New Scientist

WEEKLY February 18-24, 2017

NEURONAUTS
Learning to control our dreaming brains

THE OFF SWITCH
What really goes wrong in chronic fatigue

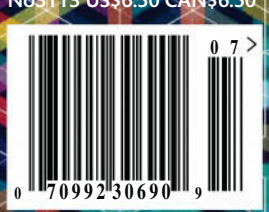
BAD HUMAN!
Dogs don't like people who are mean

COSMIC CONSCIOUSNESS Why you can't be a brain floating in space

THE HIDDEN PATTERN

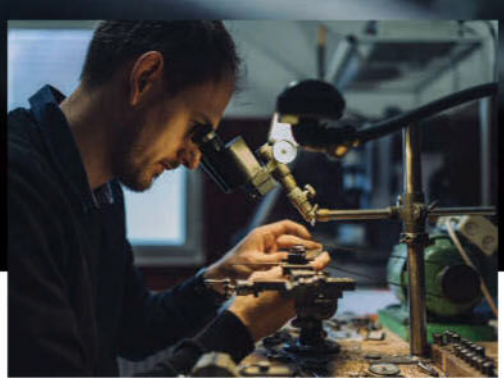
We're close to revealing the universe's underlying symmetry

No3113 US$6.50 CAN$6.50



Science and technology news
www.newscientist.com
US jobs in science

GOING FULL TERM Solving the mystery of multiple miscarriages



A watch with a truly global perspective, the **C8 UTC Worldtimer** is able to tell the time in three timezones at once. Designed in England, and built at our atelier in Switzerland, its self-winding ETA 2893-2 movement also boasts a power reserve of 42 hours. **Steel 44mm**

Swiss movement
English heart

Discover the new breed of watchmaker...
christopherward.com

Christopher Ward

CONTENTS

Volume 233 No 3113

This issue online
newscientist.com/issue/3113

News

8

Preventing miscarriage

Conceiving at an optimum time can reduce the risk

JOHN FEDELE/GETTY

On the cover

28

The hidden pattern

We're close to revealing the universe's underlying symmetry

Cover image
Simon C. Page

Features

37

Bison to the slaughter

Yellowstone's controversial cull

MICHELLE MCCARRON

Coming next week...

The coming plague
How to beat the next pandemic

Return of supersonic
Concorde is back without a bang

Leader

News

Analysis

Aperture

Features

Culture

Regulars

New Scientist events

INSTANT EXPERT: THE QUANTUM WORLD

SATURDAY MARCH 11, 2017

Six leading quantum experts, one amazing day of discovery. Get to grips with the fascinating world of quantum physics and ask our speakers the questions you've always wanted answering. By the end of the day you'll feel like an expert too.

THE BIG THEMES:

Learn about quantum computing and how to use quantum physics to power technology. Explore quantum weirdness, quantum gravity and much more.

BUY YOUR TICKETS NOW:

newscientist.com/quantumboston

10am-5pm
Suffolk University Law School
Boston, MA

OUR EXPERTS:
Seth Lloyd, Vladan Vuletic, plus 4 more speakers to be announced. Hosted by Lisa Grossman.



NewScientist

LOCATIONS
USA
50 Hampshire St, Floor 5, Cambridge, MA 02139
Please direct telephone enquiries to our UK office +44 (0) 20 7611 1200

UK
110 High Holborn, London, WC1V 6EU
Tel +44 (0) 20 7611 1200
Fax +44 (0) 20 7611 1250

Australia
Tower 2, 475 Victoria Avenue, Chatswood, NSW 2067
Tel +61 2 9422 8559
Fax +61 2 9422 8552

SUBSCRIPTION SERVICE
For our latest subscription offers, visit **newscientist.com/subscribe**
Customer and subscription services are also available by:
Telephone 1-888-822-3242
Email subscribe@newscientist.com
Web newscientist.com/subscribe
Mail New Scientist, PO Box 3806, Chesterfield, MO 63006-9953 USA
One year subscription (51 issues) $154

CONTACTS
Contact us
newscientist.com/contact

Who's who
newscientist.com/people

General & media enquiries
enquiries@newscientist.com

Editorial
Tel 781 734 8770
news@newscientist.com
features@newscientist.com
opinion@newscientist.com

Picture desk
Tel +44 (0) 20 7611 1268

Display advertising
Tel 781 734 8770
displaysales@newscientist.com

Recruitment advertising
Tel 781 734 8770
nssales@newscientist.com

Newsstand
Tel 212 237 7987
Distributed by Time/Warner Retail Sales and Marketing, 260 Cherry Hill Road, Parsippany, NJ 07054

Syndication
Tribune Content Agency
Tel 800 637 4082
tca-articlesales@tribpub.com

New Scientist Live
Tel +44 (0) 20 7611 1273
live@newscientist.com

New Scientist ISSN 0262 4079 is published weekly except for the last week in December by Reed Business Information Ltd, England.

New Scientist (Online) ISSN 2059 5387

New Scientist at Reed Business Information 360 Park Avenue South, 12th floor, New York, NY 10010.

Periodicals postage paid at New York, NY and other mailing offices

Postmaster: Send address changes to New Scientist, PO Box 3806, Chesterfield, MO 63006-9953, USA.

Registered at the Post Office as a newspaper and printed in USA by Fry Communications Inc, Mechanicsburg, PA 17055

JASON EDWARDS/GETTY

In praise of slow science

Don't ditch the means in pursuit of the end

A SCIENTIST'S work is never done. They build on the work of others, and leave their own work for others to build on. Scientific progress is a bit like a tree with deepening roots and growing branches – which sometimes take a long time to bear fruit.

Consider "bootstrap" research, a means of gathering knowledge about complex physical systems. Its seed was sown in 1920, but it has taken generations of scientists and mathematicians to cultivate it to the point where it is now attracting serious investment. In another decade or two it might be used to crack the problems of turbulent fluids and room temperature superconductivity – both big payoffs (see page 29).

The development of analytical techniques is an underrated branch of science. Without such tools, most insights would never bear fruit, remaining little more than speculation. Charles Darwin, for example, grasped the need for a unit of inheritance – which he called a "gemmule" – but lacked the statistical and biological techniques to identify one. But thanks to a long chain of researchers, mostly concerned with understanding inheritance rather than finding applications, genetics has become a multimillion dollar industry.

So the gap between identifying a problem to be solved, devising a technique and then putting it to work – a step often not even on the radar of those who initiated the process – can last a century or more. That poses a challenge to policymakers keen to evince the returns that money spent on R&D will generate. Although everyone knows they will come, no one knows how long they will take.

The temptation is to skew towards D and away from R. Why spend money on research

"Darwin grasped the need for a unit of inheritance but lacked the techniques needed to identify one"

that may not bear fruit for generations – or may never have any "practical" value – when you can invest in the development of fields that are promising today?

That question is likely to loom over the pending reorganisation of UK research funding. The government is proposing a new R&D strategy, embodied in "UK Research and Innovation" (UKRI), a single body bringing together seven existing Research Councils, Innovate UK and Research England under the leadership of Mark Walport, the chief science adviser.

This is not merely about streamlining administration. The formation of UKRI will give UK science a strong and unified voice, and an extra £2 billion a year of funding. The new body will have £6 billion of funding in total at its disposal. But some scientists are concerned this structure will give government more ability to meddle with research priorities; the promised new funding seems squarely aimed at business-friendly collaborations rather than basic research. There are also fears that small and obscure areas and facilities will be overlooked within the UKRI behemoth.

Fair enough, you might say. With the British economy set for uncertain times, taxpayers are entitled to ask that their money is put to work for the country. That's pragmatic, but short-sighted. As Walport has noted, UKRI is itself being realised more than 40 years after the case for a unified body was highlighted in 1971 by the Dainton Report on science policy.

For all our enthusiasm for development, we must make sure that research flourishes; unless we plant seeds today, there will be little fruit to harvest down the line. And as any biologist will tell you, fruit exists to ensure the existence of future generations – not as an end in itself. ■

Damning dam damage

CATASTROPHIC failures at a dam in California combined with heavy winter storms have forced hundreds of thousands to flee their homes. Although the level of the dam's lake is falling fast, more rain is forecast.

On 7 February, a huge hole was found in the main concrete channel that carries overflow water from the Oroville dam to the Feather river.

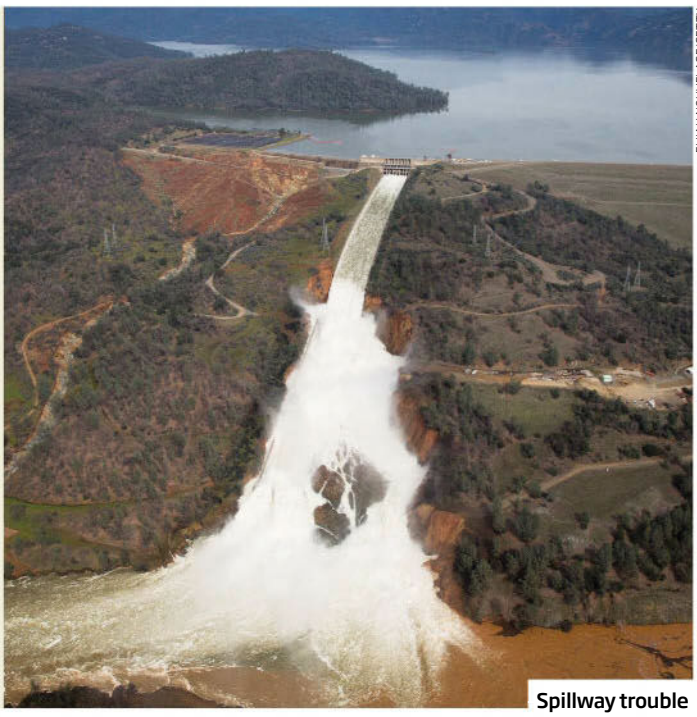
Engineers diverted this water along an unpaved emergency spillway that hadn't been used in almost 50 years – but this didn't work. On 12 February, officials ordered over 188,000 residents of downstream towns to evacuate because the spillway was at risk of collapse.

Unless the erosion of the spillway is dealt with, "what we're looking at is approximately a 30-foot wall of water", Kevin Lawson, deputy chief of the California Department of Forestry and Fire Protection, said at a press conference that night.

To lower the lake level, officials doubled the flow along the main spillway while checking it for further erosion. "That solution worked to reduce the threat," Bill Croyle, the acting director of the California Department of Water Resources, told a press conference on 13 February. He said he was unaware of a 2005 court filing from environmental groups that warned of just such a collapse.

As *New Scientist* went to press, the lake level was dropping about 2.5 metres a day and water had ceased flowing over the emergency spillway.

Now the race is on to repair both spillways before it rains again.



ELIJAH NOUVELAGE/GETTY

Spillway trouble

Twin assaults on TB

SUCCESS at last. Two new drug therapies may be able to cure all forms of tuberculosis.

"We will have something to offer every single patient," says Mel Spigelman, president of the TB Alliance, the organisation coordinating trials of the two treatments. "We are on the brink of turning TB around."

It presently takes six months of drug treatment to cure ordinary TB, and two years to cure people whose infections are resistant to drugs. People may need to take up to 20 tablets a day, plus injections.

"We will have something to offer every single patient. We are on the brink of turning TB around"

Together, the new treatments, called BPaMZ and BPaL, could make treating TB much simpler and more effective.

BPaMZ involves taking four drugs once a day. Trials carried out in 240 people across Africa suggest that it cures almost all cases of ordinary TB in four months, and most people with drug-resistant TB in about six months. In the majority of cases, the TB bacterium had disappeared from sputum within two months.

Meanwhile, BPaL, a therapy that involves taking three drugs once a day, has so far cured 40 of 69 patients with "extremely-drug-resistant TB" – the most difficult form to treat. What's more, it achieved this within six months.

Researchers presented results from both sets of trials at the Conference on Retroviruses and Opportunistic Infections in Seattle this week.

It is a much-needed breakthrough. According to the latest figures from the World Health Organization, there were 10.4 million new cases of TB in 2015, but only 20 per cent of those with resistant TB were treated, and of those only half were cured.

The new results are exciting and encouraging, says David Moore at the London School of Hygiene and Tropical Medicine, but he warns that we must be cautious about saying we can treat everyone until the results have been confirmed in larger trials.

Icy moon mission

THE search for life on Europa is inching closer to reality. NASA has released a report outlining goals for a proposed mission to the surface of Jupiter's icy moon.

The main objective is to search directly for evidence of life – which would make it the first NASA mission to do so since the Mars Viking landers in the 1970s. Europa is a prime target in the hunt for extraterrestrial life because its icy crust hides a huge saltwater ocean.

To put a lander on Europa, the report proposes using an automated "sky crane" system like the one used to land the Mars Curiosity rover in 2012. The Europa lander would hang beneath a descent craft fitted with thrusters and be steered to a gentle touchdown. Its job done, the sky crane would crash-land at a safe distance.

Scientists will discuss the report and provide feedback to NASA at two town hall meetings in the next couple of months in Texas and Arizona.

Heatwave grips Australia

AUSTRALIA is in the grip of a ferocious heatwave. It is one of the hottest on record, but climate change may make events like this the norm.

Parts of South Australia and Victoria have reached 46°C, while New South Wales and Queensland have recorded temperatures above 47°C. At least nine towns in these states had their hottest day ever recorded over the weekend.

