gambling, but can still lead to obsessive phone checking"

at the Radiological Society of North America meeting in Chicago last week.

It isn't clear why the people in this study had a GABA-glutamate imbalance, and if this might be a cause or effect of tech addiction. But Seo hopes the findings will help inform new treatments for people struggling to unhook themselves from their smartphones and the internet.

We don't have a clear picture of how widespread tech addiction

might be – or even if it really counts as an addiction. But Daria Kuss at Nottingham Trent University, UK, has found that two-thirds of smartphone notifications elicit a positive emotional response. "The rewards might not be as strong as substance or gambling addiction, but can still lead to people obsessively checking their phones," she says.

Technology companies know this, and have begun using insights from psychology to make people want to use their products more often, so it is no wonder that we constantly check our phones throughout the day. But this doesn't mean we are addicted.

"The term 'addiction' would be appropriate only for the very small minority of users who are compulsively chained to their smartphones, despite them now providing little or no fun, and instead causing clinically significant distress and impairment," says psychiatrist Allen Frances.

He previously chaired the Diagnostic and Statistical Manual of Mental Disorders task force, which guides mental health diagnosis in the US. The DSM has yet to include internet addiction as a diagnosis, for fear of mislabelling many of the 2 billion people around the world who are attached to their smartphones. ■

Let's look for dark matter in the light

WHAT if we've been hunting for dark matter in the wrong place? If the particles are small and interact even slightly with normal matter, we may be able to spot them above ground.

Dark matter detectors are usually placed deep in mine shafts so the rock above will deflect unwanted background radiation while allowing the passage of weakly interacting massive particles (WIMPs) – our best guess at the nature of dark matter.

It is possible dark matter may be less massive and able to crash into or bounce off regular matter. If so, Timon Emken and Chris Kouvaris at the University of Southern Denmark say that burying our detectors may be a mistake.

They simulated how light dark matter – particles with masses about the same as a proton or lower – would deflect and scatter as they pass through Earth and found that it might not reach far underground. They reckon there should be more of the dark stuff closer to Earth's surface, particularly on one side of the planet.

"If you put your hand outside of the car window, there are more molecules hitting your hand from the front than from the back, simply because you are moving against the molecules," Kouvaris says. "It's the same thing with dark matter as Earth moves through space." As the planet rotates, the "front" changes. This should cause a daily bump in the amount of light dark matter that we see at any particular detector.

Kouvaris says this daily variation should be highest in the southern hemisphere, and that a few detectors there could help either find light dark matter or rule it out as a major component of the universe.

Tongyan Lin at the University of California, San Diego, says it's not that simple. Even if we don't find it, tiny amounts could still exist. "It could always be 0.00001 per cent of dark matter and we may never be able to rule that out," she says. Leah Crane ■

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Why hummingbirds are so big-hearted

BIRDS fly better if they have big hearts. The best flyers, like hovering hummingbirds, have the largest.

When a hummingbird hovers, it beats its wings in a figure-of-eight pattern up to 80 times per second, much like a helicopter. This is energetically costly, says Roberto Nespolo at the Austral University of Chile.

But most birds don't fly this way. Some flap their wings up and down, like geese. Others, like eagles, soar on updraughts of hot air, while some ground-dwellers, like pheasants, undergo only short bouts of flapping.

In theory, birds using more costly forms of flying

should have larger hearts. The bigger the heart, the more blood a bird can pump to its flight muscles.

To find out, Nespolo and his team grouped 915 bird species by flight type and compared their hearts. Hummingbirds had the biggest hearts for their body size, at 3 per cent of their mass. In contrast, a pelican's heart is just 0.8 per cent of its mass.

The sizes of birds' hearts matched their flight mode. The optimal size for hovering was 2.43 times that for flapping and 3 times higher than gliding (*Journal of Experimental Biology*, DOI: 10.1242/jeb.162693).

It is surprising that flapping fliers had similar hearts to gliders, says Rebecca Kimball at the University of Florida. "I would have assumed that flapping flight would have required a lot more energy."

Hubble outdone in galaxy hunt

WE HAVE found dozens of odd galaxies too faint even for the Hubble Space Telescope to see. They lurk in a small portion of relatively dark sky within the constellation Fornax – the very region previously imaged by the Hubble Ultra Deep Field project.

Now astronomers have looked even deeper into this region using the Multi Unit Spectroscopic Explorer (MUSE) instrument at

the Very Large Telescope in Chile. They studied light from 1600 faint galaxies, including 72 not seen before (*Astronomy & Astrophysics*, doi.org/cgsd).

Generally, we detect galaxies by looking for their bright stars. But light from nearby bright stars can drown out dimmer galaxies like the 72 new ones, none of which contain stars Hubble can see.

The new galaxies all shine at

one wavelength of light known as Lyman-alpha emission, a result of the glow of hydrogen gas. Because MUSE divides light up into wavelengths, it detected a spike in that wavelength that would have otherwise been invisible.

Astronomers are not sure why these galaxies seem to shine in this way, revealing hydrogen but no stars. We know the stars ought to be there, because these emissions come from hydrogen ionised by stars.

Muscle molecule's protective power

A MUSCLE hormone may prevent complications from surgery.

Surgical procedures often involve restricting blood flow to organs to make them easier to operate on. But this can cause long-lasting damage because it cuts off oxygen and nutrients.

One way to limit this is to place a blood pressure cuff around the patient's arm before the operation and repeatedly squeeze and release it. This seems to train the body so it copes better when the blood supply to organs is cut off.

Now Chunyu Zeng at the Third Military Medical University in China and his team have found that this process works by stimulating muscles to release a hormone called irisin. Injecting mice with irisin before surgery reduced cell death, inflammation and swelling from surgery, and halved the death rate (*Science Translational Medicine*, DOI: 10.1126/scitranslmed.aaa06298).

Say goodbye to 'migraine days'

A DRUG can halve the amount of time that people are laid low by migraines.

Erenumab is an antibody that blocks a brain pathway involving a molecule called CGRP, which becomes more abundant during migraines. In a trial of nearly 1000 people who took the antibody or a placebo for six months, it was found to reduce the number of "migraine days" a person had by three or four days a month on average. It halved the duration of migraines in around half of those who took it (*New England Journal of Medicine*, doi.org/cgwh).

The study is a step forward for understanding and treating migraine, says Peter Goadsby at King's College Hospital in London, who led the trial.

Baby pterosaurs were helpless

THE largest ever trove of pterosaur eggs and embryos has been found in China. It provides evidence that the flying reptiles were born flightless, needed looking after and that their parents nested in colonies.

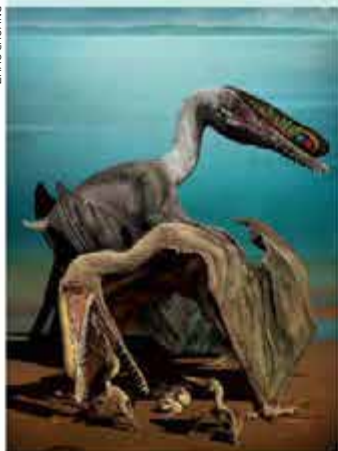
Pterosaurs evolved some 220 million years ago and only a few eggs and embryos have ever been found. The first fossil embryo was discovered in 2004, but was flat “like Cretaceous roadkill”, says Alexander Kellner at the Federal University of Rio de Janeiro in Brazil.

His colleague Xiaolin Wang at the Chinese Academy of Sciences in Beijing has now found 215 eggs from the pterosaur *Hamipterus tianshanensis*, each the size of a small chicken egg. The team used computed tomography to scan the eggs and found 16 held embryos (*Science*, doi.org/cgws).

Some embryos had fully formed femurs but not wings. Kellner says when *H. tianshanensis* hatched, it could walk around but not fly. The team says this means hatchlings needed parental care.

Previous studies suggested pterosaurs hatched ready to fly. That may be wrong, or *H. tianshanensis* may be an oddity.

The eggs held embryos in many growth stages, so cannot all have had the same mother. This suggests *H. tianshanensis* nested in colonies, says Kellner, like modern rookeries.



ZHAO CHUANG

Weird magnets could give computers breakneck speeds

STRANGE crystal magnets could lead to supercharged computers.

Historically, faster processors have been made by cramming more transistors onto silicon chips. However, there are limits to this. We have replaced silicon with magnetic solid state hard drives, but they, too, have physical limits.

To store data in such drives, the spin of tiny magnets are flipped up or down to represent the 1s and 0s of binary code. But these ferromagnets have a practical limit. They can only reorient themselves about a billion times

a second without vast amounts of energy input, limiting how fast they can efficiently save data.

Now, a team led by Tomas Jungwirth at the Czech Academy of Sciences has created a way to write data 1000 times faster on copper manganese arsenide crystals – a kind of material called antiferromagnets, in which adjacent atoms have spins in opposite directions.

The researchers made antiferromagnet squares about the width of spider silk to store each bit of data. Then they ran

extremely short electric pulses – lasting about a trillionth of a second – through them to flip the spins in each square. By firing pulses in quick succession, the spins could be flipped about a trillion times a second, they say (arxiv.org/abs/1711.08444).

It would take 1000 times as much energy to flip a ferromagnet this fast, says Jacek Furdyna at the University of Notre Dame in Indiana. He says this new material shows promise, especially as the experiment was done at room temperature.

Robofish sniffs out scent of drugs

A ROBOTIC fish may be an unlikely ally in the fight against antibiotic resistance. Swimming through streams and lakes, it will monitor the levels of antibiotics in the water, among other pollutants.

The prototype will soon be sent below the surface of the lakes near Michigan, which are under threat from industrial pollution and contaminants from farming.

“The water is getting increasingly contaminated with multiple pollutants,” says Alicia Douglas at the Water Rising Institute. Antibiotics are among them, she says, and are becoming a growing risk because we know so little about how they spread.

“The idea is to put sensors on the robots so that you can gather data from different locations in an automated manner,” says Xiaobo Tan at Michigan State University. By understanding the antibiotic levels in different parts of the lake, it should be easier to work out where they are coming from.

Robofish aren’t the only robots monitoring pollutants around the world. A robotic orca is tracking pollution in a reservoir in Tibet, and an artificial swan is doing the same in Singapore’s Pandan Reservoir.



TALA

Get a loan based on how you text

YOU might think your text messages have no bearing on your financial future, but you could be wrong. Some companies are using their customers’ smartphone habits to decide whether or not to lend them cash, according to a report by campaign group Privacy International.

The report looked at how tech-savvy loan companies operate in India and Kenya, finding them turning to increasingly intrusive sources of information to make decisions about their customers.

One example is an app called Tala that offers loans of up to \$500.

People give it permission to access their contacts, text messages and call logs, as well as GPS data showing where they have been. In exchange, they can get a loan in only 3 minutes.

Even if their loan application is rejected, Tala will keep on analysing their smartphone habits to assess their financial situation and may offer a loan if this changes.

Maria Frabboni, who researches intellectual property at the University of Sussex, UK, says the report raises concerns about how tech interferes with an individual’s notion of personal identity.



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Ban the bug?

The new weapons of war maliciously exploit software flaws. We need to talk about how we use them, says **Douglas Heaven**

US INTELLIGENCE agencies have been looking pretty stupid recently. Since last year, a group called the Shadow Brokers has been releasing cyberweapons stolen from the US National Security Agency. The WannaCry ransomware attack that knocked out computers across the world and shut down UK hospitals earlier this year was powered by one of these weapons, exploiting a vulnerability in Microsoft code.

The NSA is not sure how many other pieces of its arsenal have been leaked. “The US is battling a rearguard action with respect to its reputation,” says Tim Stevens at King’s College London.

If the US had lost control of a nuclear warhead, there would be global outrage, because a web of international treaties govern these dangerous weapons. But cyberweapons, which could

“If the US had lost control of a nuclear warhead, there would be global outrage”

cripple a nation’s infrastructure, come under no such regulations.

You might think this is just the stuff of techno-thrillers, and certainly the word “cyberweapon” is overly dramatic for what is ultimately mere lines of code. But malicious software is causing real harm. Countries like Ukraine are attacked regularly, which the nation has linked to Russia. With NATO recently asking members to contribute their cyber capabilities alongside tanks and aircraft, we need a global conversation about how these weapons are used.

Last month, the US kicked off that discussion with a new policy concerning the disclosure of vulnerabilities in computer

systems, just like the one used by the WannaCry attackers. The new rules outline how it will decide when to inform software manufacturers of zero-day vulnerabilities – bugs it has found that may be exploited to cause harm.

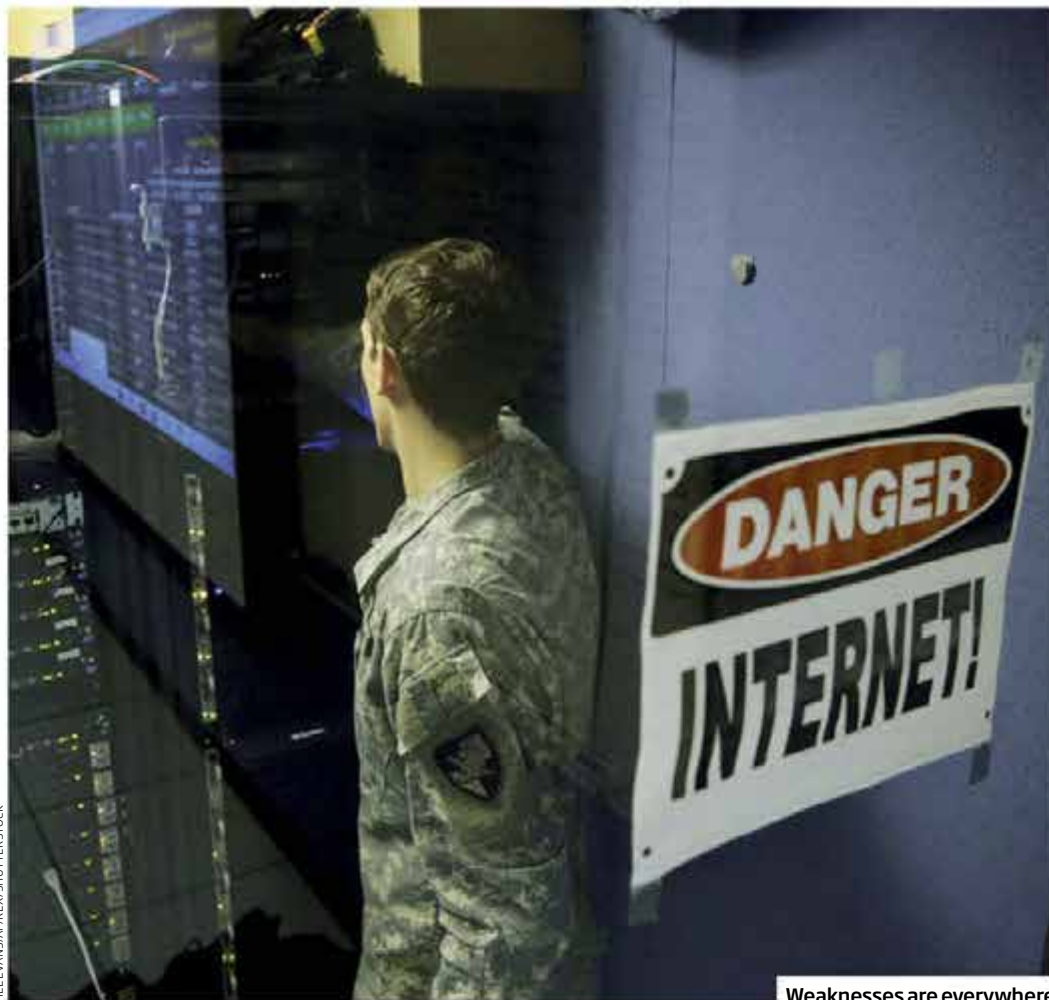
Could these guidelines mark the beginning of arms control for cyberweapons? And if so, is the US on the right track? “It’s a very early tentative first step in that direction,” says Stevens.