The heatwave began when a high pressure system stalled over central Australia, causing a build-up of heat. An approaching front then dragged the hot air towards the east coast.

Climate change has made the heatwave longer and more intense, says Sarah Perkins-Kirkpatrick at the University of New South Wales. "Usually, you would only get this kind of extreme heat if it was an El Niño summer," she says.

The heat has hospitalised people, sparked bush fires, and greater use of air conditioning has led to blackouts.

Mars landing spot

THE results are in. The list of places where NASA's Mars 2020 rover could land has been narrowed down to three.

During a three-day workshop in California, eight different landing sites were presented and

"The emphasis of Mars 2020 is searching for signs of life and laying groundwork for future missions"

put to a vote. These options were already whittled down from the 30 potentials identified in 2015.

The main goal of NASA's Mars 2020 mission is to search for signs of life, while also laying the groundwork for future missions to return samples to Earth. Bringing back souvenirs from Mars will be difficult and expensive, so NASA needs to make sure it chooses the best location to collect them from.

Top of the list is Jezero crater, which used to be home to a lake the size of Lake Winnipeg in Canada. Second is north-east Syrtis, which was once warmed by volcanic activity that created hot springs.

The third spot is Columbia Hills, previously explored by NASA's Spirit rover. Spirit discovered that hot springs used to flow in the Columbia Hills as well, making it another area where life may have existed and signs may remain.

JOEL CARRETT/EPA

A climate friendly way to cool down

ANTHONY PHELPS / REUTERS

Hundreds of pilot whales beached

Mass strandings

MORE than 400 pilot whales beached themselves on 9 February in one of New Zealand's worst strandings.

The animals became marooned on beaches at Farewell Spit, a known black spot for strandings on South Island. At least 300 died overnight before rescuers refloated some 100 whales.

The success of refloating partly depends on the severity of the

"Stranding black spots share features such as gently sloping beaches that act as whale traps"

whales' injuries and the depth of the water they are pushed into.

Most of another pod of 240 or so whales that beached on the spit on 11 February refloated themselves when the tide came in.

The cause of beachings remains a mystery. Explanations range from noise pollution to suicide, and NASA is even investigating whether solar storms could mess with whales' navigation.

But geography is likely to be a factor, considering similarities between several known stranding black spots. "They share similar features such as gently sloping beaches, and the coastal configuration as a whole acts as a whale trap," says Sharon Livermore at the International Fund for Animal Welfare.

At Farewell Spit, the tide can come in for 5 kilometres, creating a vast stretch of water no more than 3 metres deep at any point, a perilous situation for whales used to deep water. "The water gets shallower, and that's what gets them disorientated," says Livermore.

Tread carefully

GENE editing may save lives but it shouldn't be used to edit embryos just yet, says a report.

Such editing may be permitted in the future, if properly regulated and with public approval, concludes the report by the Committee on Human Genome Editing, a group of 22 researchers, lawyers and ethicists.

New techniques have made gene therapy a promising option for treating many diseases, but it comes with risks. There's a chance, for instance, that a therapy will have "off target" effects, changing unexpected genes. The report states that regulators must weigh up the risks against treatment benefits on a case-by-case basis.

While the report was not in favour of gene editing for human enhancement or "designer babies", the authors say some aspects of enhancement may be acceptable in the future.

60 SECONDS

Climate hits animals

Climate change is already harming around 700 species of mammals and birds, due to issues such as habitat loss. Almost half of land mammals and nearly a quarter of birds listed as threatened may be negatively affected by climate (*Nature Climate Change*, DOI: 10.1038/nclimate3223).

Stem cell reprise

The world's only clinical trial of a treatment based on induced stem cells resumed last week. Five people in Japan with a form of progressive blindness will receive injections into their eyes of a cell therapy derived from induced pluripotent stem cells. The trial was suspended in 2015 after cell irregularities were detected in the treatment.

Surprised bees whoop

Bees let out a whoop of surprise when they bump into each other in the hive. A new recording technique let scientists listen to this vibrational signal and discover that bees use it to express surprise when they bump into each other or their hive is shaken (*PLoS One*, doi.org/bzms).

Carrot and stick

Taxing junk food and subsidising vegetables could add 500,000 extra years of healthy life to Australia's population of 23 million. A study of consumer behaviour estimates that such a move would save A$3 billion in healthcare costs over the remaining lifetimes of all Australians alive today (*PLoS Medicine*, DOI: 10.1371/journal.pmed.1002232).

Baby croc fossil

The first evidence of live birth in the vertebrate group that includes birds and crocodiles comes from a 250-million-year-old fossil. A specimen of *Dinocephalosaurus*, a long-necked ancestor to the crocodile, was found with an embryo inside its ribcage. (*Nature Communications*, DOI: 10.1038/ncomms14445).

JOHN FEDELE/GETTY

Hoping for a heartbeat

Stop multiple miscarriages

Working out when the womb is most receptive could prevent heartache

Jessica Hamzelou

MISCARRIAGE could be caused by too many ageing cells in the womb and a fluctuating immune response. This suggests carefully timing a pregnancy could prevent miscarriage and increase the chance of carrying a baby to term.

"All the 'treatments' we've been giving to women who miscarry haven't been effective at all," says Roy Homburg at Homerton University Hospital in London. "We haven't been getting to the root of the problem," he says. "But this idea is particularly clever."

A quarter of pregnancies end in miscarriage within the first 23 weeks. There are some known risk factors, such as being older or overweight, and some pregnancies fail because of genetic abnormalities. But we don't really understand what causes miscarriages, especially in the 1 per cent of women who experience three or more in a row.

Jan Brosens at the University of Warwick, UK, thinks the balance between stem cells, ageing cells, and immune cells could be to blame. In a healthy uterus, stem cells enable the endometrial lining to build up over 10 days after every period. Some cells in the endometrium then "senesce" – they stop dividing, triggering inflammation. Natural killer cells then clear out the ageing cells. This process creates a kind of honeycomb mesh, with holes just the right size for an embryo to embed, says Brosens.

But something seems to go awry in women who miscarry. When Brosens's team took samples from the uteruses of women who hadn't had miscarriages, they found that the number of natural killer cells cycled in a predictable manner throughout the month. But in women who had miscarried several times, the numbers of natural killer cells rose for several months in a row, before they disappeared, and then began to accumulate again.

This could be because they have too few stem cells. "Forty per cent of [recurrent miscarriage] patients had no stem cells at all," says Brosens. As a result, more cells enter the tired "senescent" state, attracting larger numbers of natural killer cells, leading to bigger holes in the endometrium.

If true, it may explain why women who frequently miscarry can find it very easy to get pregnant. The large holes in the endometrium may enable an embryo to implant readily, but eventually the structure will collapse in on itself, says Brosens.

"All the 'treatments' we've been giving to women who miscarry haven't been effective at all"

However, as natural killer cells rise in number over time, a woman should eventually have very low numbers of senescent cells, minimising the effects of having relatively few stem cells. "We should have windows where things are completely normal," says Brosens, who presented his work at the Nordic Fertility Innovation meeting in Stockholm, Sweden, this month.

This could be why women can experience multiple miscarriages before having a healthy baby – they may have been conceiving when the uterus was not very receptive to a pregnancy, before chancing on optimum conditions.

Brosens and his colleagues have begun to test natural killer cell levels in women who have had recurrent miscarriages, to help them identify the best time to get pregnant. So far, they have advised around 150 women. One women recently told Brosens that she is now 26 weeks pregnant.

But the team can't be sure if their strategy is working until they run a clinical trial. "They obviously need more evidence, but the basis is a very strong argument," says Homburg.

Claus Yding Andersen at Copenhagen University Hospital in Denmark is also impressed. "There's been a lot of research into causes of miscarriage, but there has been no consensus," he says. "Brosens's theory is well justified, but it's too early to declare whether it will work." ■

DON'T BELIEVE THE MOVIES

What causes a miscarriage? Stress or a heated argument, if film and TV plots are to be believed – but that's simply not true.

In a 2016 survey of 1000 people in the US, three-quarters believed stressful events can trigger miscarriage, while two-thirds also blamed heavy lifting. But there's no evidence that either of these causes miscarriage, nor does having sex or previous use of contraceptives.

The survey also found that many people underestimate how common miscarriage is. Most people thought fewer than 6 per cent of pregnancies end this way, when it occurs in as many as a quarter of pregnancies. This includes women who miscarry without ever realising they pregnant, but miscarriage still occurs in 1 in 6 known pregnancies.

Reject universes that lead to cosmic brains

TRUST your senses. Any theory that lets bizarre brains randomly pop into existence can't be a valid description of the universe.

That might seem obvious, but such conscious observers, called Boltzmann brains, are inevitable in certain versions of cosmology. New work that claims to banish such theories not only suggests your brain isn't such an oddity, but tells us which frameworks for the cosmos are the most sound.

The notion of a Boltzmann brain is built on 19th-century physicist Ludwig Boltzmann's idea that the entropy of a closed system – a measure of its disorder – always increases. There are far more ways to be disorderly than orderly, so it's much more likely that the system will move towards disorder. But there is always an infinitesimal probability that a system will suddenly fluctuate from disorder to order.

What's more, we know that the expansion of our universe is accelerating, and the standard view is that mysterious dark energy is responsible. If dark energy remains constant throughout time, the universe will expand forever.

"If you have literally forever to wait, you'll get essentially every single possible thing fluctuating into existence," says Sean Carroll at the California Institute of Technology in Pasadena. That includes Boltzmann brains.

The idea is that given infinite time, more brains will fluctuate into existence than evolve, so most conscious observers would be the result of fluctuations. In such an old universe, then, the odds are that we are such brains, too.

Carroll isn't a fan of Boltzmann brains, and now he thinks he can show they are a bridge too far.

If our brains spontaneously fluctuated into existence, he reasons, then we must be living in the very far future, since the universe needs a near-infinite time for such fluctuations to become a reality. But our measurements suggest that the universe began a mere 14 billion years ago.

That discrepancy means that if we truly are Boltzmann brains in an old universe, then our perceptions are befuddled, too. "We'd have no reason to believe that our memories of the past are accurate," says Carroll.

He calls this paradox "cognitive instability": the inability to trust your own processes of reasoning and memory. That should be enough to rule out such universes – and the cosmological models that produce them, he says (arxiv.org/abs/1702.00850).

This has implications for theories of dark energy. For example, if dark energy weakens over time, then the universe could contract and end up in a "big crunch" – and it would never get old enough for Boltzmann brains to form. If dark energy is instead constant over time, then Boltzmann brains could crop up eventually. But whether or not the universe will fluctuate in the necessary way depends on the particulars of a theory of quantum gravity, which have yet to be worked out.

Tossing out those theories that lead to Boltzmann brains may help us decide between competing ideas, Carroll says. On that basis, it's reasonable that the universe might be headed for a big crunch, for example.

Raphael Bousso at the University of California at Berkeley has wracked his brains over this problem, and is torn about Carroll's ideas.

"If a theory predicts that the overwhelming majority of observers are Boltzmann brains, then that theory is ruled out," he says. But he thinks Carroll's argument introduces an unnecessary mystique. "There is no need for fancy notions like 'cognitive instability'."

Anil Ananthaswamy ■

FRÉDÉRIC LECLOUX/AGENCE VU/CAMERAPRESS

Minds don't just flare up

Australian foxes seen climbing trees to hunt

FOXES in Australia have been filmed climbing trees, possibly on the look out for baby koalas.

The European red fox was introduced to Australia in the mid-1800s for recreational hunting. It quickly developed a taste for ground-dwelling native species like bilbies, wallabies and numbats, leading to declines in their numbers. Tree-dwelling animals were considered safe. But now it seems this might not be the case.

In mid-2016, Valentina Mella at the University of Sydney was studying koalas on a property in the Liverpool Plains, about 250 kilometres north-west of the city. As part of her research, she set up cameras to record the animals visiting drinking fountains in eucalyptus trees spaced several kilometres apart. She was astonished to find multiple instances of red foxes scaling the trees. "I was quite shocked because I've never seen a fox in a tree before," she says.

Although the footage didn't capture active predation, the foxes could be seen sniffing around and following the scent of other animals that had been in the trees. This was evidence they were on the hunt, says Mella. They didn't touch the drinking fountains, suggesting they weren't there because they were thirsty (*Australian Mammalogy*, doi.org/bzmf).

"It's hard to hunt ground-dwellers used to foxes, but baby koalas are just sitting there. That's easy prey"

Euan Ritchie at Deakin University in Victoria, Australia, says he has heard anecdotal evidence from other ecologists of red foxes climbing trees. It may be more common than we think, he says. "Red foxes are quite agile animals, so it makes sense," he says.

If true, it might be devastating for native tree-dwelling animals. "It's probably hard to catch rabbits, for example, because they are used to foxes and are programmed to escape," Mella says. "But if a little feathertail glider or baby koala is just sitting there, that's easy prey." Alice Klein ■

Metabolism linked to chronic fatigue

Andy Coghlan

IT'S as if a switch has been flicked. Evidence is mounting that chronic fatigue syndrome (CFS) is caused by the body swapping to less effective ways of producing energy.

Also known as ME, CFS affects some 250,000 people in the UK. The main symptom is persistent physical and mental exhaustion that doesn't improve with sleep or rest. It often begins after a mild infection, but its causes are unknown. Some have argued that CFS is a psychological condition, best treated with cognitive behavioural therapy.

But research is now suggesting that CFS could, in many cases, be due to people losing their ability to fully exploit carbohydrate sugars to generate energy. To compensate, their cells rely on lower-yielding fuels, such as amino acids and fats, and build up lactate, a painful by-product. This would explain both the shortness of energy and why even mild exercise can be exhausting and painful.

Øystein Fluge of Haukeland University Hospital in Bergen, Norway, and his team have studied amino acids in 200 people with CFS, and 102 people without it. They found abnormally low levels of the types of amino acid that can be used as a fuel source in the blood of women with CFS.

These shortfalls were not seen in men with CFS, but that could be because men tend to extract amino acids for energy from muscles, instead of blood. The team saw high levels of an amino acid that is a sign of such a process. "It seems that both male and female CFS patients may have the same obstruction in carbohydrate metabolism to energy, but they may try to compensate differently," says Fluge.

Both sexes had high levels of enzymes that suppress pyruvate dehydrogenase (PDH), an enzyme vital for moving carbohydrates into a cell's mitochondria to generate energy (*Journal of Clinical Investigation*, doi.org/bzmn).

Several studies have hinted that defects in sugar burning can cause CFS, but there is uncertainty over how this is disrupted. "We don't think it's just PDH," says Chris Armstrong at the University of Melbourne in Australia, whose research has uncovered similar anomalies in amino acid levels. "We think it's an issue with sugar metabolism in general."

"No single enzyme in metabolism will be the answer to CFS," says Robert Naviaux of the University of California at San Diego, who has found depletions of fatty acids in people with CFS, suggesting these molecules are diverted as fuel.

So what could flick the switch to a different type of metabolism? Fluge's team thinks a person's own immune system may stop PDH from working, possibly triggered by a mild infection.

His team has previously shown that using a cancer drug to wipe out immune cells called B-cells in CFS patients seems to relieve the condition. These cells make antibodies, and Fluge suspects that some antibodies against infections may also disable PDH.

These metabolic effects suggest CFS has a chemical cause. "It's definitely a physiological effect that we're observing, and not psychosomatic, and I'll put my head on the block on that," says Armstrong. However, he says, psychological and brain chemistry factors might be involved in some cases. ■

HALFDARK/FFSTOP/PLAINPICTURE

Always exhausted

Virtual weather fools all of your senses

VIRTUAL reality devices can already fool your eyes and ears. Soon your other senses will be tricked too, using a device that can bring the weather in your virtual world to life.

Nimesha Ranasinghe at the National University of Singapore is working towards the ultimate VR experience. Last year, his team showed how electrodes can be used to add sweet tastes into virtual reality. His new accessory, called Ambiotherm, adds atmosphere into the mix as well.

Ambiotherm has two components that combine with a normal VR headset. The first is a wind module that contains two fans that clip on to the bottom of a headset.

"This means that we can simulate the wind blowing in your face, for example, as you ski down a mountain," says Ranasinghe.

The second is a temperature module that attaches to the back of the neck. "So when walking through a virtual desert, we can simulate the harsh sun beating down on you," he says.

The accessories don't just affect the area they are pointing at, though. In previous experiments, Ranasinghe and his team found that if heat is gradually applied to the neck it feels like the whole body is experiencing a different temperature. Similarly, wind passing the throat can give the impression of standing somewhere windy.

"We can simulate the wind blowing in your face, for example, as you ski down a mountain"

Making VR more realistic could increase its possible uses. Researchers have already shown that VR can reduce pain, reduce fear of death, and even help people who are paralysed regain some feeling in their legs.

"We're studying how human emotion can be augmented using multisensory VR. The next step is to start including smells and vibrations," says Ranasinghe. Ambiotherm will be presented at the Conference on Human Factors in Computing Systems in Colorado in May. Timothy Revell ■

Algae survive in outer space for over a year

PRIMITIVE plants are the latest forms of Earth life to show they can survive in the harshness of space, and for many months.

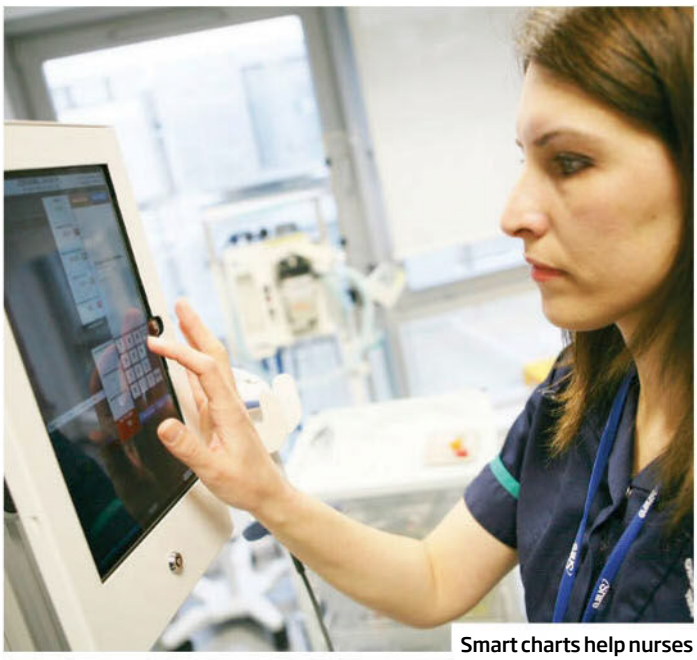
The algae were a species of *Sphaerocystis*, codenamed CCCryo 101-99, and were returned to Earth in June last year after 530 days on a panel outside the International Space Station. While space-borne, they withstood the vacuum, temperatures ranging from -20 °C at night to 47.2 °C by day, plus ultraviolet rays strong enough to destroy most life on Earth if not filtered out by the atmosphere.

"As far as I know, this is the first report of plants exposed on the surface of the space station," says Thomas Leya of the Fraunhofer Institute for Cell Therapy and Immunology in Potsdam, Germany, who organised the experiment.

It was Leya who discovered CCCryo 101-99 on Norway's remote Svalbard peninsula. When dormant, these algae become thick-walled orange cysts, rich in protective carotenoids. But when seasonal rains arrive, they rapidly resume making chlorophyll and turn green again. "If you give them water, the cysts germinate and revive," says Leya.

For the experiment, Leya dried out the algae and coaxed them into the cyst-like state, where they just ticked over without reproducing, feeding or multiplying. Mounted on the panel, the algae were open to space but overlaid with a transparent filter to cut the radiation dose somewhat. All but one sample survived the trip. "Within just two weeks they become green again," says Leya.

"The experiment shows that some terrestrial organisms are robust enough to cope with months of exposure to open space conditions without a space suit," says René Demets of the European Space Agency. It lends some weight to the "panspermia" theory, that comets and meteorites could potentially ferry life around outer space. Andy Coghlan ■



OXFORD UNIVERSITY HOSPITALS NHS FOUNDATION TRUST

Smart charts help nurses

NHS to prescribe apps that keep tabs on health

THE future of healthcare could be in your pocket. Two new medical apps that help people monitor their health at home, reducing their need to visit a doctor, are set to be rolled out to as many as four more UK National Health Service trusts over the next year.

The apps, which are currently being trialled in different NHS trusts, transmit patient data from a tablet or smartphone directly to clinicians. According to Ilan Lieberman, a member of the Royal Society of Medicine's council on telemedicine and e-health, such apps will have a huge impact on managing chronic diseases.

One system, called GDm-health, helps oversee the treatment of gestational diabetes – a condition that affects about 1 in 10 pregnant women. The smartphone app lets women send each blood glucose reading they take at home to their diabetes clinician.

"Now when a diabetes midwife logs on between clinics, she will see all the patients who are most in need of attention," says Lionel Tarassenko of the Oxford University Institute of Biomedical Engineering, who led the team behind the technology. A two-year trial at the Royal Berkshire NHS Foundation Trust showed that the system meant patients didn't need to go to the clinic in person as often, reducing the number of visits by 25 per cent.

Another system being developed by the same team is for managing chronic obstructive pulmonary disease (COPD), a condition that affects between 1 million and 1.5 million people in the UK. Patients with COPD use a finger probe to measure their heart rate and blood oxygen saturation every day and enter the results into an app. After three months, the app learns a patient's specific range of normal oxygen saturation levels, and issues an alert to clinicians when a reading falls below that range. "It is very important that the analysis adapts to individuals," says Tarassenko. If the system is too sensitive, it will send too many alerts, but if it's not sensitive enough, it might miss problems.

"It's a bit like the Wild West out there with lots of keen and very motivated people producing these apps"

In a 12-month clinical trial, the app reduced hospital admissions by 17 per cent and visits to the doctor by 40 per cent. "Patients are much more confident about managing themselves and are getting into trouble far less often," Tarassenko says.

The team has a third product ready for rollout, but this is not aimed at patients self-monitoring. Called SEND, it is an iPad app used by nurses to input details about patients' vital signs as they make their rounds of the wards. It automatically calculates an early warning score based on the vital signs, letting staff know if a patient is deteriorating.

Rury Holman at the Oxford Biomedical Research Centre thinks trialling the apps in NHS hospitals is a good idea. Although plenty of health monitoring apps already exist, he believes that if similar apps are going to be used in the UK healthcare system, it's vital they are developed in close collaboration with the NHS.

"It's a bit like the Wild West out there with lots of keen and very motivated people producing these apps," he says. "What we need are consistent standards and an interface with electronic patient records, particularly with the NHS, so that information, with permission from the patients, can be put to use centrally."

Developing these apps has taken eight years, but Tarassenko says securing the appropriate ethical clearance and building up a clear evidence base for their use is a critical journey. "It's been very important for us to have credibility with our clinical colleagues, and we will continue to do that because it's designed in the NHS, for the NHS." **Matt Reynolds** ■

Swap bacteria to fix body odour

Jessica Hamzelou

GOT BO? Blame the bacteria living in your armpits. Some people's bacteria cause body odour that no deodorant can disguise. But replacing them with bacteria from a less smelly person can solve the problem.

Our bodies are crawling with bacteria, and the microbes that live on our skin vary by region. Armpit bacteria probably have a role in making the compounds that make sweat smell, says Chris Callewaert at the University of California, San Diego.

A few years ago, Callewaert met a pair of identical twins – one of whom had particularly bad body odour. Callewaert suspected that different mixes of armpit bacteria might be responsible for their different personal scents, so he tried swapping out the stinky twin's armpit bacteria with his twin brother's.

The twin that didn't smell refrained from washing for four days, to allow bacteria deep in his armpits to rise to the surface with dead skin. Meanwhile, the stinky twin scrubbed his pits with antibacterial soap every day, for four days, to remove as much of his armpit bacteria as possible.

Callewaert transferred bacteria from the sweet-smelling twin to his brother using swabs, and found that the man's body odour problem rapidly disappeared. "The effects have persisted for over a year now," says Callewaert.

His team has since repeated this procedure with 17 other pairs. In each case, one person in the pair had a body odour problem, and the other person was a close relative. Before and after the bacterial transplants, the offensiveness of the previously smelly people was judged by a "trained odour panel" of eight people, says Callewaert.

Out of the 18 pairs, 16 saw improvements in body odour within a month. Half of the group had long-term improvements that lasted three months or more. Callewaert presented the results at the Karolinska Dermatology Symposium in Stockholm, Sweden, last month.

"It's very cool, and the idea is sound," says Emma Allen-Vercoe at the University of Guelph in Ontario, Canada. She hopes that a similar approach might be useful for treating some skin conditions, like eczema and psoriasis.

Callewaert and his colleagues are now formulating a more general brew of bacteria that could be used in place of a relative's armpit scratchings. "It's still very experimental, but I'm sure it can work," he says.

In the meantime, you might be able to improve your body odour bacteria by shaving, maintaining a healthy weight and avoiding polyester clothing and fatty foods. "People that eat fast food and meat smell worse, while those that eat vegetables smell better," says Callewaert. ■

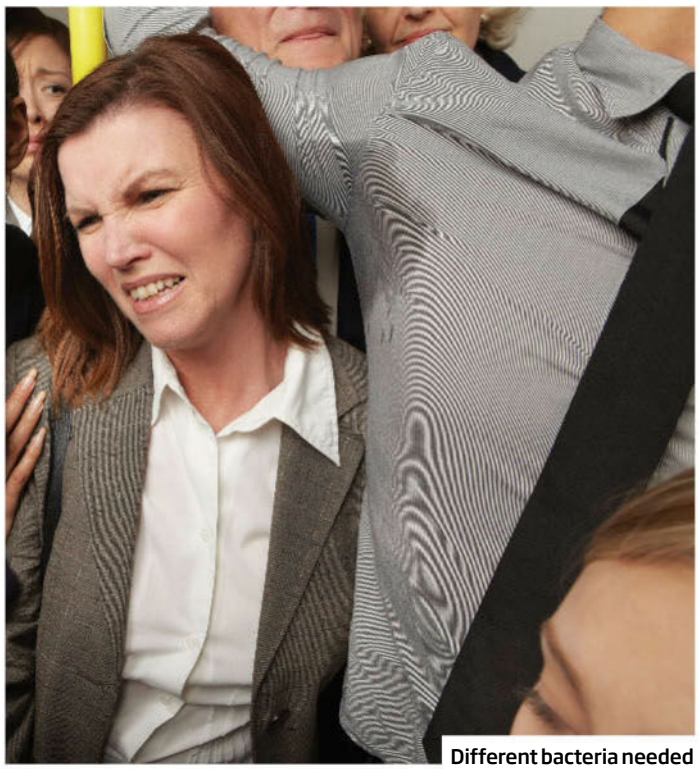


IMAGE SOURCE/REX/SHUTTERSTOCK

Different bacteria needed

AI learns to crack quantum mechanics

THE same type of artificial intelligence that mastered the ancient game of Go could help wrestle with the amazing complexity of quantum systems containing billions of atoms.