The guidelines describe basic trade-offs that must be considered before any disclosure. On one hand, telling a software firm that it has a dangerous bug allows it to patch the code and protect users. On the other, keeping that bug secret lets the US government exploit it. The guidelines say a review board should take the decision and then inform the US Congress about it.

But the guidelines are policy, not legally binding regulation.

And Edward Snowden, who exposed the secret US surveillance programme in 2013, has criticised loopholes that allow certain vulnerabilities to be exempt from disclosure. “The public harm of maintaining 10 high severity flaws far outweighs the benefit of disclosing 90 low severity ones,” he tweeted.

There’s also the matter of who decides what to disclose. The review board is almost exclusively from the security and intelligence



MELEEVANS/AP/REX/SHUTTERSTOCK

Weaknesses are everywhere

agencies, with no representatives from the public or software firms.

In any case, zero-day vulnerabilities are just one weapon in a digital arsenal. Think of a house, says cybersecurity researcher Max Smeets at Stanford University. A zero-day lets you pick the lock on the front door, but that's not much use if you can't get near the house in the first place.

For example, the Stuxnet worm, thought to have been created by the US and Israel to attack Iran's nuclear facilities, was delivered by an infected USB stick, because the target computers weren't connected to the internet. "This policy is far from a complete disclosure of the US's capabilities," says Smeets.

But even if it were, any meaningful cyberweapon policy must involve many countries. "It's essential we have an international conversation about this," says Stevens. Establishing how countries expect each other to behave would also prevent escalation, says international law researcher Louise Arimatsu at the London School of Economics. "We're all trying to avoid outright conflict."

Software stockpile

So what would arms control look like for cyberweapons? For other weapons, it requires establishing clear thresholds and agreeing on an inspection process that ensures the thresholds are met. With cyberweapons this would be difficult, or even impossible.

"When people started talking about cyber arms control a few years ago, they thought they could apply their experience with nuclear or chemical arsenals and have a treaty within 10 years," says Smeets. "Now they're realising cyber is unique."

With conventional weapons, you can try to limit the number a country has and the potential damage they could do. The 1974 Threshold Test Ban Treaty



Held for ransom

prohibits nuclear weapons of more than 150 kilotons, for example. But with cyberweapons, such measures are impossible, because malicious code can propagate unpredictably, as happened with WannaCry. "You can't just look at the code and say this will cause X amount of damage," says Smeets.

Even if you agreed thresholds, it would be hard to monitor them. Inspectors can visit nuclear enrichment facilities and audit missile stockpiles. But how would you inspect a cyberweapons programme? "You can't go through every USB stick that exists in a country," says Smeets.

Finally, tools to exploit zero-day vulnerabilities can only be weapons if they remain secret. Inspections that reveal their existence would make them worthless; something no country will accept, says Smeets.

Rather than focusing on the weapons, Smeets thinks we should be more concerned about proliferation. We might be able to persuade countries not to trade cyberweapons with rogue states, say. And if we can't control the weapons themselves, countries could reach agreement on acceptable use, such as no targeting critical infrastructure or financial systems.

Arimatsu says we may not even need an arms control treaty for cyberweapons. International law

already governs what states can and cannot do. If a country violates another nation's sovereignty or inflicts damage within its borders, it doesn't matter how it was done.

The trouble is that when countries get together to talk

"Inspectors can visit nuclear facilities, but how would you inspect a cyberweapon programme?"

about cyberweapons, they find a lot to disagree about. In 2004, the United Nations set up the Group of Governmental Experts (GGE) to improve the security of the world's computer and telecoms systems. After years of talks, the 25 member states agreed in 2013 that international law did in fact apply to the internet.

"That was a huge breakthrough," says Arimatsu. "But then they had to agree how it applied."

After more negotiations, the whole project fizzled out this June. The GGE failed to deliver a report because it couldn't agree what it should say. Michele Markoff, the GGE's US representative, claimed some countries seemed to believe there should be no constraints on their online actions. "That is a dangerous and unsupportable view, and it is one that I unequivocally reject," she said.

Smeets thinks the talks collapsed because countries

couldn't agree what kind of place the internet should be. Most Western nations believe in a free and open internet. Some, like China, believe we should have online borders that are governed and protected as extensions of a nation. Others, like Cuba, fear the militarisation of cyberspace.

That's not an unreasonable concern. In June, NATO announced that it would strengthen its cyberdefences, sharing more technology and know-how between its 29 member states. NATO has also decided that a cyberattack can trigger Article 5 of its treaty, which means an attack on one NATO state will be considered an attack on all – with the real possibility of retaliation. A response could involve a return cyberattack, sanctions or even the use of conventional weapons.

Some, like Stevens, believe the GGE meeting was our last chance for widespread international agreement on these issues. The most we can hope for now is for a few countries, like the US, to lead by example, he says.

But there's yet another thorn. When cyberweapons are used, it can be hard to know who deployed them – and harder still to prove it without risking security.

Take that house again. You could have CCTV that spots someone breaking in. You may know who the person is, but if you show your evidence you are telling people about your security system.

"Next time you want to get into my house, you'll know how to avoid the cameras," says Smeets.

So, cyberspace remains a shadowy place. "It's unlikely we will get international agreements on the use of these weapons," says Smeets. "And even if we do, they will be non-enforceable."

Arimatsu is more optimistic. She predicts that when more countries have been hit by cyberattacks, they will reconvene. "States are selfish," she says. "If they see their own rights being violated, they will want to invoke international law." ■

A blow to boundaries

Setting global limits for environmental damage is a flawed idea that we should abandon, argues **Stuart Pimm**

IT IS a seductive idea. So long as we keep the global impacts of human activity within set limits, we can carry on without jeopardising the ability of ecosystems to recover.

Breaching these “planetary boundaries”, goes the argument, takes us to tipping points: rapid and irreversible transitions to a world much less favourable to our existence. This idea combines the whiff of serious mathematics – catastrophe theory – with folksy wisdom that says “we’re safe, so long as we don’t cross the line”.

Alas, this is flawed. With the growing use of boundaries to guide policy, my colleagues and I felt the need to raise the alarm (*Trends in Ecology and Evolution*, doi.org/cgcg). First, there is no evidence that the natural systems in question work in this way. There are arguments that they cannot.

The original boundaries idea



looked at nine environmental processes affected by humanity, such as fresh water use, and the safe global limits for them. One of those – the extinction rate – was argued to have breached the limit of 10 per million species a year and was into tipping point territory.

An extinction rate changes over time and is often far from global in impact. In the minute when the last passenger pigeon died, the rate spiked. OK, so perhaps we must measure per decade. When Europeans reached many oceanic islands, it didn’t take them long to eliminate species, like the dodo on Mauritius. The global, decadal extinction rate would have been high. But why should events in Mauritius affect, say, the Amazon?

Perhaps, then, the total loss of species in a given place should be the measure. By now, the idea of a safe space based on extinction rates has lost all original meaning

Not of this world?

“Alien” bacteria found on the ISS are almost certainly of earthly origin, says **Geraint Lewis**

MYSTERY bacteria have been found in swabs of the outer hull of the International Space Station (ISS), according to Russian cosmonaut Anton Shkaplerov. He thinks the microbes couldn’t have hitched a ride during the station’s launch or on visiting spacecraft, concluding that they must have blown in from an extraterrestrial

source. Once a possible alien origin was mentioned, media speculation began.

This is not the first time such extraordinary statements have come from the Russians, who reported that sea plankton, a usually Earth-bound organism, had been found growing on the outside of ISS windows in 2014.

While that claim was dismissed by other scientists, details of the latest one are still scant. Cosmonauts have collected swabs from outside the ISS since 2010 as part of an ongoing experiment.

The notion of life surviving in the harshness of space is not new. Some have speculated that a younger, wetter Mars might have hosted life, later ferried to Earth in rocks blasted from the surface by meteor impacts. Others have considered the unlikely prospect

of life freely floating throughout the galaxy. By this “panspermia”, planets, including Earth, were seeded with life, they say. If so, this seeding could continue today.

But bear in mind that there has been no evidence for the arrival of extraterrestrial germs. What there is evidence for is the ability of terrestrial microbes to endure for months or years in space, shown in tests on the ISS. So, some hardy bacteria could survive space, and earthly contamination remains the obvious source for Shkaplerov’s findings.

A more intriguing possible path to contamination doesn’t require rockets to get it to the ISS. With an

“The ISS is not truly free of our atmosphere. Maybe high-altitude bacteria can be carried aloft to it”

and what constitutes a boundary looks arbitrary and unclear.

The boundary notion also isn't testable or applicable to the needs of those who manage nature. How do they measure a tipping point? And, given the idea's problems, what do they measure?

Third, though surely well-intentioned, there is a big moral hazard in invoking boundaries and tipping points. They can lead to pernicious policies. Their appeal is potent to interests that are harming the planet and which wish to continue doing so. After all, if the planet hasn't collapsed yet, we haven't reached the limit, so there is scope to carry on.

What to do? The UN Convention on Biological Diversity sets strict targets to address biodiversity loss, such as protecting 17 per cent of the land and 10 per cent of the oceans. Fine, but some desirable targets are less tangible: harmony, sustainability, health. These speak to the need to better grasp how our activity changes complex ecosystems, a need the boundary idea doesn't address. We must work to decipher this complexity and turn that knowledge into practical solutions. ■

Stuart Pimm is the Doris Duke professor of conservation ecology at Duke University, North Carolina

orbit that dips to 300 kilometres above our planet at times, the ISS is not truly free of the atmosphere and, maybe, high-altitude bacteria can be carried aloft, landing on the station. We know little about such bacteria, but while they might seem alien, their origin is certainly terrestrial.

Shkapterov returns to the ISS this month, and further tests may provide clues to the origin of his mysterious bacteria. Are these likely to reveal the presence of alien germs? Given what we know, don't bet your house on it. ■

Geraint Lewis is an astrophysicist at the University of Sydney

INSIGHT Food storage



ANDRII RAFALESKYI/LAMY

Must we trade flavour for shelf life?

The great tomato fridge debate

Sam Wong

TOMAYTO, tomahto - we've long agreed to disagree on pronunciation, but the debate on where to store them is just heating up. Last week, new guidelines on food labelling aimed at reducing waste were published in the UK. The most eye-catching recommendation was that consumers should keep fruit and vegetables refrigerated below 5°C. Potatoes, onions, pineapples and bananas are exceptions to the rule - but not tomatoes.

Food writer Jay Rayner called the advice "bizarre" on Twitter. "Every minute a tomato spends in a fridge it dies a little," one of his followers replied.

There is some truth in that. Last year, a study found that chilling lowers the activity of hundreds of tomato genes, some producing enzymes that contribute to flavour. These enzymes don't recover when tomatoes return to room temperature, and taste tests showed that people could tell the difference. Another study found that storage at 4°C causes a dramatic loss of aromatic compounds.

If your tomatoes are fresh off the vine, it is pretty clear that putting them in the fridge will impair their taste. But most of us buy them from supermarkets. It is likely these were refrigerated during transport, meaning the damage has already been done.

Another consideration is the temperature of your kitchen. According to the Postharvest Center at the University of California, Davis, firm, ripe tomatoes are best kept at 7 to 10°C - warmer than the fridge, but cooler than most rooms.

In summer, ripe tomatoes are likely to suffer from being left out

"Refrigerating tomatoes isn't always a good idea, but it isn't necessarily a bad idea either"

for more than a day or two. If you have a cool cellar, that might be ideal for them. Otherwise, a warmer part of the fridge - like the top shelf of the door - could be the best spot.

This may seem like a lot of fuss over a few tomatoes. But the Waste and Resources Action Programme (WRAP), the non-profit that produced the new

guidelines, says it wants to tackle the 2 million tonnes of food wasted in UK homes each year because of spoilage. A third of this waste is down to how shoppers interpret food packaging labels, says WRAP.

Of course, food labelling has to be concise and simple, and can't address all the variables we encounter in the real world. Refrigerating tomatoes isn't always a good idea, but it isn't necessarily a bad idea either. Prompting consumers to consider putting more produce in the fridge may help to reduce waste. Those of us who think chilled tomatoes aren't worth eating can ignore it.

But if we really want to extend the shelf life of food, we should allow gene-edited products into our shops. Last year, researchers developed tomatoes that stay firm and unwrinkled for two weeks after harvesting, using the CRISPR gene-editing technique.

The European Commission has been dragging its feet over whether crops altered by these methods should be exempt from the severe restrictions placed on genetically modified organisms. It is no clearer what the rules will be in the UK after Brexit.

Wherever you keep your tomatoes, we can surely all agree on one thing: the new guidelines are absolutely right to recommend that consumers shouldn't keep bread in the fridge, as it will go stale more quickly. If you do that, stop it, you weirdo. ■





The shard

IT IS the world's biggest and oldest lake, dubbed the Galapagos of Russia thanks to the thousands of species found nowhere else on the planet. And right now, it is starting to freeze.

Lake Baikal is 25 million years old and sits in a rift valley bigger than Belgium. It freezes over for five months of the year. In March, when Siberian winds howl across the surface, temperature and pressure differences in the ice cause cracks to form, and great transparent slabs like these stick out above the surface. The ice slabs and hummocks are renowned for being among the world's most beautiful. They are blue because air bubbles have been squeezed out by the high pressures the ice is formed under. Ice cubes in a gin and tonic are white because they contain lots of tiny bubbles.