Google's AlphaGo artificial neural network made headlines last year when it bested a world champion at Go. After marvelling at this feat, Giuseppe Carleo of ETH Zurich in Switzerland thought it might be possible to build a similar tool to crack one of the knottiest problems in quantum physics: understanding many-body quantum systems.

With Go, the number of possible positions on the board could exceed the number of atoms in the universe. So an approach based on brute-force calculation, while effective for a game like chess, just doesn't work for Go.

In that sense, Go resembles a classic quantum physics puzzle: how to describe a quantum system made up of billions of interacting atoms.

But the weird rules of quantum mechanics mean we can't know a quantum particle's precise location at every point in time, meaning there are trillions of trillions of possible configurations for a quantum system containing relatively few particles.

That's where artificial neural networks can help. Give such a network the rules of Go and it will figure out the optimal strategy to win the game. So perhaps it could do the same for quantum systems.

To assess this idea, Carleo and Matthias Troyer, now at Microsoft, built a simple neural network designed to reconstruct the wave function of a multi-body quantum system, or the set of probabilities describing how all the possible configurations could be arranged.

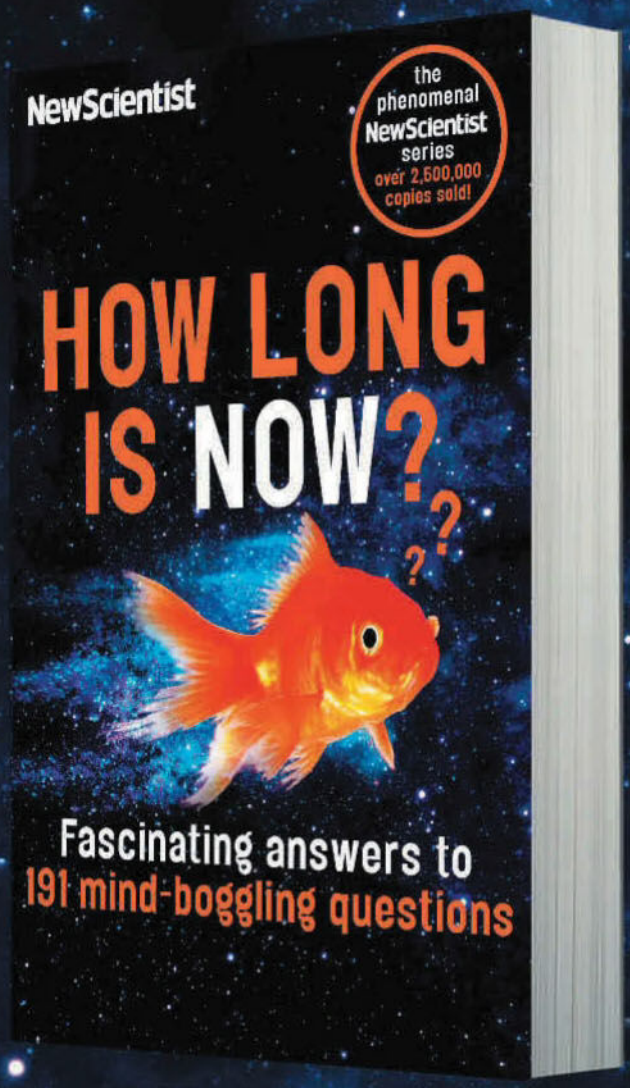
"It's like having a machine learning to crack quantum mechanics… and dreaming of Schrödinger's cat"

They tested it on a few sample problems with known solutions and found it outperformed other tools (*Science*, DOI: 10.1126/science.aag2302). That's sufficient proof of principle, Carleo says. "It's like having a machine learning how to crack quantum mechanics, all by itself," he says. "We have a machine dreaming of Schrödinger's cat."

"It's incredibly cool," says Scott Aaronson at the University of Texas in Austin. "I expect to see a lot more of this in the future."

Jennifer Ouellette ■

WHY ARE DOGS' NOSES WET?



From gravitational waves to goldfish memories, explore some of the world's most mind-bending phenomena in the latest book from NEW SCIENTIST.

NewScientist

G. BRAD LEWIS/GETTY

A window onto Earth's birth

Hottest lava is as old as Earth itself

Andy Coghlan

IT WAS there at the birth of our planet 4.5 billion years ago. Now we know how magma from that formative period has survived to the present day, occasionally making it to the surface. And it could shed light on Earth's origins.

"This deep reservoir is a time capsule preserving signatures of the earliest history of the Earth that are not recorded in any other part of the planet that we have access to," says Matt Jackson at the University of California, Santa Barbara. His team has discovered that only the hottest plumes of magma in Earth's mantle carry these rocky relics.

Lava from these plumes contains helium isotopes in proportions that can be explained only if it formed inside primordial Earth.

Helium-3 is a rare isotope, usually at least as old as Earth itself, unlike its abundant sister isotope helium-4, which is produced by the decay of elements that formed later on Earth, like uranium and thorium. The greater the ratio of helium-3 to helium-4 in a lava sample, the older that sample probably is.

Geologists first discovered lava with a high proportion of helium-3 in the 1980s, around volcanic hotspots. But it was often found alongside lava that didn't have the ancient helium signature."For over three decades, geologists have been trying to figure out why some plumes have high amounts of helium-3, while others don't," says Jackson.

"A record of Earth's early history is held in the hottest magma plumes, which act as time capsules"

Jackson and his colleagues have analysed published data to explore relationships between the helium ratios in lava from relatively shallow plumes beneath 38 volcanic hotspots, whose buoyancy, temperature and speed could be measured or inferred. "Only the hottest plumes have the high helium-3 content," Jackson says. "Cooler plumes do not."

Jackson suggests that there are extremely dense domains within the mantle that have kept the hot, slow-moving plumes and their precious helium cargo intact. In contrast, cooler plumes are more porous and have become infiltrated by helium-4, which eventually dwarfs the amount of ancient helium-3 there (*Nature*, doi.org/bzj4).

"Their explanation is elegant and simple: that hot plumes with high buoyancy preferentially transport helium-3-rich lavas, which can be observed at the surface," says John Tarduno at the University of Rochester in New York. "Their data strongly weigh in favour of a primordial origin, an astounding and challenging conclusion, considering the potential stirring induced by billions of years of plate tectonics."

"Understanding the source of these geochemical signatures in hotspot lavas has very important implications for our understanding of the dynamics of the Earth's interior," says Rizo Hanika of the University of Quebec at Montreal, Canada.

It could help geologists establish the locations and sizes of the ancient reservoirs in the mantle, she says. "Having a record of this early history is important to understanding how our planet formed and evolved in the earliest days after formation," says Jackson. ■

Robo-bee to aid farmers and their crops

WHERE bees are struggling, an airborne robot could rise to the occasion. Drones that pollinate flowers could one day help maintain crop yields.

In self-pollinating flowers, fertilisation can occur when pollen is shed from the stamens on to the pistil. Cross-pollination, however, needs pollen from one plant to reach another, often via insects like bees.

Eijiro Miyako at the National Institute of Advanced Industrial Science and Technology in Tsukuba, Japan, and his colleagues have now built a drone that fulfils that role. The manually controlled craft is 4 centimetres wide and has a mass of just 15 grams.

The drone's underside is covered in horsehair coated in a sticky gel. Pollen grains that stick lightly to the gel when the drone visits one flower will get rubbed off on to the next flower visited. In experiments, the drone was able to cross-pollinate Japanese lilies (*Chem*, doi.org/bzk8).

Miyako says the team is now working on autonomous drones that could help pollinate crops. "We hope this will help to counter the problem of bee declines," says Miyako. GPS, high-resolution cameras and artificial intelligence will be required for the drones to navigate independently between flowers and visit them correctly, although it will be some time before all that is in place.

Saul Cunningham at the Australian National University in Canberra says using drones in this way is an intriguing idea but may not be economically feasible. "The scale on which you would have to operate your robotic pollinators is mind-boggling."

More viable strategies for tackling the bee decline and its impact on agriculture are being pursued, says Cunningham. These include cutting pesticide use to help bee populations recover, and even the machine-spraying of crops with pollen. Alice Klein ■

NEW SCIENTIST DISCOVERY

Space flight: A history

A two-week, action-packed tour in the US with *New Scientist* astronomy and space experts

Nigel Henbest and Lisa Grossman

DEPARTURES:

8 MAY 2017 AND 25 SEPTEMBER 2017

SEVEN SPACE CENTRES

Hold on tight, this itinerary will take you on a thrilling ride through six states and to seven space centres. Stand nose-to-nose with the Discovery shuttle in the Steven F Udvar-Hazy Space Center and experience what it feels like to blast off into outer space at the NASA Kennedy Space Center.

AN APPOINTMENT WITH APOLLO 11

Gaze at the Apollo 11 capsule as you enter the Smithsonian Air and Space Museum before studying the Viking lander and the Gemini and Mercury capsules. Venture into the Spaceport Operations Center at Virgin Spaceport America and interact with crewmembers. Explore the US Space and Rocket Center where the Saturn V Moon Rocket is displayed.

QUIZ AN ASTRONAUT

Chat with an astronaut at the NASA Kennedy Space Center and enjoy expert talks from astronomer and astronaut-in-training Nigel Henbest (May) or *New Scientist*'s physical sciences editor Lisa Grossman (September). You'll also have time to soak up the local atmosphere in Washington DC, Orlando, New Orleans and Houston.

WHAT'S INCLUDED

- All hotels and internal flights*
- Lectures and talks from space and astronomy experts
- Entry to museums and tours, including VIP experiences

14 nights from £4030 per person

FIND OUT MORE ABOUT THIS UNFORGETTABLE TRIP

Call now on **+44 (0)203 3089 917** or visit **newscientist.com/travel/spaceflight**

INTREPID real life experiences...

* BAGGAGE COSTS ARE NOT INCLUDED ON INTERNAL FLIGHTS

CHIP SOMODEVILLA/GETTY

Dogs and monkeys prefer good people

Sam Wong

BE NICE – or your pooch may judge you. Both pet dogs and monkeys show a preference for people who help others, and the results might explain the origins of our sense of morality.

By the age of 1, humans already start to judge others by how they interact. This has led to suggestions that children have a kind of innate morality that predates their being taught how to behave. Comparative psychologist James Anderson at Kyoto University in Japan and his colleagues wondered whether other species make social evaluations in a similar way.

They began by testing whether capuchin monkeys would show a preference for people who help others. The capuchins watched an actor struggle to open a container with a toy inside.

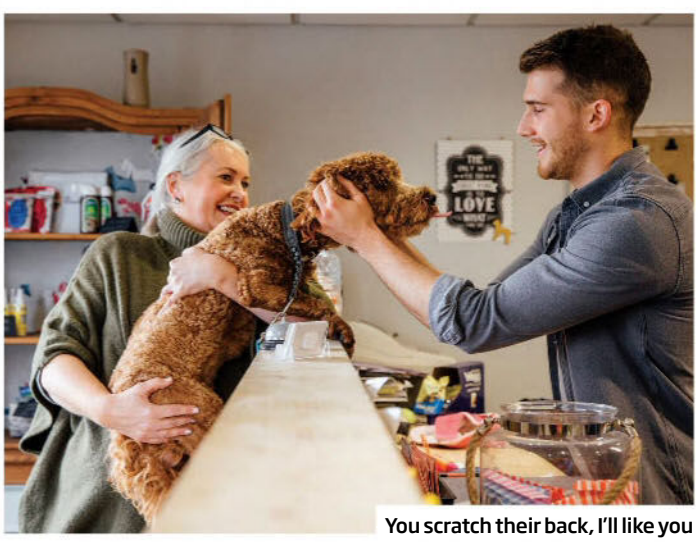
Then this actor presented the container to a second actor, who either helped or refused to assist. Afterwards, both actors offered each capuchin food, and the monkey chose which offer to accept. When the companion had been helpful, the monkey showed no preference between accepting the reward from the struggler or the helper. But when the companion had refused to help, the monkey more often took food from the struggler. Dogs did the same.

The team also investigated capuchins' attitude to fairness. In this test, actor A requested balls from actor B, who handed over three balls. Then actor B asked for balls from actor A, and A either gave three balls back or no balls. Lastly, both actors offered the monkeys a reward as before.

The monkeys had no preference when actor A had given back the balls, but chose actor B more often when A had not returned the balls (*Neuroscience & Biobehavioral Reviews*, doi.org/bzj5).

Anderson thinks the results show that monkeys and dogs make social evaluations in a similar way to human infants. "If somebody is behaving antisocially, they probably end up with some sort of emotional reaction to it," he says.

Dogs' long relationship with humans means they have evolved to be extremely sensitive to our behaviour – not just in relation to them, but also to other humans.



SOLSTOCK/GETTY

You scratch their back, I'll like you

But monkeys in the wild are likely to use similar processes to decide which members of their group they can cooperate with, says Frans de Waal of Emory University, Georgia. "Chances are that if these animals can detect cooperative tendencies in human actors, they also can in their fellow primates."