Proclaimed a UNESCO world heritage site in 1996, Baikal holds just over 23,000 cubic kilometres of fresh water - more than all five North American Great Lakes combined. It faces a variety of ecological threats, including industrialisation in nearby parts of Russia and Mongolia, pollution from tourism, algal blooms and, of course, climate change. As a result, ice cover is reducing and water temperatures are increasing. Rowan Hooper

Photographer

Philippe Bourseiller

Reportage by Getty Images

The elephant in the gloom

Dark energy must be weirder than we thought, with dramatic consequences for the universe, says **Gilead Amit**

A CENTURY ago, the universe was a calm and stable place – at least in the minds of cosmologists. Even as the guns rumbled on the Western Front and the world convulsed in total war, Albert Einstein was putting the finishing touches to his vision of a perfectly balanced cosmos. In a paper he presented to the Prussian Academy of Sciences in February 1917, he added a new ingredient to his freshly baked equations of general relativity – one designed to guarantee that the universe could ride out eternity unchanged.

Today Europe is at peace, but there is uproar in the universe. We have long since abandoned Einstein's idea of a static, unchanging cosmos in favour of a universe that is not only constantly expanding, but whose expansion is continually accelerating, at the mercies of the mysterious agent called dark energy. No one knows what this dark energy might be, beyond the fact that it must make up two-thirds of everything there is.

Except that even this intruder might not be enough. New measurements of how fast the universe is speeding apart suggest that the one thing we thought we knew about dark energy is wrong. A new phantom could be stalking the universe, and the prospect is giving cosmologists chills. It would not only cause the universe to speed away from itself faster and faster until it rips apart, but also imply that none of us should even be here in the first place. "You take it literally, and it has weird ramifications," says Adam Riess of Johns Hopkins University in Baltimore, Maryland.

When Einstein put the finishing touches to his theory of general relativity in 1915, he was left with a dilemma. His equations provided an elegant description of the workings of a cosmos dominated by gravity, aside from one thing: they offered nothing to keep it static, as it was presumed to be, rather than ballooning wildly or collapsing in on itself. His solution was a classic fudge – a new term crowbarred into the equations, a "cosmological constant" to provide the extra energy required to stabilise the universe.

Einstein was never a fan of his own invention, and it wasn't long before astronomers Edwin Hubble and Milton Humason handed him a reason to disown it. In the 1920s, they showed that distant galaxies were speeding away from our own, and therefore that the universe was expanding. Einstein reputedly decried the constant as his greatest blunder.

A shifting constant

Dismissing it may have been a greater one. In the late 1990s, the cosmological constant made a triumphant return to the stage, when two groups of astronomers, one led by Riess, used light from distant exploding stars called supernovae to show that the universe's expansion was accelerating. The existence of a repulsive dark energy that counteracts the gravitational pull of all the matter in the universe seemed all but incontrovertible. There were all sorts of ways to account for this interloper, but oddly the simplest fix was to





reinstate the cosmological constant. Although it was originally intended to provide stability, when given just the right value it could produce the desired dark energy effect. The latest observations suggest that whatever is described by the cosmological constant accounts for 68 per cent of the universe.

What could it be? The explanation favoured by most physicists is that it represents the energy density of space, a manifestation of fundamental quantum effects active even in the vast swathes of nothingness between galaxies and star systems. But according to our best estimates, the strength of these quantum fluctuations would be 10^{120} times higher than is necessary to account for the rate at which the universe is ballooning. "The cosmological constant is extremely problematic," says Alessandro Melchiorri at the University of Rome. "Theoretically, we don't have any explanation."

"Cracks have appeared that could bring the pillars of cosmology crashing down"

Even so, dark energy and the cosmological constant are now firmly established as pillars of the standard model of cosmology, known as Lambda-CDM. The Greek letter lambda denotes the cosmological constant; the CDM is cold dark matter, an equally mysterious invisible and inert form of matter needed to hold galaxies together.

The Lambda-CDM model has proven itself remarkably robust over the past couple of decades, capable of explaining all facets of our evolving view of the cosmos. But in the past few years, cracks have begun to appear that threaten to bring the whole edifice crashing down.

The cracks come in the form of discrepancies between observations of the universe today and what Lambda-CDM says it should look like based on extrapolations of the early universe. The most significant is to do with the rate at which the universe is currently expanding, a figure known as the Hubble constant. Until recently, the accepted figure came from the European Space Agency's Planck satellite, which measured the light of the big bang as it looked 380,000 years after the event. These most accurate measurements of the cosmic microwave background (CMB) to date have given us unprecedented insight into the universe's earliest visible moments. ➤

Armed with this data set, the researchers took the patterns they spotted in the CMB and projected them 13 billion years forward to arrive at a figure for the universe's rate of accelerated expansion today: 67.3 kilometres per second per megaparsec.

The numbers extrapolated from Planck fit nicely with recent observations of the cosmos. "The data are more or less in agreement with a cosmological constant," says Melchiorri. But projecting from the CMB is not the only way to calculate the Hubble constant.

Ever since Hubble's day, astronomers have measured it directly by using the light from distant stars and galaxies. Certain stars, known as standard candles, give off a predictable amount of energy, which allows for the careful measurement of distances in the nearby

have been reduced, and the two figures have grown apart (see diagram, below). Riess's latest measurement puts the Hubble constant at 73.2 kilometres per second per megaparsec, with a 99.9 per cent confidence that the figure is not consistent with the Planck data.

"That starts to get pretty serious, that level of conflict," says Riess.

There is a chance it could disappear when the researchers clean up their data further, or it could still be a statistical fluke. But it's not the only thing that's got cosmologists worried.

Phantom menace

Catherine Heymans at the University of Edinburgh, UK, works on the Kilo-Degree Survey (KiDS), an attempt to map a broad swathe of the sky using a technique called weak lensing, which measures the way light bends around concentrations of mass. Their observations place limits on another key prediction of the Lambda-CDM model: the way dark matter clumps together across the cosmos. Their latest analysis, published this year, reveals a significantly different value to that predicted by Planck, with dark matter distributed a lot more smoothly than expected.

Heymans recalls that when she presented the conflicting results in 2012, it seemed that George Efstathiou, a senior figure on the Planck team, was always sitting in the front row, hand raised. "He would say, 'Catherine, can you tell the audience what you've done

wrong?'," she says. "I didn't have the balls to say 'George, can you tell the audience what your team's done wrong?'"

Perhaps no one has done anything wrong. Over the past century, we have gone from seeing the universe as stable to imagining it expanding at a constant velocity to assuming that this velocity increases at a constant rate. The simplest way to reconcile the tensions with Lambda-CDM, says Shahab Joudaki at the University of Oxford, another member of the KiDS collaboration, is to go a step further and relax the requirement that dark energy's density must remain constant over the lifetime of the universe. The acceleration attributed to the cosmological constant is itself increasing – and so the cosmological constant is anything but.

The idea that dark energy can evolve is not new. The most popular variant, known as quintessence, was first proposed in the 1980s. It treated dark energy as an all-pervading field, akin to a fifth force of nature, whose strength can shift over time. But old-fashioned quintessence doesn't quite cut the mustard. To explain the latest results, you need a dark energy that evolves in some surprising ways.

The way dark energy behaves can be summed up by the relationship between its energy density and the outward pressure it exerts. Under Lambda-CDM, the ratio of those two properties is a constant with a value at or just above -1. Under traditional quintessence models, it is allowed to grow as high as it likes, ensuring the energy density fades away with time. For the latest data to make sense, however, the ratio has to go into a forbidden zone below -1, which means the strength of dark energy in the universe has to increase with time. Negative energy – the kind pulling the universe apart – has to be generated ceaselessly and out of nowhere.

This is a deeply odd scenario, says Heymans. Energy of any kind isn't usually generated from nothing. Models that predict such seemingly impossible behaviour were traditionally ignored, acquiring the dismissive moniker of phantom dark energy. But the ghosts are now at the feast.

The consequences for the ultimate fate of the universe are dramatic. Go forward in time far enough and the accelerating acceleration overtakes the forces holding matter together at every scale. Ultimately, each of the universe's constituent particles will be torn apart in a scenario known as the big rip.

There would also be some nasty consequences in the here and now that call

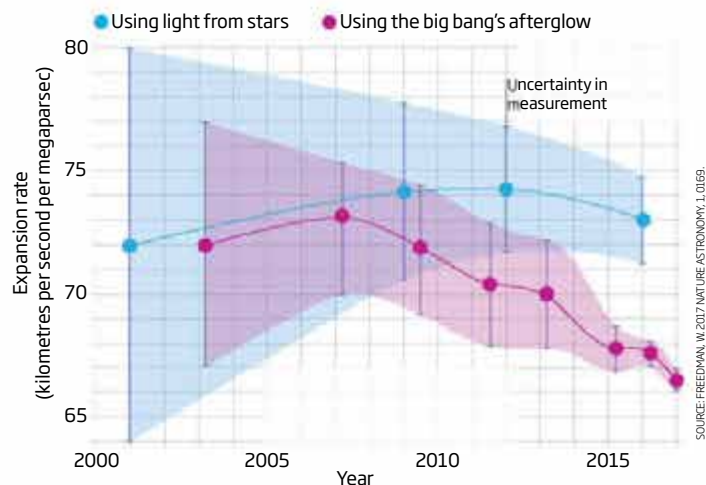
"The latest measurements suggest the cosmological constant is anything but"

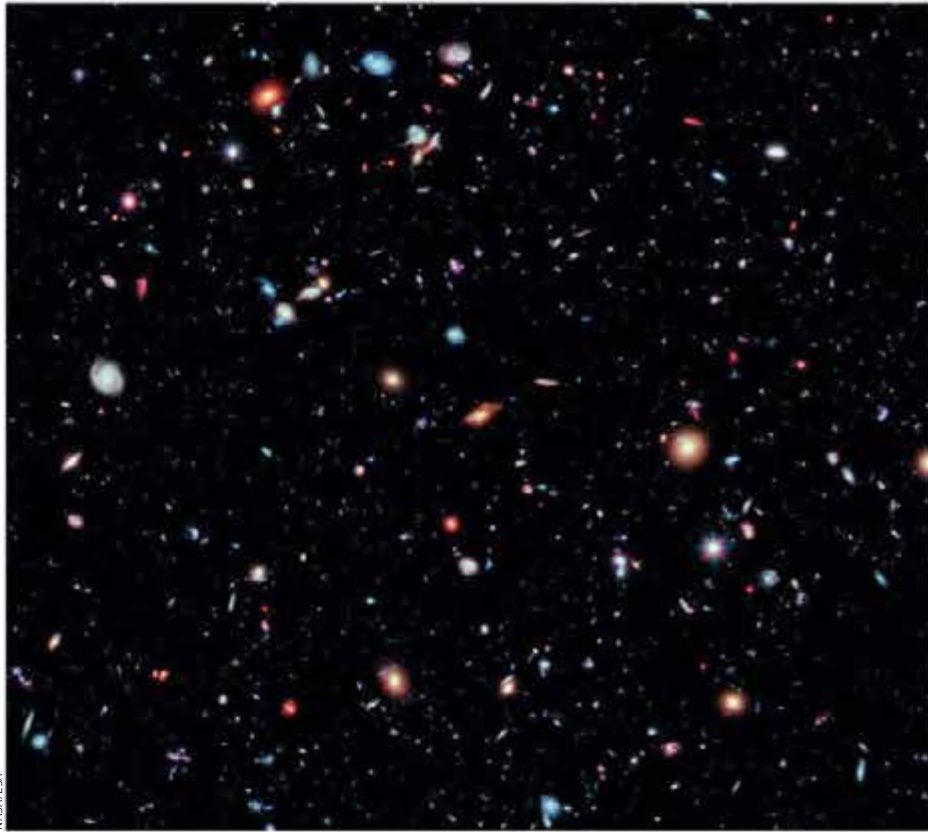
universe. Looking at entire galaxies lets us take those measurements further out, in a technique known as the cosmic distance ladder.

Riess has spent the last decade leading a collaboration adjusting and extending this ladder. When he published his first results in 2011, the uncertainties on his measurement and those derived from the Planck data were sufficiently large to make them consistent. Since then, however, those uncertainties

Growing apart

The results from two methods for clocking how fast the universe is expanding have been diverging over time as the measurement accuracy has improved





NASA/ESA

the whole idea into question. In a universe pulled apart by phantom dark energy, ordinary matter would be too unstable to have persisted for as long as it has. Everything would have decayed into dark energy long before we came into existence. For Claudia de Rham at Imperial College London, this is a sign that we don't understand something more fundamental. "I wouldn't take phantom dark energy as the end of the story," she says.

So what could be hiding behind the phantom's mask? One idea is that the universe's two most antisocial residents – dark matter and dark energy – might be

secretly interacting in some way, causing the effects we see. If dark matter is continuously decaying into dark energy, for example, then that could explain the latter's growth. Another option is that there are several undiscovered energy fields that mingle in such a way as to produce a repulsive force that shifts over time. These multi-field models are not popular, says Alessandra Silvestri at Leiden University in the Netherlands, as they would make phantom dark energy behave in ever more baroque ways.

The fact that theorists are even eyeing such uncharted territories makes experimentalists nervous, spurring them on to subject the

latest measurements of the Hubble constant to ever more elaborate cross-checks and blind analyses. Heymans has been particularly unsettled. "I flip between waking up in mass panic in the middle of the night going 'Oh god, there's all these theoretical physicists coming up with these really mad theories', and 'well, if they're going to come up with these crazy models, then fine, so be it, I'd just better carry on,'" she says.

Many hope the discrepancies grow ever harder to ignore, forcing us to confront new physics. "If it is flat Lambda-CDM, then I might go and do something else with my life," says Bob Nichol, director of the Institute of Cosmology and Gravitation at the University of Portsmouth, UK.

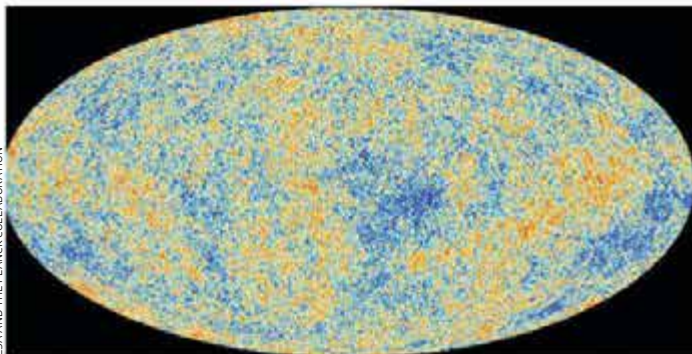
Siren songs

A new generation of observatories should settle the matter once and for all. The Euclid space probe, due to launch in 2020, and the Large Synoptic Survey Telescope, scheduled to start surveying the southern sky as of 2019, will help refine our measurements. And while the uncertainty on gravitational wave measurements, which can also clock the speed of cosmic expansion, is currently too large to discriminate between the data sets, they may yet offer a crucial independent judgement.

Earlier this year, the Laser Interferometer Gravitational-Wave Observatory (LIGO) and Virgo detectors sensed faint ripples in space-time resulting from the collision of two neutron stars, and astronomers were able to follow up with telescopes. It was the first time an astronomical event has been observed using both gravitational waves and light. That combination gives us a new way to measure the rate at which the universe's expansion is accelerating, one that promises enhanced accuracy because it doesn't rely on the assumptions built in to other methods.

This first "standard siren" is not enough on its own. But, with the few dozen more detections we might expect over the next decade or so, the precision should reach the point at which we will know for sure whether we need to think again about dark energy.

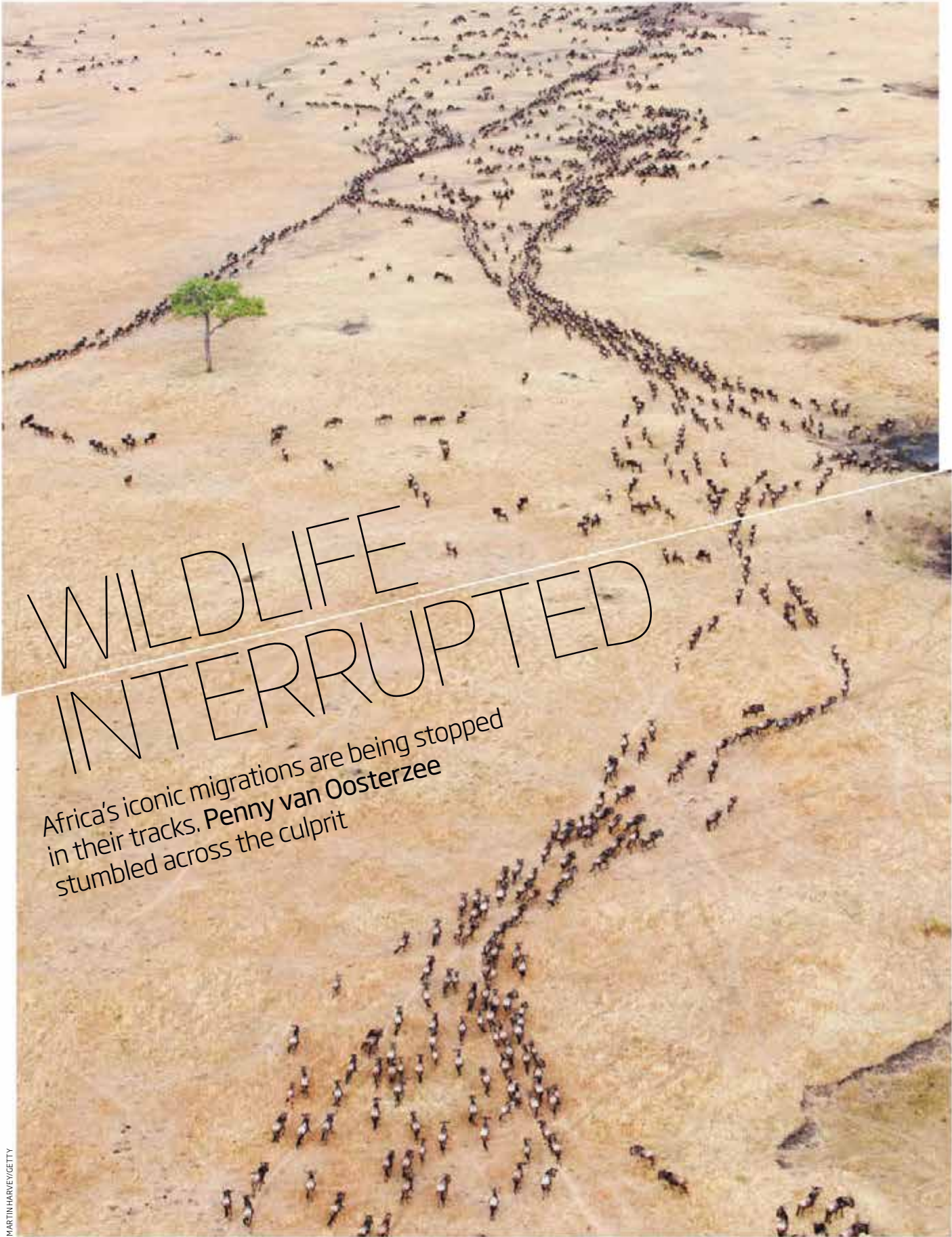
Ultimately, as exciting as it would be to mark the cosmological constant's centenary with a fatal blow, there are no guarantees for its successors. "I've sat through enough talks right now that I don't think there is a good theory," says Nichol. "A plague on both your houses. None of it feels right." ■



ESA AND THE PLANCK COLLABORATION

The big bang's afterglow (left) and distant galaxies (above) give us measures of cosmic expansion

Gilead Amit is a features editor at *New Scientist*



WILDLIFE INTERRUPTED

Africa's iconic migrations are being stopped in their tracks. Penny van Oosterzee stumbled across the culprit

MARTIN HARVEY/GETTY

WE DEFLATED our tyres so that they could ooze through the Kalahari sand on our search for herds of wildlife migrating across the savannah. Eager ecologists from Australia, we scanned the horizons for dust clouds or heaving bodies. Instead, we were shocked to find that southern Africa's great plains were mostly empty. We expected teeming herds of wildlife; we were confronted by a profusion of fences that sliced across the landscape.

We had not realised before our holiday visit in April and May this year that Africa's iconic migrations are dying. Fourteen large mammals used to travel en masse across the continent, but five had already stopped by 2008, when the first migration audit was carried out. Most of those that remain are now in jeopardy, and the fences we encountered over and over again share the blame. My colleagues have warned of disastrous and far-reaching consequences, yet the problem has received relatively little attention from the international community.

Long-distance migrations are among the most spectacular and heroic of natural events, and the majority are in Africa. For 10 million years, hoofed animals – ungulates – have evolved in lockstep with its savannah grasses. They thrived thanks to one outstanding characteristic: mobility. In their millions, wildebeest, eland, impala, kob, hartebeest, springbok and many others tracked the shifting seasonal patterns of greening vegetation. Two regions reign supreme: the Serengeti Mara of East Africa and the Kalahari of southern Africa focused on Botswana, which was where we were. The wildebeest is the keystone species in both places: without it predators such as the lion, cheetah and wild dog wouldn't survive.

On we travelled through different varieties of fences, from simple wire-strand cattle fences to 2-metre-high, double-layered ones set with a gap of 10 metres or more in between, free of large mammals. "The sheer extent of fencing makes it a substantial modifier of the landscape, extinguishing entire migrations and even pushing species to extinction," says Michelle Gadd of the US Fish and Wildlife Services. Between 2007 and 2012 she carried out a thorough assessment of the impact this has had on wildlife in southern Africa. "There was only about 30 reports and few of these had seen the light of day – never published because they were unpopular with the host country governments," says Gadd.

The erection of large fences in Botswana began relatively recently, with the Kuke fence in 1958. Then a British protectorate, Botswana

was considered good only for cattle, and the fence was built to separate them from wildlife that were thought to carry diseases like foot-and-mouth. Running hundreds of kilometres across the northern edge of the Central Kalahari Game Reserve, the fence blocks access to the waters of the Okavango delta (see map, page 37).

At independence in 1966, the European Union gave Botswana privileged access to European beef markets as long as it built even more fences to create zones free of foot-and-mouth disease. Thousands of kilometres were erected in the 1970s and 1980s, splitting the rangeland into 17 zones and severing migration routes. Today, Botswana's perimeter is less than 4300 kilometres, but within the country there are more than 5000 kilometres of fences that serve the cattle industry.

To be clear, fencing does have benefits. It can prevent poaching, illegal resource extraction and conflicts between people and wildlife. But their ecological and economic impact were not assessed before they were built, says Gadd. "They frequently plough straight through areas where there are no cattle at all." She says the fences serve political purposes not ecological ones. In her study, she found just one impact assessment, whose recommendations to relocate and take down various fences were mostly ignored.

In Botswana, like elsewhere on the continent, fences are particularly problematic during droughts when animals migrate out of the Kalahari desert in their hundreds of thousands in search of water. Deaths aren't uncommon during droughts, but the scale of the losses after fences were erected was

staggering. Gadd uncovered reports of die-offs along fence lines in the order of 300,000 wildebeest carcasses, 10,000 hartebeest and 60,000 zebra from the handful of incidental surveys carried out. Precise numbers will never be known.

Further north in Tanzania, thousands of tourists visit the Serengeti each year to witness the iconic wildebeest migration – an industry worth \$1.2 billion. But not so long ago Botswana was home to a similar event. "It was the severe drought of the 1980s which triggered perhaps the last great migration of wildebeest out of the Kalahari," says Doug Williamson, who was there studying the migration of antelopes. He has the dubious distinction of bearing witness to the end of Botswana's wildebeest migration.

"Over a quarter of a million animals headed north for water toward the Okavango, only to find their usual route blocked," he says. Fences channelled the wildebeest east to the ephemeral Lake Xau, which at the time was unfenced but had been emptied by cattle. "The die-offs were massive," says Williamson, "and the migration simply ceased." The Kalahari wildebeest, once said to rival the millions in the Serengeti, were reduced to an aerial count of 260 animals in 1987. As a result, the migration has permanently ceased.

Back home in Australia, a new research paper awaited us shouting its chilling headline: "Fencing bodes a rapid collapse of the unique Greater Mara ecosystem". A group led by Mette Løvschal of Aarhus University in Denmark had examined satellite images of the Greater Mara – the northern extent of the Seregenti Mara which stretches from ➤

ON THE MOVE

Of 24 known mass animal migrations, five have ceased and one species has gone extinct

AFRICA

Hartebeest
Springbok **ceased**
Black Wildebeest **ceased**
Blue Wildebeest
Blesbok **ceased**
Tiang (topi)
Burchell's zebra
Quagga **extinct**
White-eared kob
Grant's gazelle
Thompson's gazelle
Mongalla gazelle
Scimitar-horned Oryx **ceased**
Eland

NORTH AMERICA

Pronghorn
Bison
Caribou/reindeer
Elk

EURASIA

Caribou/reindeer
Siberian roe deer
Chiru
Kulan **ceased**
Mongolian gazelle
Saiga
Mongolian saiga

Source: Harris et al (2009)

Tanzania into Kenya – from 1985 to 2016. The migrations there are among the last of their kind, representing a unique and irreplaceable African heritage, says Løvschal. For centuries, wildlife and semi-nomadic pastoralists roamed the area, following changes in rainfall.

Since 1977, however, there has been a precipitous decline in wildlife, averaging 70 per cent across Kenya, including in the Greater Mara. The drop mirrors the 76 per cent increase in livestock in the region. Wildlife now comprises only 10 per cent of the total animal flesh on Kenya's rangelands. Rapid population growth, land privatisation for cultivation and a more sedentary lifestyle have come with their signature trademark: fences.

Løvschal's satellite study shows how they expanded over time from clusters in the north into open savannah closer to the border with Tanzania. The team found that fence-building increased precipitately in 2014 due to

rapid population growth and changes in government land policies that encouraged settlement and privatisation.

"The resultant land degradation is now threatening to lead to the collapse of the Greater Mara within just a few years," says Løvschal. Long-distance migrations support more than just the species that are on the move. Migrating herbivores like zebras, oryx and springbok pattern the very structure of the savannah by eating different vegetation and following rain showers. They are also food for big cats, hyaenas and wild dogs. Without the web, without the migrations, the whole system would collapse, warn Løvschal and her colleagues, destroying one of the last bastions for Kenyan wildlife. Already, part of the wildebeest population that migrates northwards, where the study shows fences are densest, has seen a catastrophic drop in numbers.

Løvschal, an archaeologist, sees a parallel with the mid-1st millennium BC in northern Europe, when thousands of hectares of wildlife-rich land were rapidly enclosed and parcelled out into "Celtic Fields" for agricultural intensification. "My concern is that once the fences are in place [on the African landscape] they won't be removed. Just like the Celtic Fields, still visible today, that caused a chronic landscape state shift."

Safari success

What could stop such a catastrophic outcome for the Greater Mara? A possible answer comes from the Mara North Conservancy, a model of community-based natural resource management. After decades of land fragmentation and degradation, a partnership was agreed in 2009 between 800 pastoralist landowners and the private tourism sector to lease land in return for income from tourist safaris and associated tented camps. A similar model has proved to be successful in Namibia. There, conservancies now cover 16 per cent of the country and are recognised for their contribution to helping wildlife recover.

In 2008, Grant Harris at the American Museum of Natural History did the first global audit of migrations of hundreds to thousands large terrestrial mammals and found 24 located in Africa, North America and Eurasia. "It's shocking that our planet has these masses of large animals moving long distances and we know so little about them," he says.

Tragically, one thing we do know is which ones we have already lost. Of the 24 species that Harris identified, one – the quagga – was extinct and another five had stopped migrating by the time Harris and his team looked (see "On the move", page 33). As regards the causes, there are two main ways to destroy mass migrations, says Harris. One is to kill the animals outright by over-hunting. "The second is to stop them from having access to food or water, like fencing them out."

An early casualty of the combination of hunting and fences was the springbok migration across the Karoo region of South Africa – the country's largest with perhaps millions of animals. In 1897, the last great concentration of springbok was forced into a small cul-de-sac of savannah where they were hunted, leaving only a minimal population unable to build up numbers large enough to resume migration.