And our own sense of morality may even have its roots in these sorts of primitive evaluations of others. "In humans, there may be this basic sensitivity towards antisocial behaviour in others. Then through growing up, inculturation and teaching, it develops into a full-blown sense of morality," says Anderson.

The capacity to evaluate others could stabilise complex social groups by enabling individuals to exclude uncooperative members, says Kiley Hamlin at the University of British Columbia, Canada. This could discourage bad behaviour and help individuals avoid harmful social interactions.

De Waal sees a strong link between morality and reputation. "Human morality is very much based on reputation building, because why would you try to be good if no one cares?" he says. "I don't think you can conclude that it makes the monkeys moral beings, but 'image scoring', as reputation building is sometimes called, provides an important key mechanism." ■

Pedestrians signal to stop driverless cars

SHOULD I stay or should I go? An LED display for driverless cars aims to give pedestrians at a crossing the power to communicate with vehicles, signalling for them to stop or drive on.

Blink, created by researchers at the Royal College of Art and Imperial College London, turns the awkward dance of eye contact and hand gestures that happens when a car slows down while someone is waiting to cross the road into something driverless cars can understand.

Blink integrates an organic light-emitting diode display into the windscreen and rear window of a car and uses light signals to show pedestrians when the car is aware of their presence. If the car's sensors detect a pedestrian, a figure lights up, accompanied by a bleep.

If a pedestrian raises a hand as a stop sign, the figure turns green, indicating the pedestrian can cross, and the car is prevented from moving forward. If they place a hand out to the side to motion the car forward, the figure turns red and the car continues.

But George Filip at the University of Nottingham, UK, isn't convinced it is a good idea to give pedestrians control over autonomous cars. He says cities could end up gridlocked because pedestrians keep stopping cars.

Manufacturers should wait until the novelty of driverless cars has worn off before creating car-pedestrian communications systems, he says. "We need to learn how people actually interact with autonomous vehicles."

"The concept invests pedestrians with the car-stopping powers of lollipop men and women"

The idea is to help people feel more comfortable around driverless cars, says Blink co-creator Raunaq Bose. "This provides a really nice opportunity to rebalance the road power dynamic." The concept effectively invests pedestrians with the car-stopping powers of lollipop men and women.

The team hasn't yet tested the device on a driverless car, but Bose says several automotive companies have expressed interest.

Matt Reynolds ■

A LIBRARY OF KNOWLEDGE... POCKET SIZED

GET UNLIMITED ACCESS TO THE NEW SCIENTIST APP

Visit **newscientist.com/app** or call **1-888-822-3242** and quote offer 9055

NEW SCIENTIST DISCOVERY

Journeys of discovery

Climb high into the Himalayas, snorkel off the Galapagos or journey deep into the Madagascan forest for an expert look at wildlife conservation.

INDIA:

TRACK SNOW LEOPARDS IN LADAKH

FEBRUARY 2018, 13 DAYS
FROM $6195

Rather than hunting these elusive, endangered creatures, Ladakh farmers are now protecting them. Find out why on an unforgettable expedition into the breathtaking Indian Himalayas with *New Scientist*. You'll take part in camera-trapping and hear from an expert geologist who has studied the Himalayan area for decades. In the company of the Snow Leopard Conservancy, spend five days tracking snow leopards and spot blue sheep and ibex along the way.

MADAGASCAR:

LEMURS, BAOBABS AND THE TSINGY PARK

SEPTEMBER 2017, 13 DAYS
FROM $5950

Experience Madagascar's unique ecosystem by privately chartered plane. Visit the Durrell Wildlife Conservation Trust team and accompany community rangers on a daytime patrol. You'll learn how the endangered, cat-like fossa is being protected and listen out for the ear-splitting indri lemur. And we'll explore the mind-boggling Tsingy de Bemaraha National Park and take a walk through the iconic Avenue of Baobabs.

ECUADOR:

DARWIN'S GALAPAGOS

APRIL 2018, 11 DAYS
FROM $6760

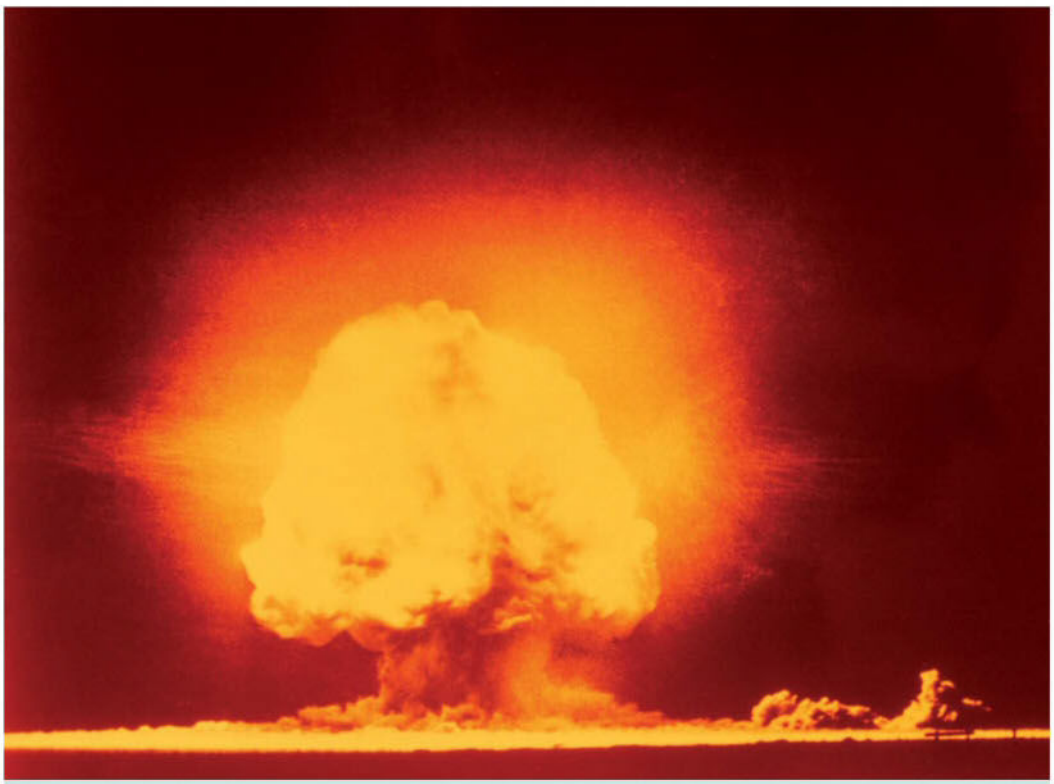
Jump on board our *New Scientist* charter for a one-off tour of this unique ecosystem, accompanied by naturalist and wildlife photographer Jonathan Green. Learn about the geology of the island, discover why the native creatures are so friendly and get the chance to quiz field researchers in an exclusive visit to the Charles Darwin Research Centre. See giant tortoises and sea lion colonies, spot the endemic waved albatross and get the chance to snorkel at sea then amble on shore.

We've teamed up with Steppes Travel to offer readers a chance to get close to geology and nature, with field experts and naturalists for company. Speak to our wildlife experts today.

Call now on **+44 (0)1285 600 129** or visit **newscientist.com/travel**

SteppesTravel

Price subject to change due to exchange rate, to be confirmed at time of booking



LOS ALAMOS NATIONAL LAB/SPL/GETTY

Glass from nuclear test site shows moon was born dry

RESIDUE from the first detonation of a nuclear weapon has cracked open a window into the moon's past.

On 16 July 1945, the US army detonated a nuclear weapon for the first time in an operation codenamed Trinity (see photo, above). As the bomb exploded with an energy equivalent to 20 kilotons of TNT, the sand underneath it melted, producing a thin sheet of mostly green glass, dubbed trinitite.

The explosion heated the area around the bomb to temperatures above 8000°C and pressures nearing 80,000 atmospheres – similar conditions to those created as the moon formed in a colossal collision between Earth and another rock, probably about the size of Mars.

James Day at the Scripps Institution of Oceanography in California and colleagues studied the distribution of zinc, which they used as a proxy for water, in trinitite collected at different distances from the explosion.

They found that the closer to the explosion the trinitite formed, the less zinc it had, especially its lighter isotopes. Those evaporated in the intense heat of the explosion, while the heavier isotopes remained.

The trinitite showed remarkable parallels to moon rocks retrieved in the Apollo missions (*Science Advances*, doi.org/bzj3). That means zinc and other volatile elements, notably water, probably evaporated as the moon formed, or soon afterward.

Swimming together lifts dolphins' spirits

SYNCHRONISED swimming gives bottlenose dolphins a more positive outlook on life.

In a study of eight captive animals, individual dolphins had two targets they could swim towards. Only the one on the right delivered a herring meal, and once the dolphins learned this, they swam faster towards it.

When presented with a new and ambiguous middle target, some dolphins still swam rather fast, presumably hoping for herring. Those were dubbed the "optimistic" dolphins.

When researchers analysed the animals' movements in the weeks before the experiment, they found that these dolphins were also the ones that had done the most swimming in sync with their peers – moving closely alongside their fellow dolphins and matching their movements (*Behavioural Brain Research*, doi.org/bzjn).

Swimming together is considered important for increasing bonding between the animals, and the researchers argue that it could be linked to positive emotions. "I think it's the social behaviour that drives the dolphins' optimistic decisions," says Isabella Clegg, a zoologist at the University of Paris-North, and lead author of the study.

Star cluster hosts rare black hole

WE HAVE caught another glimpse of a shy cosmic monster. Middleweight black holes are elusive, but we may have spotted one inside a bright star cluster.

Black holes come in two main weight classes: those about 10 times the sun's mass and supermassive ones with millions or billions of solar masses. Most claims for middling black holes have been inconclusive.

Now, Bülent Kızıltan of the Harvard-Smithsonian Center for Astrophysics and his colleagues have used a new technique to discover one. They tracked 23 pulsars – stars that emit precisely timed radio signals – in the globular cluster 47 Tucanae and found that a black hole of roughly 2200 solar masses at its centre was needed to explain their motion (*Nature*, doi.org/bzh7).

The black hole's existence also suggests similar objects may have seeded supermassive black holes.

'Mirror' keeps music and posture right

HUNCHING is bad for musicians' health, so a new system tries to discourage it by making it bad for their music too.

The Musician's Mirror, created by London-based designer Arthur Carabott, provides an audible warning if it spots poor posture. To use it, musicians input images of themselves adopting a good and bad posture, and highlight the parts of the body they want its software to focus on.

Musicians then practise in front of the system's camera. At the first hint of bad posture, they get an audible warning: white noise for an acoustic instrument, while for an electric one the notes are made to sound out of tune. The worse their posture, the more jarring the response.

Cockeyed squid's bulging mystery

HERE'S looking at you, squid. Cockeyed squid have one huge, bulging eye and another normal-sized eye, but the reason has remained a mystery.

Now we have an answer. Kate Thomas of Duke University in North Carolina studied 161 videos of the creatures collected over 26 years by remotely operated submarines in Monterey Bay, California.

The squid live at depths of 200 to 1000 metres, where there is little light. The videos show that the squid normally swims tilted so that the large eye is consistently towards the sky. The findings provide the first behavioural evidence that the two eyes are adapted to look in different directions.

It seems the large one points upwards to spot prey silhouetted against the sunlight, and the smaller one points down to spot bioluminescent organisms against the darkness below (*Philosophical Transactions of the Royal Society B*, DOI: 10.1098/rstb.2016.0069).

Based on measurements of the eyes and the light levels they would be exposed to, Thomas's team calculated that having a big upward-pointing eye greatly improves visual perception, while a downward-pointing eye would gain little from being large. "That gives you the context for how this trait might have evolved," says Thomas.

MBARI

Meteorites point to solar system's short-lived youth

THEY grow up so fast. A new limit on how long the early solar system was filled with dust and gas gives us clues to how quickly the sun and planets formed.

Some 4.6 billion years ago, our solar system was just a baby sun engulfed in its solar nebula – a disc-shaped cloud. The nebula created a strong magnetic field, which helped drive the formation of planets, in part by generating turbulence in the cloud.

One way we can glimpse this past is by examining meteorites formed in the nebula. When hot, iron-rich material is exposed to a magnetic field, its electrons align like tiny compasses. Cooling preserves those orientations, literally in stone.

Ben Weiss at the Massachusetts Institute of Technology and his colleagues tested three meteorites that cooled a mere 3.8 million years after the sun began to form, a date pinned down by the ratio of their uranium and lead content. "They're this amazingly well-preserved time capsule," he says.

They found that the magnetic field locked into these meteorites was much weaker than found in similar objects formed a few million years earlier. Since the solar nebula generated the field, it must have dispersed, or at least been on its way out, by the time the younger meteorites cooled (*Science*, DOI: 10.1126/science.aaf5043).

Without the solar nebula, the growth of the sun and its large gas planets would have slowed or stopped. This means that the blueprint for much of the solar system was largely in place when it was just 3 to 4 million years old.

Antibiotics may harm infant lungs

EXPOSURE to antibiotics in the womb could weaken the immune system and make lung disease more likely – at least in mice. The antibiotics harm the animals by killing important gut bacteria, finds a study led by Hitesh Deshmukh at the Cincinnati Children's Hospital Medical Centre, Ohio.

The team identified chemicals released by bacteria that tell a new pair of lungs when to build immune cells, how many to make, and when to use them. Disrupting gut bacteria temporarily was enough to make young mice more likely to contract pneumonia and die (*Science Translational Medicine*, doi.org/bzjs).