There is an ironic twist to the tale. "Fences may never provide freedom from foot-and-mouth disease in southern Africa," says Genevieve Weaver. Four years ago, she and



DANIEL DUGMORE

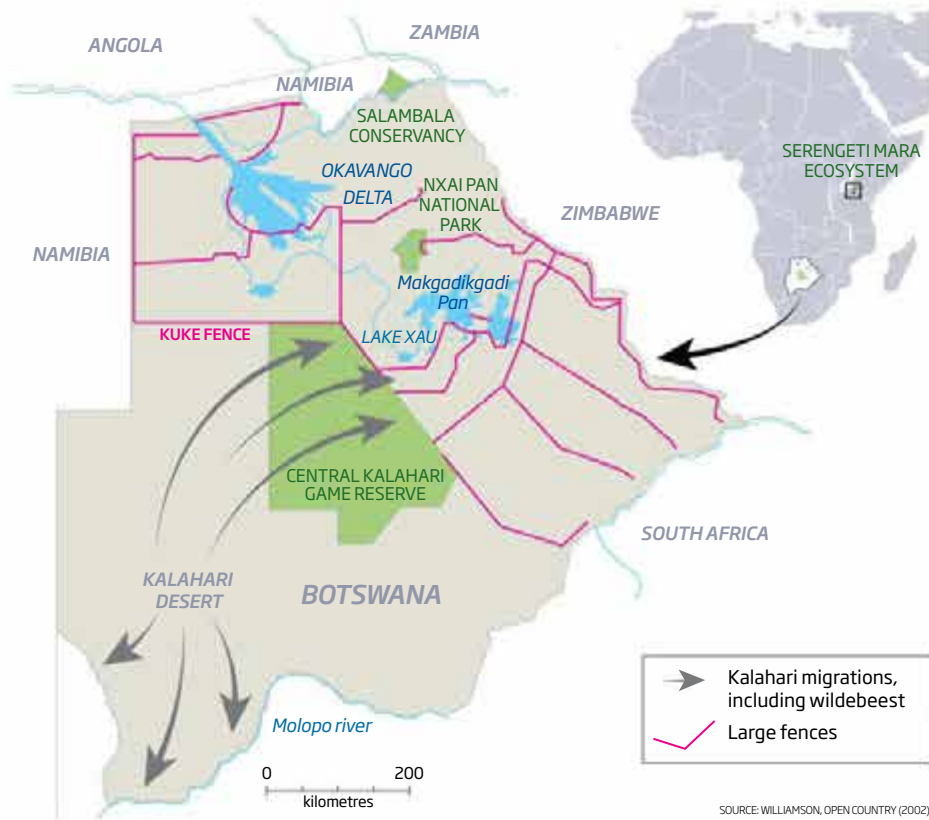


MINT IMAGES/GETTY

No roam on the range: fences are there to keep cattle free of disease, but stop wildlife from getting to watering holes

Fenced out

Botswana is famous for its long-distance migrations, but these are being interrupted by fences, which can block animals' access to water



ZEBRA WANDERLUST

It's only in recent years that we've discovered just how far zebras can travel (see main copy). In September 2012, WWF researcher Robin Naidoo and his team collared eight adult females in Namibia's Salambala Conservancy. The conservancy is just north of the border with Botswana. By early January 2013, all the animals had moved to Nxai pan in Botswana. The migration was done in two weeks in December.

"Community members knew that zebras moved away from the Salambala Conservancy in the wet season, and colleagues in Botswana knew zebras appeared on the Nxai Pan in the wet season. We didn't know they were the same zebras," says Naidoo. The straight-line return distance is 500 kilometres, just short of the 600-kilometre zebra migration discovered in 2007. But Naidoo's animals actually travelled for an average of 955 kilometres, making it ostensibly the longest known migration in Africa - for now.

others from the EcoHealth Alliance in New York carried out a thorough global review of foot-and-mouth in wildlife and came to this sobering conclusion: apart from the African buffalo, the disease is endemic to livestock, not wildlife. That isn't to say wildlife cannot catch it – they can – but they aren't reservoirs. Cattle mostly are. "Past outbreaks that were blamed on African buffalo may have been caused by carrier cattle," says Weaver, adding that livestock and human movement remain significant causes of outbreaks.

Nor are fences the only way to control foot-and-mouth disease. Policies like commodity-based trading, for instance, require farmers to keep their practices up to certain norms through testing, vaccination and standards for meat preparation. They can then participate in the international beef market even if they live in a country or region that is not completely free of the disease. The approach has been successful in India, the world's largest global exporter of beef.

What's more, fences have had economic and social costs. "In Africa, people have kept cattle for hundreds of years despite the existence of diseases like foot-and-mouth," says Roman Grynberg at the University of Namibia. Yet today, the industry is only profitable for a very small proportion of well-connected cattle

owners, some of whom are themselves high-level decision makers. "Not only have ill-conceived fences not insured the long-term viability of the cattle industry, they have also jeopardised a much bigger industry – wildlife tourism." According to numbers collated by the US department of agriculture in 2015, tourism comprised 16 per cent of Botswana's GDP. The livestock industry accounted for 2.5 per cent.

So what happens in areas where there aren't any fences or if you take them down?

"Without migrations, one of the last bastions of Kenyan wildlife could be destroyed"

The movement of zebras around Botswana offers a clue. In 2007, several were given radio collars to monitor how they moved around the Okavango delta. To the researchers' surprise, they left the delta entirely, headed south-east for 100 kilometres, skirted around the corner of fenced cattle ranches and made their way to the mineral-rich grasslands on the fringes of the Makgadikgadi salt pans. The full round trip, nearly 600 kilometres, was the longest ever migration recorded in Botswana.

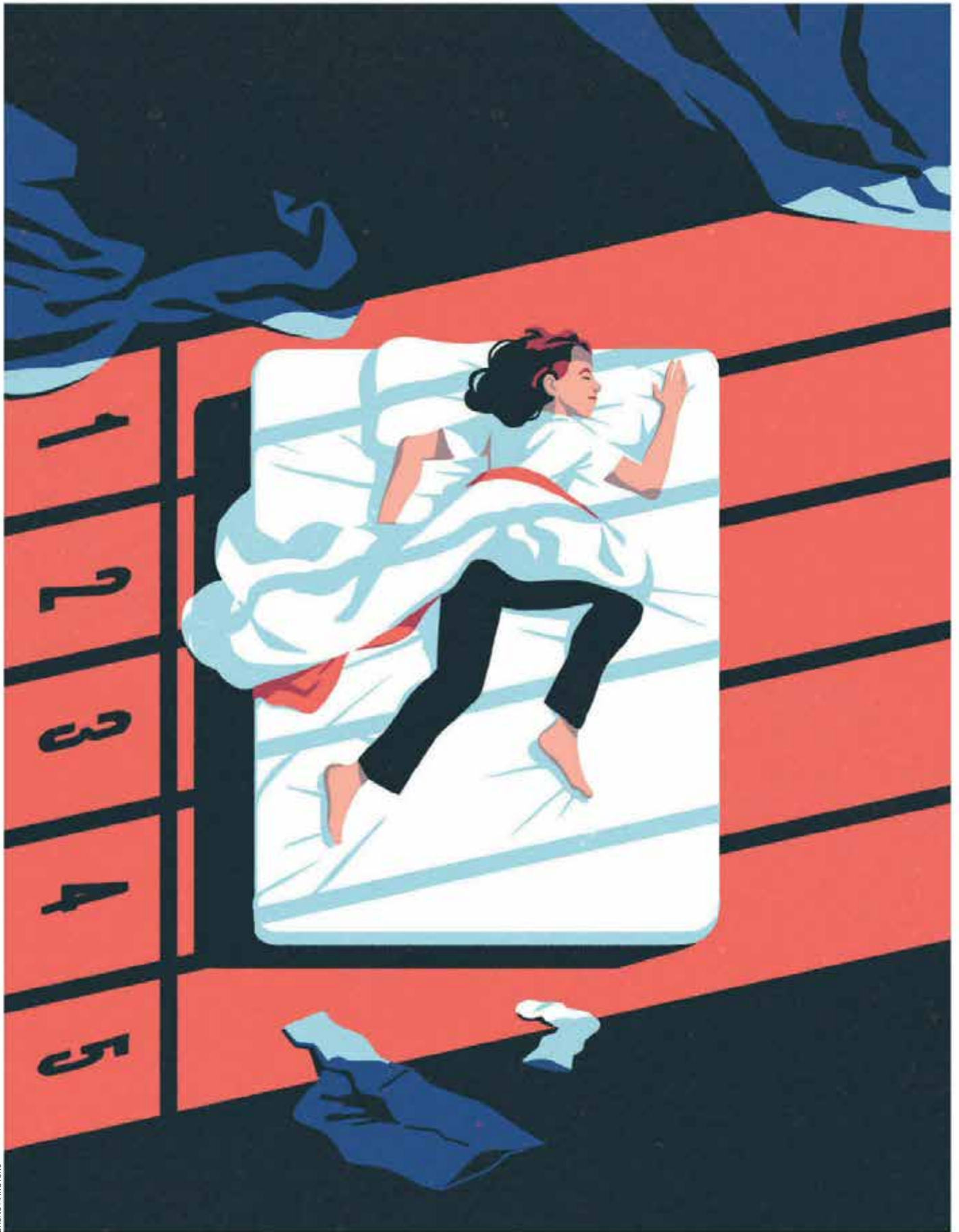
A fence that had blocked this route starting

in 1968 had been taken down in 2004. It was assumed that the zebras, which have a lifespan of around 15 years, wouldn't be able to re-establish their ancestral migration. Instead, the study showed they had an in-built ability to find their way after fences were removed.

It also demonstrated just how much we still have to learn about some of the most iconic migrations in the world, even as they are being halted in their tracks by advancing fences. Four years after the 2007 study, a new one suggested the zebra made another, even longer journey (see "Zebra wanderlust", above), the longest in Africa.

Yet another remarkable mass migration flies under the radar in war-torn South Sudan. Thought to have been wiped out in the conflict, a migration of a million antelope, known as white-eared kob, was found in 2014 to be alive and well. In 2017, a team based in Ethiopia led by Pablo Schapira of the African Parks Network collared 63 kob and found one that had travelled 825 kilometres, which acts as a proxy for the distance covered by several large herds. There are no barrier fences in South Sudan. Yet. ■

Penny van Oosterzee is an ecologist at James Cook University in Australia



Night exercises

Our movements during sleep reveal surprising connections between dreaming mind and waking body, finds Michelle Carr

IT WAS the wreckage of yet another TV that finally convinced one man to seek help. Psychologist Antonio Zadra remembers the patient well. “When we asked what brought him in, he said, ‘Well, that’s the third TV set that I threw at an intruder who isn’t there. It’s getting damn expensive.’”

Zadra, who studies sleepwalking at the University of Montreal, is interested in why anyone would do things like this in their sleep. And it turns out that the answer is important to all of us.

You might think that when you close your eyes and drift off, your body basically shuts down, and dreams then play out in your head. Due to the inhibition of muscle movement, or muscle atonia, that normally occurs during dreaming sleep, most of us don’t act out our dreams or have one-sided conversations. Just 1 per cent of people sleepwalk regularly. But three-quarters of us will talk in our sleep and a third of us will sleepwalk at some point. And we all occasionally shift position or mumble. Now we are learning that even the seemingly subtle twitches and murmurs we make actually have a surprisingly important impact.

Work by Zadra and others is revealing that our bodies play a far more active role in what happens during sleep than people generally think – and not just for sleepwalkers or people chucking appliances at the wall. Their findings suggest that movements in our dreaming minds, or sleeping bodies, serve a far more

fundamental purpose, one that shapes how we move and talk in our waking lives.

Despite spending roughly a third of our lives in the land of nod, what exactly sleep is for, and why it is so crucial to our health, largely remains a mystery. Little by little, we are solving the problem: we now know that sleep is essential for laying down memories, clearing out the gunk that builds up in our brains during the day and even staving off cognitive decline. And there are countless ideas about the purpose of dreams – from a

“Movements in our sleeping bodies shape how we move and talk in waking life”

way to rehearse for life-threatening situations in the real world to working through thorny problems without life’s many distractions.

Our sleeping movements might be more than just a glimpse into our dreams, though. It is becoming clear that a few hours’ kip makes a difference to our coordination. Research has consistently found that sleep improves performance on motor tasks, from tracing a design from a mirror image to improving reaction times or performance in sports like tennis or basketball. Such findings suggest that while we’re out, the brain is replaying our recent movements and strengthening these motor memories.

So perhaps our night jiving is related to this?

Up until now, most of the evidence for the strengthening of motor memories comes from animal studies. For instance, when a rat with a chip implanted in its brain learns how to navigate a maze, we can watch in real time as the map of the labyrinth is encoded in the hippocampus, an area associated with specific memory for places. When we observe the rat’s brain during rapid eye movement (REM) sleep, when most dreams occur in humans, the same neural patterns occur, as if the brain is replaying the trajectory through the maze.

To see if unusual physical movements in our sleep, known as parasomnias, could correspond with us replaying things we’ve learned, researchers have started studying some of the more animated human sleepers – from those who let out light grumbles or sit up in bed, to more extreme cases when people eat, drive or even have sex while asleep.

To try to learn more, neurologist Isabelle Arnulf and her team at the Pierre and Marie Curie University in Paris invited 19 regular sleepwalkers to spend a few nights in their lab. Before they bedded down, the sleepwalkers – and 18 people who don’t sleepwalk – learned a game that involves tapping blocks placed around their bodies as quickly as they could.

Nothing much happened during the first few nights that the participants slept in the lab. But then Arnulf and her team finally saw something in one of the sleepwalkers: ▶



MAIA FLORE/AGENCE VU/CAMERA PRESS

“This patient opened her eyes and instead of running out of bed or speaking, she put her hands in the posture we had waited for... and made fictive taps in the air.” She was playing the game. In related experiments in which Arnulf’s team asked 18 sleep talkers to memorise a story, one was heard repeating phrases from the tale aloud during sleep.

These fascinating findings upend some long-held ideas. Until now, we knew that motor learning took place within the brain during sleep. But these studies show for the first time that physical actions are being replayed in the dreaming world and rehearsed in the body too.

Of course, that is in sleepwalkers, who Zadra recently found are actually in a hybrid state of sleep and wakefulness. What about sleepers who are more reliably out for the count? In theory, Arnulf says, similar processes may be at play: evidence suggests that parts of the motor cortex, which controls our movements, are active while we sleep, but it may be that the muscle atonia that keeps our bodies still prevents the final physical motion. In other words, we rehearse everything up to the point

of the actual movement. But, ultimately, doesn’t that mean it’s all in our heads?

Definitely not, says Mark Blumberg at the University of Iowa, who studies sleeping movements. “Although many people think of sleep as a period of inactivity, nothing could be further from the truth,” he says. During REM sleep, in particular, our bodies move a lot,

“Instead of acting out dreams, our bodies may be dreaming out acts”

twitching or making little jerking movements, like those you might see in the whiskers of a cat or the flickering eyelids of a baby. In fact, every single skeletal muscle of the body twitches during REM sleep, from those controlling our limbs to our fingers and faces.

This twitching seems to be critical to developing knowledge of our own body. For infants, who spend about 8 hours in REM sleep each day, these movements help to draw the map that links the brain to motor neurons in the spinal cord and, in turn, onto the skeletal

muscles. These are the maps we rely on throughout our waking lives: they are what underpin our ability to control our muscles, to move how and when we want to.

“Twitches are a way of probing the body,” says Blumberg. They often occur in a discrete fashion, meaning just one muscle moves at a time. In rats observed while sleeping, researchers could watch specific movements happen independently: shoulder rotation, elbow extension, wrist flexion. The same seems to be happening with us. Blumberg says to think of it like a switchboard controlling a mess of light bulbs hanging from the ceiling. You could turn the switches on one by one to figure out which switch controls which light bulb. Or even better, keep all of the other switches turned off so you can easily pick out the single bulb that flickers on. This is what we can do during REM sleep. Because the rest of our muscles are in a state of paralysis, and each twitch works on a single muscle, the signal is very clear.

Redrawing the map

For adults, twitching in our sleep is a way of recalibrating the sensorimotor system as we grow older. After all, these maps must be continually adjusted as our bodies grow and change in size and shape. And when a stroke or other kind of traumatic brain injury happens, the maps must be repaired. These new findings may explain why, in the longer term, deteriorating muscle control and worsening sleep quality go hand in hand as we age, and why our physical coordination suffers after we miss sleep.

So the movements we make in our sleep help us maintain muscle control, coordination and other essential physical processes we use while awake. But that is only part of the story.

We know that our brains can drive some of our sleeping actions. Lucid dreamers, who are asleep but able to direct their dreams, find that they can control their eye movements, tap out Morse code and even perform some simple physical exercises when they’re out, for instance. And particular physical actions—such as Zadra’s patient lobbing a TV set at a perceived intruder—certainly seem to spill over from dreams.

However, our bodies may shape our dreams too. One of Blumberg’s studies shows that the sensorimotor cortex of the rat brain was five times more active during twitching in sleep than during waking movements—but most interestingly, the activity occurred *after* twitches. The twitching seemed to be

driving brain activity, not resulting from it. Jerking movements in our sleep have long been thought to reflect us acting out dreams, but this work suggests the opposite: our twitching bodies may instead have us dreaming out acts.

The finding is consistent with research showing that the brain isn't simply the puppeteer of the body, telling it what to do and when. It is a two-way street, and we often incorporate outside sounds or sensations into our dreams. Perhaps the most famous example of this is from the late 1800s, when the French physician Alfred Maury dreamed he was being guillotined after his headboard fell onto his neck. In more recent work at the Dream and Nightmare Laboratory in Montreal, researchers found that inflating a pressure cuff on the leg of one participant was associated with a dream about their cat jumping on their legs.

Determining when these actions originate in the brain or body isn't just an academic matter: it can make a real difference to how we treat sleep disorders when people act out in ways that can cause harm. For sleepwalkers, most actions are nothing to worry about, even if it is bewildering to wake up munching a teabag sandwich or repainting the front door (see "Sleep troubles", right). They can be far more unsettling though, as in cases of so-called sexsomnia. One man had sex with his wife nightly for an astonishing 13 years without remembering – and didn't believe her when she said he'd forgotten until a doctor confirmed it. Occasionally, though, things are more dangerous, such as when US comedian Mike Birbiglia jumped out of a window while sleeping. They can also be early signs of serious illness or include outbursts of violence.

SLEEP TROUBLES

We all move a bit in our sleep: muscles in the body twitch, our eyes flit back and forth during dreams and facial expressions and short vocalisations are common (see main feature). So when do these behaviours become a cause for concern? Behaviours like sleep talking or sleepwalking typically begin at younger ages, are relatively benign and become less common as we get older. The odd episode certainly isn't anything to fret about, but if it begins to undermine your quality of life or becomes violent then you should seek medical advice.

For 1 in every 100 people, routinely acting out in sleep may be a sign of REM sleep behaviour disorder (RBD), in

which our normal inhibition of physical movements during sleep fails. The condition features violent grabbing, punching, kicking and flailing that happens from 20 to more than 100 times a year, usually during dreams involving aggression, fleeing or attack. It affects 1 in 12 men over 60.

Some 90 per cent of people with RBD will go on to develop neurodegenerative disease, often Parkinson's, within 14 years of their symptoms first appearing.

Strangely, although people with Parkinson's have impairments in movement and voice control while awake, recordings of movements and talking in their sleep show that they regain their normal voice and

move without tremors.

Some researchers think this is because the sleeping actions initiate in the brain stem, whereas it is problems in the motor cortex that may be responsible for tremors and other impairments when people are awake. But as Parkinson's is caused by a lack of the neurotransmitter dopamine, the increased dopamine levels seen during REM sleep might also explain the restored coordination.

"We dream of reactivating this elevated motor control in waking life," says neurologist Isabelle Arnulf at the Pierre and Marie Curie University in Paris. There is also hope that, given the link between the two, treating RBD could reduce the risk of neurodegenerative disease.

A condition often linked to violent outbursts in sleep is REM sleep behaviour disorder, in which normal, paralysing muscle atonia and the jerky twitches of REM sleep are both disrupted. It is marked by actions such as kicking and flailing, which often coincide with dreams about fighting or fleeing from danger. It is possible that these dream movements are driven by exaggerated muscle twitches emanating from the body, but their sometimes complex nature suggests this isn't always the case: people with the

condition have been recorded breaking into song or reciting memorised political speeches.

It can be that an underlying sleep disorder, such as sleep apnoea, triggers sleepwalking episodes. But many of the most successful treatments, including cognitive behavioural therapy, target waking behaviours that can up the chances of night-time shenanigans. There is evidence that poor sleep habits, stress, alcohol, antidepressant drugs, sleeping pills and other medications can increase the likelihood of sleepwalking or talking by interfering with the transition between sleep stages or decreasing sleep depth.

For people like Zadra's TV-throwing patient, for instance, cutting back on alcohol, getting into a better sleep routine or avoiding certain medications can be enough to interrupt the harmful cycle.

Even for those of us who seem to slumber soundly, these insights reveal that our sleeping bodies are far more active than we knew. As we begin to build a picture of what sleep is for, it seems our dreams play a crucial role in shaping our ability to move through the waking world. Yet another reason not to skimp on a good night's sleep. ■



Sleepwalking is more common in children than adults, and is more likely when you are sleep deprived

Michelle Carr is a sleep researcher at Swansea University, UK

The great Soviet rescue plan

Leonid Kantorovich believed he could turn the USSR into a land of prosperity and plenty... if only its leaders would listen

IN THE summer of 1959, Sokolniki Park in Moscow played host to a glitzy exhibition showcasing the shiniest of American capitalism. It was supposed to be part of a cultural exchange programme. But on the opening day, the only things being swapped were thinly veiled barbs.

As Vice-President Richard Nixon and Soviet leader Nikita Khrushchev shuffled past gleaming cars and model kitchens featuring dishwashers and TV dinners, they couldn't help themselves. Nixon bragged about higher standards of living in the US. Khrushchev pointed out that the average American couldn't afford any of this stuff and, besides, the average Soviet citizen would have it all before long. Then he made a promise: "When we catch you up, we will wave to you as we pass you by."

These days, we associate the Soviet era with bleak images of scarcity and repression: empty shelves, endless bread lines and remote Siberian labour camps. But in the late 1950s and early 1960s, there was a genuine conviction in the USSR that communism would bring prosperity and plenty. In 1957, according to official figures, the USSR's gross domestic product was growing faster than the GDP of almost every other nation on the planet, including the US.

Soviet citizens began to move into new apartments with private bathrooms. Some were even splashing out on fridges, radios and televisions. And yet even as Khrushchev was making bold promises, Soviet managers knew that these gains in living standards and growth rates disguised the fact that productivity was low and stagnant, and the economy hugely inefficient. Khrushchev understood that if the Soviet Union were to "catch up and overtake" the US, new ideas were sorely needed.

A mathematician called Leonid

Kantorovich had answers, if only the authorities were prepared to listen.

Born in St Petersburg in 1912, Kantorovich's earliest memories were formed by the Bolshevik revolution, which left his family destitute. He entered the maths programme at Leningrad State University when he was 14, had research published within two years, and was made a full professor in 1934, aged 22. However, in 1937, with German fascism looming large, he vowed to focus on more practical matters. So he was only too happy to help when the plywood industry asked him how it might maximise productivity.

Plywood, like everything else in the USSR, was part of the planned economy. At its heart

Communism could work, Leonid Kantorovich thought, it just needed optimising



ITAR-TASS PHOTO AGENCY/ALAMY

was Gosplan, the state agency that translated the broad objectives laid down by politicians into specific national plans. No one within Gosplan, or indeed the USSR, was in any doubt that communism was morally superior. But without a market to balance supply and demand, how should planners set targets and prices? The plywood producers wanted to know if there was any way to decide targets that took into account all of the variables involved, such as transportation of raw materials, the number of workers required, and so on.

Kantorovich came up with a solution that contained the fundamentals of what we now know as linear programming – a way of applying geometry to problems with multiple variables and extracting the optimum strategy. It involves depicting the problem as a multidimensional geometric shape, with each dimension representing one of the variables. The optimum value of the thing you want to know – how much raw material to use, say – invariably lies on one of the corners of that shape, immediately reducing the problem to something solvable.

Kantorovich realised that his method would work not just for plywood, but for any problem with multiple variables. What's more, he was convinced it could optimise the workings of whole industries or regions, or even the entire national economy. He set out his "method for resolving multipliers" in a 1939 booklet, *The Mathematical Method of Production Planning and Organisation*, and sent the proposals to Gosplan, certain of his idea's worth.

The agency ignored him – probably suspicious of a scheme that appeared to contradict the Marxist principle that value was determined by workers' labour rather than geometry. Undeterred, Kantorovich found time during the war years to continue



HOWARD SOCHUREK/THE LIFE PICTURE COLLECTION/GETTY



Above and right: the 1959 Sokolniki Park exhibition, where Khrushchev debated kitchens with Nixon, and citizens admired the latest TV sets
Left: Kantorovich receiving the Nobel prize



EVERETT COLLECTION HISTORICAL/ALAMY

with what he called his “deliberations in the realm of economics”, developing his ideas into a book. After the war, he was pleased to be able to employ his methods to optimise the use of steel sheets at the Leningrad Carriage-Building Works, later reporting proudly that he had managed to save raw material.

Yet the authorities remained hostile to the very idea that maths could be applied to economics. In Kantorovich’s words they “met the new methods guardedly”. This was diplomatic: the truth is that pushing his seemingly anti-Marxist ideas too hard could have placed him in harm’s way.

Times changed, though, after Stalin died in 1953. The American National Exhibition in Sokolniki Park was one part of what is now known as Khrushchev’s thaw, a relaxation of repression and censorship, and a greater openness towards the West.

In this environment, mathematical economics was no longer seen as dangerous. Kantorovich was given permission to open a lab at the University of Novosibirsk in Siberia to work with the newly created Central Economic Mathematical Institute in Moscow. At the opening ceremony, Kantorovich even felt emboldened to criticise mainstream Soviet economists for their aversion to optimisation and other mathematical methods.

Through the 1960s, mathematical methods became more mainstream. But by then, the Soviet Union was in no state to benefit from optimal planning. In a planned economy, the idea is that everyone sticks to the plan. In reality, factory managers cooked the books to “hit” targets and workers didn’t blow the whistle for fear of reprisals.

The Soviet economy was riddled with deep, dark recesses that would confound the cleverest mathematical formulae. Political

“Though the authorities ignored him, his work really did change the world”

leaders were not about to implement recommendations based on optimal planning either. For instance, no one was prepared to close down an inefficient factory simply because some calculations said so.

So the truth is linear programming was never substantially incorporated into Gosplan’s methods, says Robert Service, a Soviet historian at the University of Oxford. Yet it would be a mistake to cast Kantorovich as a failure, because his work really did change the world.

He was unknown in the West until an English version of that first booklet was

published in 1960. In the meantime, American mathematician George Dantzig, who was charged with improving the logistical efficiency of the US Air Force during the war, arrived at a strikingly similar solution. Dantzig went further, developing linear programming methods into a series of mathematical instructions known as the simplex algorithm. This soon proved itself the smoothest and most powerful of problem-solvers.

Unlike their Soviet counterparts, capitalist captains of industry were only too happy to adopt it. Gulf Oil was one of the first to benefit, using the algorithm to find the perfect blend of petroleum products for a high-octane aviation fuel. Since then, the simplex algorithm has been put to work pretty much everywhere you look – and in lots of places you don’t. You could say it is the algorithm that runs the modern world.

The Soviet Union never came close to catching up with America, let alone overtaking it. But Kantorovich’s contribution did not go unnoticed: for his co-discovery of linear programming, he received a share in the 1975 Nobel prize in economics. That was welcome reward for a man who had always hoped his work would be useful. ■

By Daniel Cossins

Thirst for change

Protecting natural resources is increasingly contentious. What does that mean for water and who should control it, asks **Fred Pearce**

Replenish: The virtuous cycle of water and prosperity by Sandra Postel, Island Press
River of Life, River of Death by Victor Mallet, Oxford University Press
Private Oceans: The enclosure and marketisation of the seas by Fiona McCormack, Pluto Press

IT MUST be something in the water. Environmental optimism seems to be catching, especially among experts fed up with gloom and doom. From curbing climate change with solar farms to global forest restoration projects, green redemption is the new narrative. But if there is a politics of protecting natural resources, who is writing the rules?

The latest convert to green optimism is US water guru Sandra Postel. She is the author of pessimistic texts on the global water crisis, such as *Pillar of Salt*. Now she brings us *Replenish*.

Postel remains opposed to the conventional infrastructure of water management in the 20th century, including most big dams and state irrigation projects. She hasn't joined the eco-modernists who want to pour more concrete to save the planet. But she sees a world of water projects that "work with, rather than against, nature". Her optimism lies in the belief that governments and corporations are starting to get the message.

Some smell a rat. They fear her new world is all about privatising nature and putting a price tag on its bounty. I rather think they are right.

Water is one of the planet's most important resources. We need it as much as the air

we breathe. And not just for drinking and washing. Keeping the average US lifestyle afloat requires 7500 litres of water a day, says Postel, most of it to grow food. To sustain the needs of more than 7 billion people, dams now intercept more than a third of all river flows, while our pumping of underground water far exceeds the recharge from rainfall. No

"At individual and civic levels, we use water with staggering inefficiency. It flows through our fingers"

wonder water tables are in free-fall and many of the world's rivers are running dry.

Water-short nations survive by importing water-thirsty crops like wheat, rice and cotton. But how much longer can this continue given that major exporters of this "virtual water", such as Australia and the US, are themselves often running on empty? Especially when climate change makes the

Battling to prevent pollution of water supplies from a new pipeline



MARK RALSTON/APP/GETTY

science of predicting where and when the rains will fall less and less reliable.

But Postel doesn't think it has to be like this. At individual and civic levels, we use water with staggering inefficiency. It flows through our fingers. We could do things much better, she argues, if only we stopped treating it like a birthright that falls from the sky and more like a precious resource that sustains all life on Earth. "The water cycle is broken," she writes. "But one river, one wetland, one city, one farm at a time, we can begin to fix it."

But how? Some see the issue in religious terms. Not for nothing are many of the world's rivers sacred. Others want new laws. Courts in several countries have recently given rivers a legal status as if they were human.