In the US and UK, antibiotics are given to women before undergoing a Caesarean section, to protect against infection with *Streptococcus* bacteria. But the drugs act indiscriminately against a wide range of bacteria, both good and bad.

"It is time to begin pushing back on practices that were established decades ago," says Deshmukh. "To prevent infection in one infant, we are exposing 200 infants to the unwanted effects of antibiotics."

D. KRONAUER

Beetle hitches a ride on army ants

IT MUST be a real pain in the backside. A newly discovered species of beetle bites army ants' bottoms and hitches a ride. *Nymphister kronaueri* uses its mandibles to latch on when its hosts are on the move to a new nest, attaching between the ant's thorax and abdomen.

Christoph von Beeren at the Technical University of Darmstadt in Germany and Daniel Kronauer at the Rockefeller University in New York noticed the beetle when they saw an ant in a collection vial that looked as though it had two abdomens. "When Daniel shook the vial, the beetle detached and expanded its legs and antennae," says von Beeren. "That is the moment we realised we had discovered something new here."

Army ants frequently move nests, so the beetle would be left searching for a new host colony almost every night if it didn't have some way to keep up, he says. Given that it managed to go undetected by people, despite living with one of the most well-studied species of army ant (*Eciton mexicanum*), von Beeren says it's likely there are more such critters out there waiting to be found (*BMC Zoology*, doi.org/bzjm).

ZACKARY CANEPARI / PANOS PICTURES

Not quite *Westworld* yet

Fresh face for sex robots

Will robot companions be second-rate surrogates, asks **Victoria Turk** – or will we break the mould?

IT'S too late for this year, but if you find yourself without a partner next Valentine's day, you might be able to get one made to order. By the end of 2017, a California-based company promises to have a lifelike, artificially intelligent, "sex capable" robot woman ready for sale.

Sex robots inevitably prompt tabloid titters, but their imminent arrival also raises serious questions. Ethical concerns about how they will change attitudes to sex and relationships abound, as well as what impact they will have on existing prejudices. Take, for example, the ethical critiques posed by the Campaign Against Sex Robots, which argues that building an army of hyper-realistic Stepford wives will amplify existing sexist views.

But some technologists raise another objection, which could alter the playing field entirely and change the kind of questions we need to ask: the sheer failure of imagination. We are entering a brave new world of human-robot relations – why waste cutting-edge robotics and AI on machines that simply re-enact our stalest clichés and prejudices? The calls to diversify sex robots raise the question: should they really look human at all? The answer depends who you ask.

Picture a sex robot, and you probably imagine a scantily clad, animatronic porn star, in all likelihood female, with perfect proportions, flawless skin and a passive demeanour. It doesn't look much like a robot.

"The head will be able to have conversations, text you at work and welcome you home after a long day"

This is the creature Abyss Creations plans to unveil this year. Abyss is better known for its life-sized, silicone "love dolls" (mainly female) called RealDolls. They can't move or speak, but for around $7000, their appearance can be customised down to the colour of the nail polish.

Unlike these inert dolls, the distinguishing characteristic of the coming "Realbotix" line will be its mind – an artificial intelligence that can interact with its user. The first stage will be an app released in April. To begin with, this will let users create a purely digital woman's persona, assigning values to a range of traits including "outgoing", "shy", or "intellectual".

Making love machines

Later this year, the firm plans to implant that virtual personality into a robotic head (prototype pictured left), which will snap onto the body of an existing RealDoll. The head will be able to make different facial expressions to reflect this personality, and communicate via a voice interface. Similar to a voice assistant like the Amazon Echo, it will use machine learning, speech recognition and text-to-speech software running in the cloud to understand and respond to its user (personal information will be stored locally on the device for privacy).

The eventual plan is to roboticise the doll's entire body, but Abyss CEO Matt McMullen thinks that to mimic natural human interaction, the head is the priority. "People spend far more time looking at each other from the neck up," he says. "Having a robot that can actually look at you, and look around the room, and communicate with you is infinitely more interesting than, say, a body that can perform sexual gyrations."

The head will be able to have conversations on a range of topics, text you while you're at work and

welcome you home after a long day. Essentially, Abyss Creations is not trying to make a sex robot but a complete robotic woman – an AI "girlfriend experience" where you call the shots and loyalty is hardwired. "Some

"Why waste cutting-edge robotics and AI on devices that simply re-enact stale clichés and prejudices?"

people struggle with forming intimate connections with other people," says McMullen.

It's not hard to imagine the possible objections to this. Kathleen Richardson, founder of the Campaign Against Sex Robots, thinks the dolls reflect misogynistic attitudes that objectify women and "reinforce this idea that women are primarily for sex". Abyss does plan to make a male version of the robot eventually, but McMullen says that most customers for RealDolls are heterosexual men, which is why the company decided to kick off the RealBotix campaign with a female robot.

Ethical problems aside, Lynne Hall at the University of Sunderland, UK, has a more pragmatic objection to humanoid sex robots: the technology just isn't there yet. At this point, it's hard enough to make a bipedal robot that can climb stairs, never mind one that could pass a Turing test in the bedroom. More to the point, even when robots look nearly lifelike on the surface, as soon as they move or speak, they become unconvincing, and this "uncanny valley" effect can make them more off-putting than sexy. In other words, these won't exactly be *Westworld*.

If robotic imitations are so unconvincing, says Hall, then why, in a world of hook-up apps, would you pay thousands for this second-rate experience? She advocates breaking the mould with something altogether different.

A robot's form, says Hall, should follow its function. "If you think about everything else that robots do – a robot hoover looks like a hoover," she says. "Why would a sex robot need to take on the physical appearance of a person?"

This raises a question robotics researchers were hotly debating at the Congress on Love and Sex with Robots in London last December: what exactly is the difference between a sex robot and a sex toy? Key to a sex robot, Hall suggests, is a level of autonomy or intelligence that propels it beyond mere sex toys. Rather than having buttons that correspond to specific pre-programmed actions, it should be able to make its own decisions on how to act, perhaps by responding to voice cues or biofeedback, or by employing machine learning to understand what you like.

"This ability to act gives the robot agency in that it is a separate entity acting in the context, whereas the sex toy is being used," she says.

This definition doesn't rule out humanoid sex robots, but nor does it limit the other forms they can take. Trouble is, the idea of a non-human sex robot is so new that no one has yet built one. Kate Devlin, a lecturer in computing at Goldsmiths, University of London, suggests looking at soft robotics – which uses things like flexible polymers and fluids rather than rigid parts.

AMER GHAZZAL / ALAMY STOCK PHOTO

Brings James Bond to mind

There are also a variety of human-computer interfaces to consider (see "Brave new sex tech", right).

Hall imagines e-textiles – fabrics that contain digital components – playing a role, perhaps in conjunction with teledildonics (remotely controlled sex toys) or virtual reality. More satisfying than shagging a robotic doll could be pulling on your smart "sex pyjamas" that know the best way to stimulate you, while you immerse yourself in the scene of *Casino Royale* where James Bond emerges from the ocean in his tight trunks.

Beyond humanoid

Or perhaps you want the independent intelligence animating your sex robot to be wholly non-human. At a hackathon held alongside the Congress, one team created a robotic sex device called Ride the Market, Fuck the System – a fist that vibrates according to fluctuations of the stock market. It's makers say it allows people to "physically experience" economic data.

Once liberated from the constraint that sex robots need to fit into a humanoid mould, there's no limit to the bizarre possibilities that could emerge. Trudy Barber at the University of Portsmouth, UK, imagines a scenario in the more distant future involving nanobots. For example, Barber envisages ingestible nanobots that could stimulate "a sense of orgasmic pleasure in any body part when it is touched".

Not everyone is convinced that weirder is better when it comes to sex robots. McMullen thinks they have to have at least some human-like features, or we simply won't be attracted to them. "We could make sex-capable robots with seven legs and tentacles and two heads," he says. "I just don't know that people would want to have sex with them."

But maybe it's worth finding out. Hall thinks that badly replicating the kind of sex we can already have with each other is not only a pointless endeavour – it could be missing a trick. One way or another, robots will help shape a brave new future for sex. Instead of sticking to the same old routines, shouldn't they introduce new experiences we haven't even thought of? "We're so functionally fixed on the human body and human representation," says Hall. "We're not thinking, 'Could sex actually be better?'" ■

BRAVE NEW SEX TECH

Whether or not sex robots should look human is an open question (see main story). But for less ambitious sex toys, there is already an appetite for technology that goes beyond strict adherence to human form, judging by the examples on offer at a recent hackathon.

BONK IT!
An adult version of game Bop It! that remotely controls sex toys. Flick it, twist it, spin it, pull it and bop it to change the speed, strength and operating mode of a smart vibrator.

ZIP HOODY DOO DAH
A pair of hooded sweatshirts designed for expressing enthusiastic consent. Look at sexual suggestions with a partner and unzip if you're into an idea. If you both unzip, the hoodies will flash and you're good to go – and already halfway undressed.

LOVEPAD
A soft robotic device made of silicone that flexes and curls when you squeezes a controller shaped like a breast.

NSFW TO ASCII CLIENT
A program that turns "not safe for work" (NSFW) photographs into ASCII images – pictures made of standard computer characters. Search for a porn keyword and it will retrieve a relevant image from PornHub and present it to you in dots and dashes – without tipping off censoring software.

Crossing the line

Why has there been such a fierce debate about scientists getting political since Donald Trump's election, wonders **Michael Brooks**

MANY researchers will engage in their first overt political act on 22 April, marching in protest at US president Donald Trump's anti-science stance. The prospect has fired debate over how politically active scientists should be.

To understand why, you have to grasp the nature of the relationship between Western science and politics, one rooted in the era of state-funded research.

This truly began in the years after the second world war, when governments realised that whoever had the best scientists would win the next war. The deal was: scientists are largely allowed to work undisturbed, publicise their findings if they want (most don't) and get paid reasonably well, sometimes in permanent, unassailable employment. In return, some results of this effort should enhance national security and create wealth and jobs.

Part of the pact was that, as Churchill put it, scientists "should be on tap, but not on top" – they shouldn't get involved in political decisions or seek control over their outputs. Most tacitly agreed, content to be part of a system that allows them to quietly indulge their innate curiosity while earning a decent living. Polymath Jacob Bronowski described it well: scientists became "the monk of our age, timid, thwarted, anxious to be asked to help".

Embedded in society for decades – but at arm's length and always struggling for credibility and authority – science is trusted to deliver something that no one can quite define, through workers who place themselves in often-intimidating buildings that most people would never choose to visit. It occupies a somewhat remote cultural niche, a situation that has long suited all involved.

Tip of the iceberg

The UK's lack of lettuce is a taste of climate impacts to come, says **Olive Heffernan**

SEVERE snowfall across southern Spain has devastated crops, squeezing supplies of vegetables such as broccoli, spinach and courgettes (zucchini) reaching the UK. Some supermarkets are resorting to rationing – notably of iceberg lettuce.

With shortages expected to last until spring, and price hikes on the cards, the "lettuce crisis" has come as a shock to most consumers. Some have turned to panic buying, although others are buying to resell to hard-hit restaurants and cafes. A few, however, have welcomed the crisis as a rare opportunity for the public to contemplate exactly where their food comes from.

As it turns out, half of all vegetables eaten in the UK are grown overseas. In winter, most come from southern Spain's Murcia, Almeria and Valencia regions. But recent extreme weather, including flooding, snow and poor light, have left entire fields of salad crops lying frozen, to spoil, in the solid ground.

If there's one thing this can teach us, it's the extent to which climate change can wreak havoc on food grown for the world's wealthy. Europe is likely to see far more freak weather if global temperatures rise by 2°C.

"Neither we, nor our lettuces, are immune to the threats gathering on the horizon"

Yet most of us cling to the idea that in a warmer world, food shortages will be a problem for someone else, somewhere else, chiefly those who already struggle to feed themselves.

Make no mistake, the world's poor will be the worst affected. But an inability to see ourselves as part of this problem may explain why we are so desperately under-prepared for the shortages and price spikes that may ensue in a climate-altered future.

Earlier this month, the UK government came under fire from

Trump has changed that. The appointment of those who pay no heed to scientific discoveries; the dismissal of climate change findings; the gagging of researchers; the planned dismantling of the Environmental Protection Agency – these all send a message that the terms and conditions of the pact have radically shifted. Hence the outrage and the call for the monks to leave their cloisters and march.

So should they get political? Researchers have perhaps been naive in their assumption that, whatever the compromises, they ultimately exist to serve the public good. In reality, they serve government ends. But those ends and the public good generally aligned. Something has snapped because, in the last few weeks, science has been subverted, or sidelined, to serve business interests, religious inclinations and personal ideologies.