Postel finds some potent symbols to guide her agenda of replenishment. She devotes several pages to what happened when dam engineers on the Colorado river in the south-west US allowed a little water to escape across the border into Mexico to



MUNEM WASSIF/AGENCE VU/CAMERA PRESS

replenish the river's shrivelled up delta. But that was a meagre start, and after a few weeks they turned the tap off again.

But for all her language about sharing and stewardship, Postel ultimately finds environmental salvation in the power of the dollar. She wants water to be owned, so it has a value to individuals and corporations. If they own and trade it, her argument goes, they will also safeguard it and use it well.

Her book focuses on examples where capitalism nurtures water. Most are in the US. She finds that water markets from California to New England deliver the precious resource to those who derive most economic value from it – almond farmers in California, city dwellers in New Mexico's deserts or salmon fishers in the north-west.

From brief foreign trips, she lauds how farmers are trading water rights in Australia's Murray-



Darling basin, how Indian brewers secure sufficient barley supplies from a desert region by paying farmers to irrigate more efficiently, and how corporations from Quito to Kenya reforest watersheds to keep rivers flowing.

Is this the privatisation of nature? Some will say so. In many ways, it is just a reworking of the old saw of the American West

“Early this year, a court in northern India gave the Ganges the status of a ‘living human entity’ ”

that “water flows uphill toward money”. And Postel is sometimes squeamish about consequences. For example, she seemed scandalised to discover that a Saudi company bought up water rights in the Arizona desert to grow alfalfa destined for feedlots outside Riyadh. The trouble is that when you place your faith in

markets, the results aren’t always what you hope for – even in the US. The water cycle is certainly being marketised; it remains to be seen whether that becomes what Postel calls a “virtuous cycle”.

Those who are sceptical of this market agenda need to remember what can happen when rivers aren’t owned, but are just places to dump waste as cheaply as possible. That tale is told with scary verve by *Financial Times* journalist Victor Mallet in *River of Life, River of Death*, the story of his journey down the river Ganges.

No other river serves so many. Half a billion people live on its banks, including the inhabitants of two megacities, Delhi and Kolkata. Indians revere the river with an intensity rarely seen elsewhere. For them it is holy. Early this year, a court in northern India gave the Ganges the status of a “living human entity”.

But Indians abuse it too.

Running on empty: how can we prevent water shortages?

Famously, they consign cremated bodies to its waters. But that is the least of the river’s problems. On its way from the Himalayas to the Bay of Bengal, it is emptied of clean water and refilled with raw sewage and industrial toxins. It is overwhelmed. When someone dropped a lighted match into its murky waters near the holy city of Haridwar, the river burst into flames that couldn’t be doused.

This reckless abuse is terrifying. But would the Ganges be cleaner if someone owned it? Would the river of death be transformed into a river of life? Or might the market dictate that its most productive use is as a free sewer?

Anthropologist Fiona McCormack asks a similar question of Earth’s oceans in *Private Oceans*. She charts their “enclosure and marketisation”,

seeing this taking place through the assignment of fishing quotas to corporations, which effectively give them ownership of the oceans’ prime assets.

This “ocean grab” is, she says, dispossessing the traditional custodians of fisheries, causing the collapse of small fishing communities around the world, for example, within Hawaii, the European Union and her homeland, New Zealand. Knowledge built up by communities over generations is being sidelined and the science of sustainability corrupted. What began as ecology ends up a stooge for maintaining property rights.

The narrative of privatising the oceans is the same as Postel’s for monetising water supplies. It holds that commonly owned resources are always trashed and destroyed, and that only private ownership can halt this “tragedy of the commons” by putting cash value on preserving natural assets.

But neoliberalism’s green face forgets one thing. As Nobel-prizewinning economist Elinor Ostrom and others argue, communities aren’t blind destroyers but are usually the best guardians of forests, animals and coral reefs. Things go wrong when control is stripped away from them and outside predators move in. The tragedy isn’t community control, but its breakdown by private asset strippers. Markets are the problem not the solution.

In an increasingly marketised world, it is hard for communities to exert the kind of control that McCormack sees as fundamental to successful management of natural resources. But from Trump’s US to New Zealand’s Maori fishing communities, and from Brexit Britain to the Amazon rainforest, the call to “take back control” is being heard across all parts of the political spectrum. The tide may be turning. Perhaps there is something in the water. ■

Fred Pearce is a consultant for *New Scientist*

Breakout time

Escape of all kinds dominates new sci-fi, finds **Abigail Nussbaum**

An Unkindness of Ghosts by Rivers Solomon, Akashic Books
You Should Come With Me Now by M. John Harrison, Comma Press

THE generation ship story has been enjoying a minor resurgence in recent years. Writers like Kim Stanley Robinson and James Smythe have used its confined setting to convey feelings of claustrophobia, and to explore what happens when humanity tries to craft a habitat and society from scratch.

In her debut *An Unkindness of Ghosts*, Rivers Solomon uses the generation ship setting to craft a challenging narrative of inescapable racial prejudice. In an explicit rejection of sci-fi's typical futurism, Solomon transposes the antebellum plantation system on to her novel's setting, the spaceship Matilda.

While white "upper-deckers" live in luxury, black "low-deckers" are crammed together, brutally policed, and made to perform backbreaking labour producing Matilda's food and resources. The ship is governed by a philosophy that combines white supremacy, quasi-Christian fundamentalism and restrictive gender roles. Its leader, the Sovereign, can subject the citizens of the lower decks to sadistic punishments, or even the cavalier withdrawal of their basic means of survival, at whim.

Some readers might balk at the obvious metaphorical weight of this. It doesn't really make sense that a spaceship hundreds of years in the future, even one in which racial prejudice holds such sway, would model its society so

exactly on the slave-holding South. But Solomon quickly makes it clear that her goal in creating Matilda isn't verisimilitude, but affect.

Her world-building is impressionistic, focusing on seemingly trivial details, such as the pronouns that different low-decker groups use to address children who haven't yet chosen a gender. Through these snapshots, she paints a portrait of low-decker society as vibrant, sophisticated, highly adaptable and responsive to its environment.

It's a direct rebuke to the stereotypes of slavery in historical fiction. The slaves on the Matilda are powerless, but they are neither passive nor lacking in awareness. Their circumstances may not be what we associate with sci-fi or the generation ship story, but they are precisely the kind of people we expect to find in such stories: curious, bold and intelligent.

A new book by M. John Harrison is an event. For more than four

decades, he has been dismantling the heroic assumptions at the heart of genres like epic fantasy and space opera, exposing their emptiness with equal incisiveness and compassion. His latest collection, *You Should Come With Me Now*, comprises more than 40 stories, some of them short-shorts or experimental pieces, others more traditionally structured.

"The slaves on the Matilda are powerless, but they are neither passive nor lacking in awareness"

They run the gamut of fantasy, sci-fi, horror and plain weirdness, but all are suffused by a typical and familiar sense of sadness.

The recurring idea in many of the stories is the need for escape, and the impossibility of it. Trapped by family, jobs or the sheer mundanity of their lives, Harrison's characters seek a fantastical way out.

But even for those who find it,

the result is seldom as liberating as they had hoped. The fantastical worlds they escape to always turn out to be as shabby as the ordinary one. The queen of fairyland is a resigned old woman showing tourists around her castle.

A spaceship engine gifted by aliens takes us to an advertisement for hair gel.

In other hands, this might come across as cynical or hectoring, but Harrison is far too subtle a writer for that. There is genuine sorrow here, for people so desperate for an escape that they would break the rules of reality to find it. And genuine anger too, at a world that leaves people so disappointed that escape feels like their only option.

There is also humour, moments of absurdity in which the ridiculousness of all worlds, real and fantastical, is laid bare. ■

Abigail Nussbaum is a programmer and Hugo-winning literary critic based in Tel Aviv, Israel



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The appointments are all part-time from 1 August 2018 and normally for three years. Gresham Professors must present six one-hour lectures each academic year. Attendance at Academic Board meetings four times per year and some social events is also expected. The lectures attract large numbers of people and are also recorded and available through the internet, so candidates should have an interest in reaching a global public audience. The post offers excellent opportunities to widen public exposure for the successful candidate, as well as the opportunity to expand his/her communication skills. The College pays an annual stipend of £7,000 (plus reasonable expenses) and encourages applications from all backgrounds and communities.

In addition to the above Gresham Professorship, opportunities may be available for a number of part-time Visiting Professorships at Gresham College, tenable from August 2018 for a period of 1 – 2 years (renewable). Visiting Professors will be expected to deliver three lectures each year during their term of appointment. As above, applications within the aforementioned disciplines will be considered.

Further information about these positions is available on the Gresham Website at:
www.gresham.ac.uk/vacancies/IT
www.gresham.ac.uk/vacancies/environment
www.gresham.ac.uk/vacancies/physic

Informal discussion may take place with the Academic Registrar, Dr Valerie Shrimplin, Gresham College, Barnard's Inn Hall, Holborn, London EC1N 2HH, Telephone 020 7831 0575, v.shrimplin@gresham.ac.uk

The closing date for application is 9 January 2018.

Interviews are expected to be held in London on 9 February 2018 (Environment), 2 March (Physic) and 9 March (IT).

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EDITOR'S PICK

We must break the taboo of male infertility



From Marie-Claire Mason,
London, UK

Moya Sarner's excellent article about male infertility highlights how little is still understood about this subject (18 November, p 28). Men suffer in silence as a consequence.

In my book *Male Infertility - Men Talking*, published in 1993,

I interviewed 22 men who wanted to share their experiences of male infertility with me on the strict understanding that their identity mustn't be revealed. It was very much a taboo subject.

Each story was unique, but there were some common threads: feeling marginalised and guilty, and standing on the sidelines looking on as their partner received treatment rather than themselves. The emphasis on the woman left them feeling uncertain about loss and what they felt about fatherhood.

They suffered in silence, not wanting to burden their partner with their anguish. The good news is that men today are starting to talk more openly about their experiences, support each other and question why they are being left on the sidelines.

A little bit of delusion may be good for you

From Perry Bebbington,
Kimberley, Nottinghamshire, UK
I'm surprised at two of the entries in the list of supposed delusions (18 November, p 40). At the risk of revealing my own delusions, the first is: "Do you ever feel as if some people are not what they seem to be?" Many people aren't what they seem to be, fraudsters and psychopaths being good examples. Not being sensitive to this possibility lays one open to all sorts of problems.

The second is: "Do you feel that you are a very special or unusual person?" Everyone is special and unusual - just like everyone else.

From Steve Terry, Allanton,
North Lanarkshire, UK

I read through the list of delusions and honestly answered "No" to all

21 of them, giving me a score of zero. Does this mean that I genuinely have no delusions, or am I deluded in thinking that I'm not delusional?

From Elsa Beckett,
London, UK

Do people ever try to actively justify a delusion? Lately, I learned that a relative is a "flat-Earther". Has a group of them ever mounted an expedition to bring back proof of the world's edge?

No matter how you look at it, reality is real

From Robert Cailliau,
Prévessin-Moëns, France
The collapse of the wave function is a favourite theme in *New Scientist* and again you have a whole article about our role as observers in shaping reality (11 November, p 28).



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“Really tiny, or just really far away?”

John Kochen requests clarification on the small, strange galaxies spotted in Hubble’s Ultra Deep Field

But are we not just part of the whole? If we lack free will, then we don’t “decide” to observe or not. Everything, including us, is at the same level of “just happening”.

The moon is there whether we think of looking at it or not.

From Peter Slessenger, Reading, Berkshire, UK

The thought experiment designed by Eugene Wigner describes a friend in a closed room who knows the state of a quantum particle, whereas the author doesn’t. An analogous real-world experience is sending a letter to *New Scientist*, or some other equally august organ.

I know I’ve sent it off, and I get a reply to acknowledge receipt. But the wave function of whether my epistle is actually printed doesn’t collapse (for me) until I open subsequent issues and see if it is indeed there.

Making a killing in the arms industry

From Sam Edge, Ringwood, Hampshire, UK

The argument espoused by David Hambling, that having autonomous killer robots is no different to autonomous vehicles making life-and-death decisions, is completely flawed (11 November, p 22).

Civilian autonomous vehicles will operate under civil law and will have to be designed to follow regulations or they won’t be allowed on the roads. As has been repeatedly demonstrated, arms manufacturers will supply whatever the customer wants – and the customers aren’t the ones who will be adversely affected by the product.

International law requires landmines to be detectable after deployment. To comply with the

letter of the law, manufacturers supply devices with metal bands, but these are easy to strip away before they are laid.

US gun manufacturers supply semi-automatic weapons that are trivially easy to convert to being fully automatic. Does anyone really think that arms firms aren’t going to make it easy to turn off the “ethical governor” – if such software is even possible?

From Sami Wannell, London, UK

David Hambling asks whether autonomous armed drones could make better decisions than humans. They are maybe more fairly described as differently biased rather than less biased. This is similar to how a medical artificial intelligence might discharge poorer patients, making its own immoral choices from its amoral code base.

And the hope of there being less risk to soldiers could be more accurately put as “less risk to soldiers from rich countries”.

The importance of realising we all die

From Frank Aquino, West Leederville, Western Australia
When I read your leader on death, I thought, “OMG, someone actually read *My First One Million Years*, a book I wrote (11 November, p 5). I doubted anyone ever would.

Whether or not your writer did actually read it, they are nevertheless spot on. The first prehistoric realisation that we are going to die one day has become the driving force for everything humans have ever done and will ever do. This includes, but isn’t limited to, inventing gods, religions and all that jazz, and must surely count as the single

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A moon in the retrograde is worth two in the bush

From Ronald Baker,
Colchester, Essex, UK

Leah Crane mentions that the moon Triton was captured into a retrograde orbit, one going the opposite way to Neptune's spin (18 November, p 16).

A near miss with a pre-existing moonlet is more effective at producing capture than is actual collision – a larger prograde momentum (one in the direction of the planet's spin) is transferred to the captured moon. If that were the case with Triton, we wouldn't expect any crater and so there would be no strong size constraint on the moonlet.

A sizeable moon in retrograde orbit will, once captured, have a strong tidal effect on the primary (Neptune in this case) in such a way as to make the moon's orbit become both smaller and more nearly perpendicular

to the primary's equator.

Since the tidal effect is strongest when the moon is closest to the primary, it also tends to make the orbit more circular. Capture of further small moons into prograde orbits becomes more probable in the presence of a large moon in retrograde orbit, so some of Neptune's outer moons may have been captured after Triton.

The long journey to Mars begins in near space

From Shelley Charik,
London, UK

Leah Crane outlines some of the problems facing a Mars mission (28 October, p 10). Radiation and low gravity could make the long trip sufficiently damaging to the astronauts' health to rule it out on ethical grounds. So any spacecraft must be heavily shielded and spin to provide quasi-gravity.