Trump has broken the tacit deal that was struck all those decades ago. The March for Science isn't about politics, climate change or even science in general. It is about the public good. So if you want to go, you should. ■

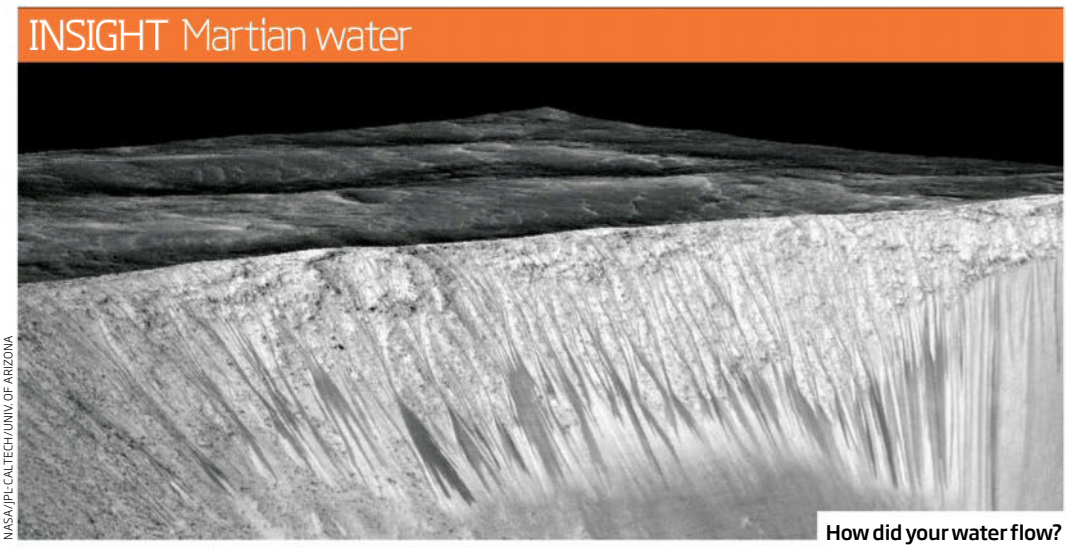
Michael Brooks is a *New Scientist* consultant and the author of *The Secret Anarchy of Science* (Profile)

charity the Food Ethics Council, for dismissing a warning of the need to protect the UK food system against such threats. The London-based independent Committee on Climate Change had made the warning and listed food security as one of the country's six top climate risks.

In light of the lettuce crisis, a government rethink would be prudent. The public, too, might want to face the fact that neither we, nor our lettuces, are immune to the storm clouds gathering on the horizon. ■

Olive Heffernan is a freelance environment writer

INSIGHT Martian water



NASA/JPL-CALTECH/UNIV. OF ARIZONA

How did your water flow?

Why water on Mars still doesn't make sense

Chelsea Whyte

SOMETHING doesn't add up. Mars has ice caps, and there is evidence in the terrain that water flowed in rivers and lakes there billions of years ago. We have a decent understanding of how water behaves on Earth, and there's no reason to think the laws of physics are different on Mars. And yet, we can't figure out how water could have existed in liquid form on young Mars.

Every time we try to replicate the conditions under which the liquid water could have existed, a new complication throws a wrench into our models. Last week, yet another paper tried to chip away at the mystery (*PNAS*, doi.org/bzjh). And like so many before it, instead of resolving the problem, it introduced another.

This 40-year-old mystery is known as the Mars paradox. If and when we resolve it, we might need to throw away a lot of textbooks.

Today, Mars's cold, rocky terrain is dry and blanketed in dust. But observations of clay minerals and remnants of lake and river deposits are unequivocal: water flowed freely between 3.5 and 4 billion years ago.

The trouble starts when you look at the conditions on Mars at that time. Even today, Mars's thin atmosphere and distance from the sun keep it, on average, at about −61°C, cold enough to hold existing water in permanent polar deposits. Billions of years ago, under a younger, less-heating sun, it was even colder.

So given that the freezing point of water is the same on Earth as Mars, how was Mars ever warm enough for liquid water to flow? One plausible explanation is that greenhouse gases trapped heat in the way they do on Earth. These gases could have been produced by many sources, including volcanic eruptions. The gas with the best track record of trapping heat is carbon dioxide, because we know how much high concentrations heat Earth.

"Every time we think we understand it, a new complication throws a wrench into the models"

The problem is, no amount of CO_2 can warm Mars enough for liquid water. Even with an atmosphere of pure CO_2, the closest you get is −33°C.

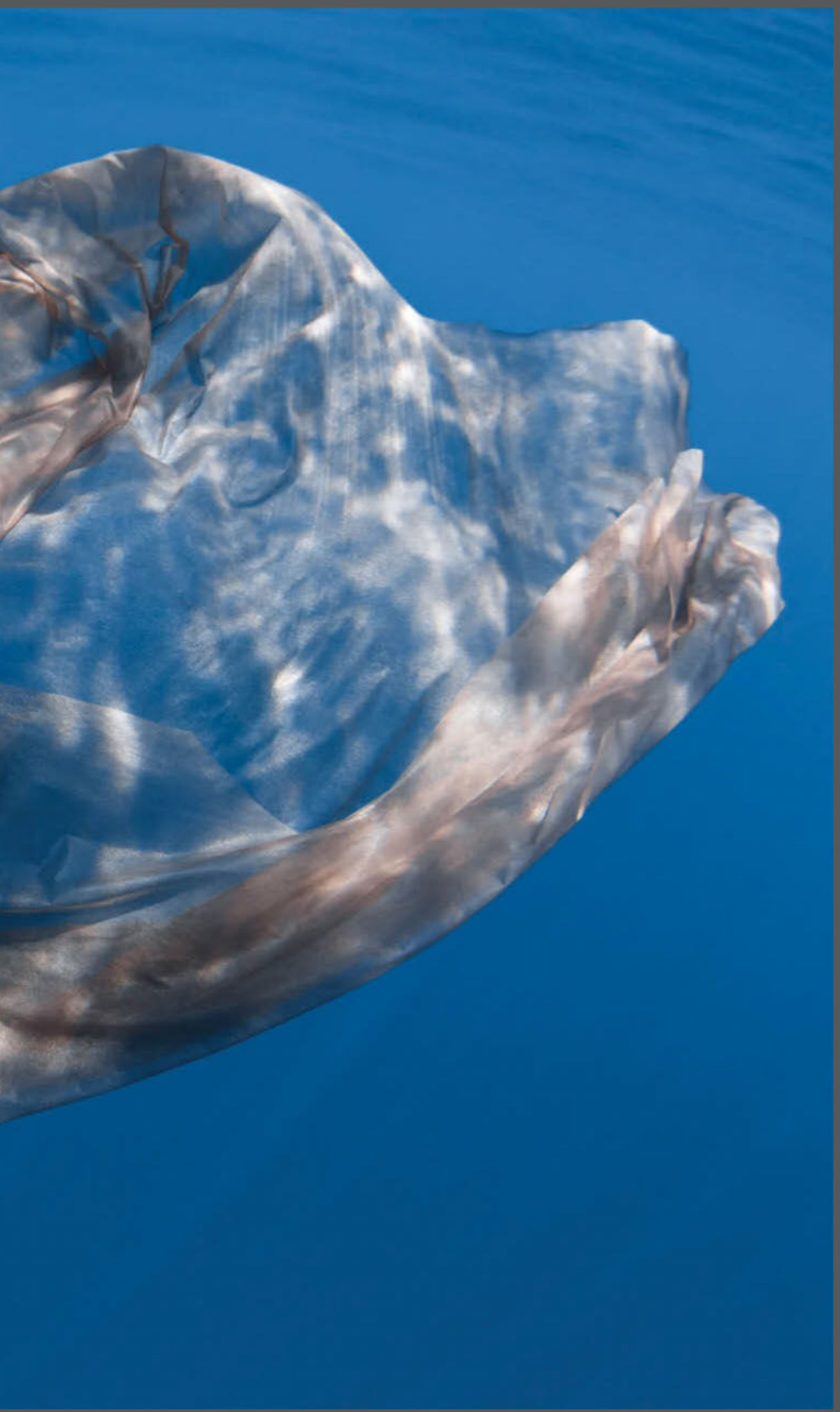
Not that the early Martian atmosphere was pure CO_2. Last week's paper examined sediments laid down 3.5 billion years ago, and found that the atmosphere then contained only scant amounts of carbon dioxide.

Perhaps the maths could work if you added some methane or hydrogen? No. With that little CO_2, it doesn't matter how much hydrogen or methane or other gases you add into the equation. You need a thick atmosphere to begin with to shield these sensitive greenhouse gases from solar radiation.

Last week's paper offered another alternative: water salty enough to remain liquid even at water-freezing temperatures. Then the atmosphere wouldn't need much CO_2.

But this too could fall short. Ultra-saline water can flow – on Earth at least – but a Mars that cold wouldn't allow enough precipitation to account for the standing water etched into Mars' sandstone and mudstone over millions of years.

So is there some planetary mechanism we still don't understand? A mixture of greenhouse gases we haven't yet hit on? Perhaps the real trouble is our understanding of water itself. We already know it can bedevil a few laws of physics, like when colder water flows to the top of a glass. Whatever the answer, we're running out of obvious solutions. We're going to be in truly alien territory when the mystery is solved. ■



Skinny stripping

IT LOOKS like a plastic bag floating in the ocean, but it's something much stranger: a transparent chunk of skin from a sperm whale. It got rubbed off during a mass "scratchathon", a phenomenon that sees dozens of animals periodically gather, apparently to socialise and groom each other by rubbing their massive bodies together.

"This is a large piece of skin that came off an adult female sperm whale, part of a family group of nine individuals," says Tony Wu, who captured this image in the Indian Ocean.

During these gatherings, the whales can lose considerable amounts of skin. They also produce lots of faeces, accounting for the cloudy water in the image below.

"The shedding of skin is part of a natural antifouling mechanism to stop them being encrusted with other marine animals and parasites," says Luke Rendell, a marine biologist at the University of St Andrews, UK.

Rendell says sperm whales typically live in groups with no more than six to 12 members. But on occasions like these photographed by Wu, as many as 70 animals come together for hours or days. "They love touching against each other and one of the rewards may be exfoliation," says Rendell. Andy Coghlan

Photographer
Tony Wu
naturepl.com

THE HIDDEN PATTERN

A strange symmetry connects some of reality's hardest problems. Can we crack its code, asks **Gabriel Popkin**

JORI BOLTON

SOME people see the future in tea leaves. David Simmons-Duffin is more interested in the boiling water. The jostling of water molecules as they turn from liquid to gas represents a problem that, for theoretical physicists like him, is just too hot to handle.

So what, you might say, as long as we can still make a decent cup of tea. But dive a little deeper into how water boils, and a pattern begins to emerge – the same pattern that crops up in all sorts of places where matter starts to shift shape. Whether it's the collective properties of electrons that make a material magnetic or superconducting, or the complex interactions by which everyday matter acquires mass, a host of currently intractable problems might all follow the same mathematical rules. Cracking this code could help us on the way to everything from more efficient transport and electronics to a new, shinier, quantum theory of gravity.

Simmons-Duffin, who works at the Institute for Advanced Studies in Princeton, New Jersey, and his band of fellow researchers don't claim to have cracked this code yet. But they have made more headway in a few years than people did in the generation before – using a key in a problem that first surfaced almost a century ago.

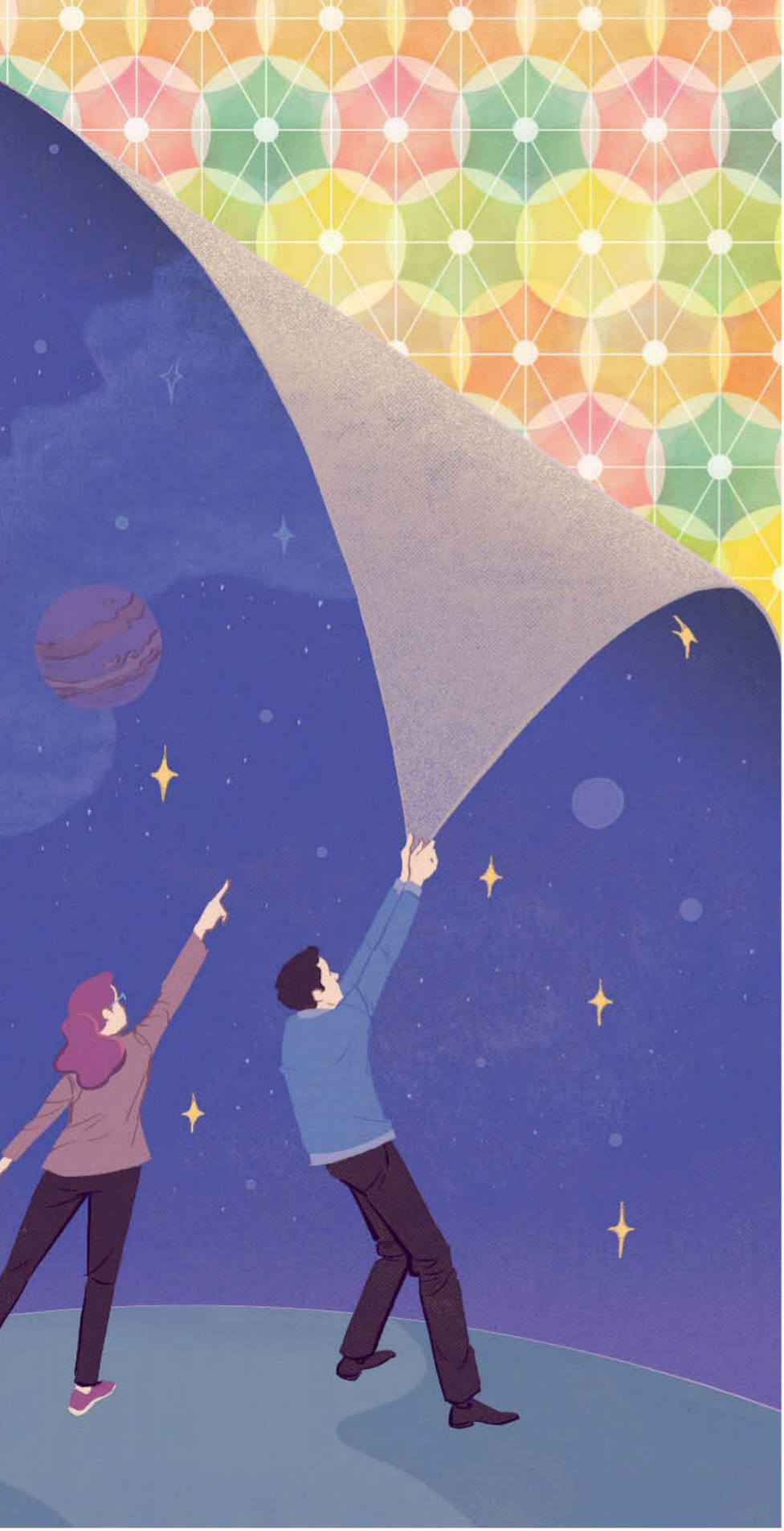
Physicists like simplicity. Their discipline is all about keenly observing the world and drawing out unifying mathematical rules that govern its workings. Take orbiting planets. First Johannes Kepler meticulously sifted through the available data to establish three mathematical rules that governed their motions. Then Isaac Newton showed that those three rules were just facets of one simple equation: his universal law of gravitation.