With current technology, it couldn't take off from or land on Earth or Mars. So it would have to be built on the moon and land on Deimos. In preparation, robot ships would carry components

for a base and landing shuttle to Deimos, where robots would prepare them for Mars transit and build the base. Only then would a crewed landing be feasible.

That could be a long way off. By then, robots may be sufficiently intelligent to make human exploration redundant.

■ The editor writes:

Building in orbit offers many advantages, such as being able to mine asteroids for radiation-shielding clay (newscientist.com/article/2124676).

Oh what a wonderful dream to have

From Haydn Webb,
Duporth, Cornwall, UK

It was fascinating to read how Nikolai Koltsov developed the concepts of genetics during the upheaval of the Russian revolution (21 October, p 40). As he lay dying, he said: "How I wish that everybody would wake up. That everybody would wake up."

Many of us must still be dreaming. In the same edition (p 24), Paul Marks writes that it

was wrong to aim for Mars before we had managed to live on the moon. It is good to dream about having such a choice. When we wake up, we will realise that our technology should be used to put our home, Earth, in order first.

Did little green fingers sow life on Earth?

From Geoff Butcher, Tewkesbury,
Gloucestershire, UK

I was fascinated by the implications of Claudius Gros's idea of distributing the seeds of life throughout the galaxy (18 November, p 10).

The fact that this is being contemplated means it is very likely that any other intelligent life in our galaxy has done so too.

To me, this vastly increases the chances that life on Earth came from outside the solar system.

Robot truck convoys could be a heavy burden

David Cooper,
London, UK

Proponents of electric truck convoys (25 November, p 22) should consider that their control systems must avoid collapsing the road bridges they cross, before they invest in a technology. As a bridge engineer myself, perhaps I should welcome the prospect of increased business?

For the record

■ SSRI antidepressants work better than placebo in 1 in 5 people; but don't stop without consulting your qualified medical professional (25 November, p 28).

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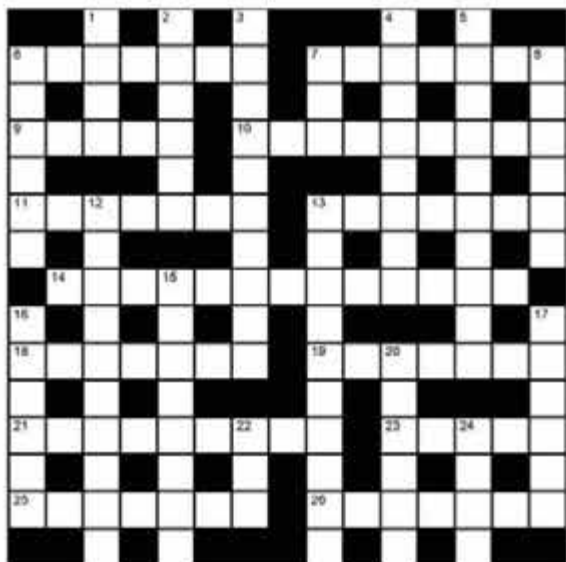
TOM GAULD

THE GRANT FAIRY



CROSSWORD

Compiled by Richard Smyth



Crossword No13

ACROSS

- 6 Below 0° (3-4)
7 US city, world headquarters of 3 down science (5,2)
9 Computing language; Beginner's All-purpose Symbolic Instruction Code (5)
10 Component of atmospheric circulation (5,4)
11 The complete or partial obscuring of one celestial body by another (7)
13 In human anatomy, spaces surrounding the nasal cavity (7)
14 Term for the twinkling of stars (13)
18 In biology, relating to the body's waste fluid (7)
19 Worker or machine that applies permanent mechanical fasteners (7)
21 In cosmology, the earliest stage of the big bang (6,3)
23 Female reproductive organ (5)
25 Sorosilicate mineral discovered in 1977 by Joe Ana Ruiz (7)
26 Bright green variety of beryl (7)

DOWN

- 1 Long-legged wading bird of the family Threskiornithidae (4)
2 Agaric mushroom aka a cortinar (2)
3 Property of systems in which behaviours are not explicable by analysis of component parts (10)
4 Private computer network run by a company or other organisation (8)
5 Columnar vortex occurring over a sea or lake (10)
6 In mathematics, a set contained within another set (6)
7 Astronomers' term for a solar day on Mars (3)
8 Item of laboratory glassware developed by Emil Erlenmeyer (1-5)
12 CH₃CH(OH)COOH, an organic compound active in various biochemical processes (6,4)
13 An assembly of photovoltaic cells (5,5)
15 Biogeographic realm covering Greenland and most of North America (8)
16 Gerard ____ (1905-73), astronomer who gave his name to a belt of small bodies beyond the orbit of Neptune (6)
17 Studied using Röntgen radiation (1-5)
20 Colour at the end of the visible spectrum of light (6)
22 Mitochondrial ____, matrilineal most recent common ancestor of all living humans (3)
24 Protein belonging to a family of transmembrane and secreted metalloendopeptidases (4)

Answers to Crossword No12

ACROSS: 8 KOCH, 9 INDOSAURUS, 10 PHENOL, 11 NARCOSIS, 12 HAIL, 13 CLAVICULAR, 17 ORES, 18 REACT, 19 LUCY, 20 GEOCACHING, 22 RAIN, 23 HAMILTON, 27 APOGEE, 28 SOLID STATE, 29 ILEX. DOWN: 1 JOSHUA TREE, 2 SHINGLES, 3 DIELECTRIC, 4 EDEN, 5 USER, 6 SUDOKU, 7 FUJI, 14 ACARI, 15 INTEGRATED, 16 ARCHIMEDES, 19 LORDOSIS, 21 CHITIN, 24 AXON, 25 TASK, 26 NLAB.

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GRADE inflation is an issue usually reserved for the summer months, when British newspaper editors are furrowing their brows over the latest round of A-level results. But Feedback finds similar trouble in the debate at Westminster tabled by South Thanet MP Craig Mackinlay to discuss drug harms in light of the US opioid crisis.

Mackinlay painted a bleak picture of the current UK situation: broken homes, addled minds, young people running amok, not to mention the revolving door of drug-related crime he presided over for 12 years as a magistrate. Something, it was clear, had to be done, and Mackinlay's suggestion was a new tier in the classification system, AA, for fentanyl and similar opioids.

For those unfamiliar with the murky world of UK drug legislation, the classification system attempts to categorise "recreational" drugs on a sliding scale of criminality, from A to C, so that judges might know how slowly the door between prison and the street should rotate. Yes, even politicians like to score, and in this case reached for an A star grade for especially naughty chemicals.

Feedback would have thought that

being familiar with the UK's broken drugs policy, Mackinlay might have focused on a harm-reduction strategy. But perhaps when all you have is a gavel, every drug user looks like a criminal.

It fell to Norman Lamb, MP for North Norfolk, to point out that no drugs debate is complete without alcohol ("used very heavily within these buildings", he quipped). Given the current regime imposed by the Psychoactive Substances Act - which makes selling any chemical capable of affecting the mind an offence - Feedback is worried there aren't nearly enough letters in our alphabet to categorise them all.

IN HIS opening remarks, Mackinlay praised the House of Commons library, "which has considered data from a huge variety of sources". Perhaps he ought to have paid attention to one document in particular, a report drafted in 2014 that showed "[no] obvious relationship between the toughness of a country's enforcement" and the rate of drug use.

And from what patchouli-

scented den of liberal hippies did this conclusion emanate? Er, the Home Office, when it was under the directorship of Mackinlay's boss, Prime Minister Theresa May.

SURELY the woman who produced this report would stand by its findings? We had a chance to find out last week when Crispin Blunt, MP for Reigate, asked the prime minister to comment on the global failure of drug prohibition policies, and whether alternatives would be considered.

"When I was Home Secretary, a piece of work was undertaken which did look at a number of countries and the different ways in which they approached this issue of drugs," May replied promisingly. "I am sorry to say I take a different view [from Blunt]. I think it is right that we continue to fight the war against drugs."

Which makes Feedback wonder, with such compelling intuition to guide them, why do politicians bother to commission these reports at all?

LOOKING on from the sidelines, the drug policy charity Release tweeted stats showing that in the past five years fighting this war, "there has been a 44 per cent increase in drug-related deaths", in the UK and a 109 per cent increase in deaths related to heroin and morphine. Perhaps the government hopes that given time, there will be no addicts left alive to confound their policies and clutter up their prisons?

SPEAKING of people whose opinions remain stubbornly at odds with reality, Feedback is delighted to learn that Flat Earth theorists are planning to launch their own fact-finding mission, quite literally.

Mike Hughes is a 61-year-old limousine driver from California who has constructed a steam-powered rocket in his garage. Hughes aims to one day reach an altitude of 110 kilometres, a vantage point from which he hopes to see through the lie of the spherical Earth conspiracy.

Using a ramp built into an old mobile home, Hughes had planned to jump 550 metres over the ghost town of

Amboy, California, last week, an effort sponsored by the Research Flat Earth group among others. Sadly, the launch was scrubbed after the Bureau of Land Management - clearly agents working in the capacity of the shadowy spherical world order - refused Hughes permission to fly over the historic town in his homemade rocket. Perhaps a balloon would be more practical?

MULTIPLE news sources couldn't resist the sweet nectar of a recent press release from supermarket Asda, announcing that it would soon be selling pineapple plants that NASA suggests could stop snoring.

Naturally, Feedback is sceptical that a spiky fruit can silence a noisy bedmate unless thrown at them. But what is the "new research" claimed to support this medical marvel? Alas, the papers are less vocal on that particular



detail. Feedback suspects an oft-quoted study from 1989 that examined the efficiency with which common houseplants could remove volatile organic compounds such as benzene, trichloroethylene and formaldehyde from the air.

Important for astronauts, but maybe less so those of us who can crack open a window for some fresh air.

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PAUL McDEVITT

The Pentagon has told reporters at MuckRock that a list of information exempt from FOIA request is itself exempt from FOIA request. Are these Rumsfeld's famed unknown unknowns?

Brothers apart?

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

■ There are several reasons. First, atomic nuclei are bombarded with neutrons inside supernovae, causing the nuclei to grow bigger and bigger. Some of the neutrons turn into protons, giving rise to elements higher and higher in the periodic table. Four of the stable nuclei are lead (Pb), but only one is gold (Au).

Furthermore, nuclei with an even number of protons and an even number of neutrons are more stable than those with an odd number of one or the other. Lead has 82 protons, whereas gold has 79. The lead isotopes Pb-204, Pb-206, and Pb-208 also have even numbers of neutrons. That means their potential energy is lower than one would otherwise expect, and therefore more of those isotopes get produced than those with an odd number of protons or neutrons, like the stable isotope of gold, Au-197.

In addition, many elements heavier than lead are produced in supernovae, but then decay into stable Pb-206, Pb-207 or Pb-208 – creating even more lead.

All of these explain why there is a lot more lead than gold in the solar system. In Earth's crust, there is another factor. Gold is a siderophile, meaning it associates with iron. When our planet was a

largely molten mass, the gold mostly went with the iron and settled into Earth's core.

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

■ Supernovae aren't the only source of lead in the universe, for this reason: lead is the last stable element in the periodic table. This means that all elements heavier than lead will undergo radioactive decay. There are various chains in which an atom of one element will release radiation and become another (radium can emit an alpha particle and become radon, for example). The most common of these chains are the thorium, radium and actinium series, all ending with stable, unreactive and frankly boring lead.

These decay chains occur constantly in Earth's crust, continuously replenishing reservoirs of lead. This helps explain why it is so much more abundant than gold.

Incidentally, this transmutation of elements is precisely the sort of thing sought by alchemists of past centuries. Unfortunately, instead of expensive, shiny gold, it gives us dull, cheap lead, which doesn't exactly gleam on the finger of those to be betrothed.

*Bradley Clarke
Brighton, UK*

■ For a long time, astrophysicists believed that heavy metals such as gold or lead were forged in exploding supernovae. However, observations of gamma-ray bursts by a NASA telescope have now

confirmed an entirely different theory, which is that our universe's metals are created when large, extremely dense neutron stars in orbit around each other collide.

It takes billions of years for such collisions to occur, but when they do, they release huge amounts of energy and create vast quantities of gold, lead and platinum, with platinum in larger quantities than lead.

*Nadia Chigmaroff
West Vancouver, British Columbia,
Canada*

Diverse opinion

Invasive species often start with just a few individuals and multiply to huge numbers across a continent, but they don't seem to suffer from a lack of genetic diversity. Or do they? If not, why not?

■ The answer is complex, but the bottom line is that an invasive plant species starts with a big advantage: its natural predators, parasites and pathogens are generally absent from its new environment. Therefore, it doesn't need the genetic diversity which would otherwise ensure that such threats only affect a proportion of the population.

In addition, a large proportion of invasive species do not reproduce sexually. The extreme example is Canadian pondweed. It blocks watercourses worldwide, yet it is only female plants that have escaped from North America. These can give rise to

new plants in an entirely "vegetative" way – seeds are never produced.

In less extreme examples, many invasive species are "apomictic", producing viable seeds but not sexually, so seeds are not genetically distinct from the parent. Blackberries are a classic example. Mutations do occur in apomictic species, and the lack of sexual reproduction means they could persist in the offspring. This might sound like a recipe for disaster, but these species are typically "polyploid", meaning they have more than one copy of each chromosome, so the mutant version is diluted. They do change over time, but these changes don't spread through the population. This means that the taxonomy of an apomictic genus is a nightmare.

The other typical characteristic of an invasive species is strong vegetative reproduction through runners and roots. Even copious seed producers, such as tree of heaven and Australian fireweed, spread locally and mostly vegetatively. Sex, again, plays only a minor part.

*Guy Cox
St Albans, New South Wales,
Australia*

This week's question

RED LEAF, YELLOW LEAF

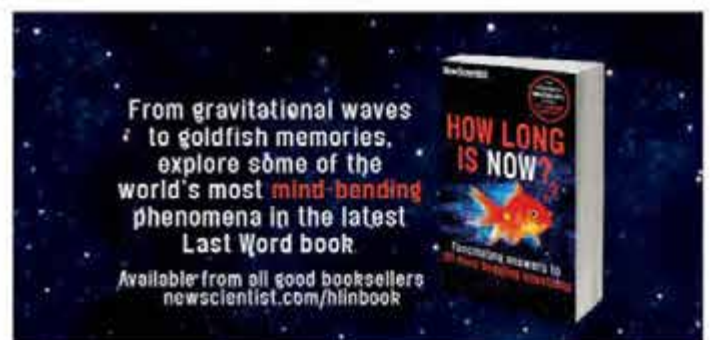
Why do some leaves turn yellow in autumn, while others turn red?
*Tony Sandy
Kilmarnock, East Ayrshire, UK*

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