The challenge of change

Sadly, most things in the world are messier. Even heavenly motions become too complex to calculate from first principles when many bodies are involved. When it comes to atoms in a gas, or electrons in a solid, all thought of tracing their individual motions goes out the window. The quantities of information involved are too vast and the behaviour too complex to make accurate predictions.

Physicists call such problems strongly coupled, and have invented a number of ways to get to grips with them: rules of thumb and sneaky approximations that allow them to characterise what's going on. One particular focus of interest for such models is what happens when a strongly coupled system changes state – when it undergoes a "phase transition".

Boiling water is a textbook example of a phase transition. As the temperature rises, the liquid molecules start jostling about more



vigorously, allowing the most energetic ones to escape as gas. We're all used to this happening at 100 °C under atmospheric pressure. If we raise the pressure, the boiling temperature rises too. Push hard enough, and you reach a point where you can no longer tell liquid and gas apart so clearly. This is known as water's critical point – a feature of a different sort of phase transition that remains poorly understood.

Over the past century or so, we have gradually realised that similar critical points crop up all over the place. One example has garnered particular interest: how magnetic materials lose their magnetism above a certain temperature.

> "The model didn't work, but it proved a better fit to reality than anyone realised"

In 1920, German physicist Wilhelm Lenz challenged his doctoral student Ernst Ising to have a stab at modelling this transition. Ising's approach was to imagine the material as being made up of millions of tiny atomic magnets that could be aligned either north-south or south-north. Each would initially tend to point in the same direction as its neighbours, giving the material an overall magnetism. But each could also flip randomly – and the higher the temperature, the more likely they were to flip, breaking the magnetism.

The model didn't work. As Ising eventually showed in his PhD thesis in 1924, it lacked the hoped-for phase transition. It also only applied to a simple one-dimensional row of atoms. With anything more complex, the couplings between neighbouring atoms were just too complex for Ising's approach.

That didn't stop others trying, but it wasn't until 1944 that the Norwegian physicist Lars Onsager solved Ising's model in two dimensions. That revealed the model to be a better fit to reality than anyone had realised. Not only could it acquire magnetism, but above a critical temperature it could also lose it.

For such a simple approximation, the 2D Ising model has proven far more powerful than it has any right to be. It has since been ›

used to simulate a bewildering array of other phenomena that flip between states: from the way infectious diseases suddenly spread through a community to signalling between neurons in the brain.

Small wonder that many people have yearned to solve the Ising model in three dimensions. "It's something that could open up entirely new fields in mathematical physics," says Zohar Komargodski, a physicist at the Weizmann Institute of Science in Rehovot, Israel.

A big indicator of what that might bring came in the late 1960s, when Russian theorist Alexander Polyakov, now at Princeton University, was studying interactions between fundamental particles. Polyakov realised that they too represented strongly coupled systems that could undergo sudden phase transitions. For example, the fundamental particles known as quarks are usually bound by the strong nuclear force into particles such as the protons and neutrons of the atomic nucleus. But raised to higher and higher energies, quarks may reach a critical point where they overcome the strong force, allowing them to exist independently. So solve the 3D Ising model, and you might solve fundamental problems such as why protons and neutrons exist with the masses they do – and therefore why atomic matter as we know it exists.

Bootstrap it

Not everyone was convinced. "I remember in the 60s, some senior physicist, a very good one actually, asked me what I'm working on now," says Polyakov. "I said, I'm trying to understand elementary particles by looking at a boiling kettle. I got a very strange look; obviously he thought that I'm a crackpot. Nobody believed that it was serious."

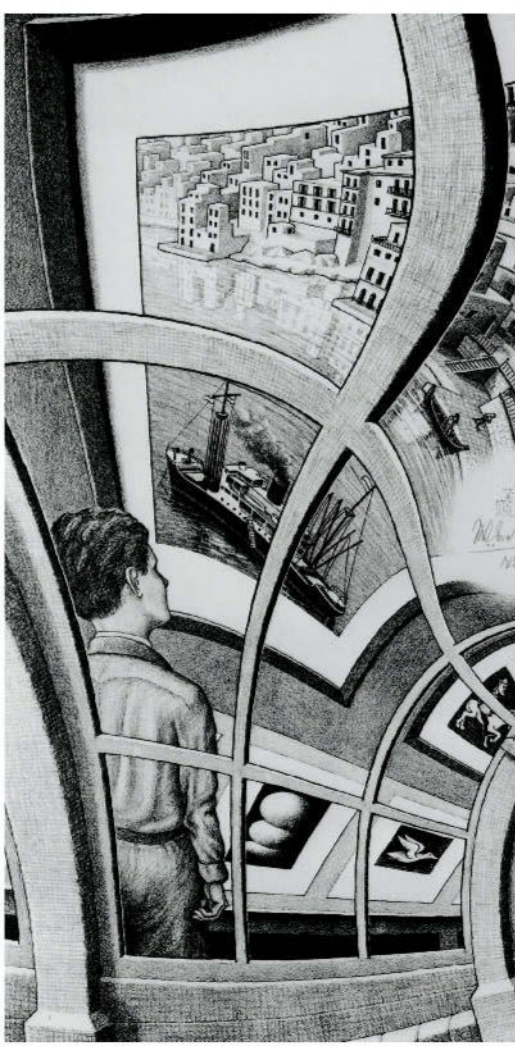
What he was suggesting was a shot in the dark. Mathematically, the 2D Ising model and the equations that govern the behaviour of elementary particles are linked by certain symmetries. In particular, at their critical points they share a property known as conformal symmetry, meaning that they look the same under conformal transformations – complicated mathematical functions that distort space but, within a small region, leave angles unchanged, as in M.C. Escher's famous *Print Gallery* drawing (pictured, right). If the same were true of the 3D Ising model, a complete mathematical description of it at its critical point might describe any other strongly coupled system with the same symmetries.

> "I'm trying to understand elementary particles with a boiling kettle"

Polyakov's approach was certainly a radical one. Rather than start out with a sense of what the equations describing the particle system should look like, Polyakov first described its overall symmetries and other properties required for his model to make mathematical sense. Then, he worked backwards to the equations. The more symmetries he could describe, the more he could constrain how the underlying equations should look.

Polyakov's technique is now known as the bootstrap method, for its ability to pull itself up by its own bootstraps and generate knowledge from only a few general properties. "You get something out of nothing," says Komargodski. Polyakov and his colleagues soon managed to bootstrap their way to replicating Onsager's achievement with the 2D Ising model – but try as they might, they still couldn't crack the 3D version. "People just thought there was no hope," says David Poland, a physicist at Yale University. Frustrated, Polyakov moved on to other things, and bootstrap research went dormant.

It remained that way until 2008, when Slava Rychkov, a physicist at CERN near Geneva, Switzerland, and the École Normale Supérieure in Paris, and his colleagues were beginning to wonder whether the Higgs boson – the particle thought to give mass to



TURBULENCE AHEAD

In May 2000, the Clay Mathematics Institute in Peterborough, New Hampshire, published a list of seven particularly fiendish problems, and offered a million-dollar reward for the first correct solution to each. Only one of the Millennium prizes has so far been claimed, leaving six up for grabs.

One with particular practical significance concerns the Navier-Stokes equations, which describe the complex behaviour of fluid under turbulent conditions. They become difficult to solve at the transition from smooth to turbulent flow, says Zohar Komargodski of the Weizmann Institute of Science in Israel, because the fluid particles start interacting too vigorously to model.

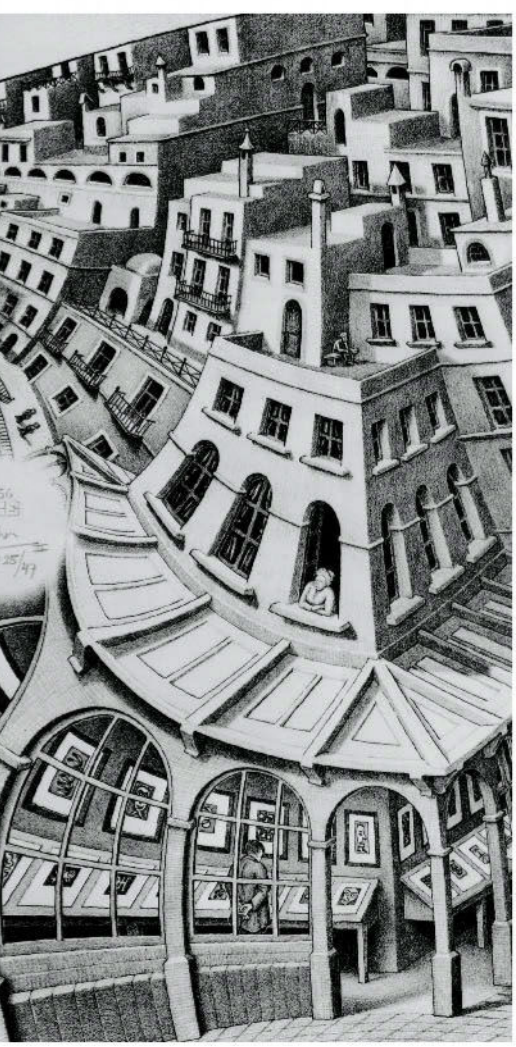
This is another example of strong coupling of the sort that crops up in situations as diverse as particle physics, magnetism and boiling water (see main story). Some physicists believe that if we could understand strong coupling in one of these domains, cracking the Navier-Stokes equations could be next.

Komargodski notes that previous attempts to make connections between turbulence and this branch of physics have been unsuccessful, but there is still room for hope. "It might not be so different in the end," he says.

all other fundamental particles – might not actually exist. They were trying to build an alternative theory without the Higgs when they stumbled across the bootstrap method. "It was one of those lucky moments," says Rychkov. "We basically said, either we can try to tackle it using the bootstrap, or we will never be able to solve this problem." And solve it they did.

They proved to be on the wrong side of history: the Higgs boson was discovered at CERN in 2012. But the success reignited interest in bootstrap research. Simmons-Duffin got wind of Rychkov's work and, together with Poland, used the same technique to analyse mathematical functions describing how quantities such as the orientations of neighbouring atomic magnets

The distorted symmetry of Escher's *Print Gallery* is a feature of many physics problems



are related. They hadn't actually set out to solve the 3D Ising model – but bizarrely, their work started to reproduce its characteristic features. "It seemed to know about the 3D Ising model," Simmons-Duffin says. "This was a big surprise."

He and Poland teamed up with Rychkov and others to find out how much more they might learn. Using bootstrap methods, they constrained key properties of the model over a thousand times more tightly than had ever been achieved before, while providing the first rigorous mathematical foundation for describing systems at their critical point. "For 30 years it was all based on voodoo," says Komargodski.

The achievement is impressive but raises its own questions, says Polyakov. "It's not obvious why it should be so precise. There's something hidden which we don't understand."

It's not just particle physics that could benefit from the bootstrap approach. The problem of modelling turbulent fluid flows, one of the thorniest in all of mathematics, might also be susceptible (see "Turbulence ahead", left). Theorists are already applying the method to materials research, for example to probe the critical points that may be involved in high-temperature superconductivity. At present, the highest temperature at which any known material can conduct electricity without resistance is around -140 °C. The cost of cooling to such temperatures limits us to a few speciality applications, such as levitating trains that float above magnets made of superconducting coils. A superconductor that works at or near room temperature could enable lossless electricity transmission and cheap, powerful magnets, potentially revolutionising the power industry.

As yet we have no general theory of how these materials work, and no way to predict new combinations of elements that could be superconductors at even higher temperatures. But simulations suggest that high-temperature superconductors may show conformal symmetry at their critical points – making them amenable to the new approach.

A new realm

One practical problem remains: the bootstrap tends to generate predictions for appropriate combinations that are so precise that they outstrip our ability to create samples with sufficient purity or uniformity to test them. "It's like going from a Mercedes to a Rolls-Royce," says Subir Sachdev, a theoretical physicist at Harvard. But he is optimistic. "I don't think they quite have a home run yet," he says. "But I think they will."

Certainly some are betting big on the bootstrap's potential. This August, the Simons Foundation, a private organisation based in New York that funds maths and physics research collaborations, awarded $10 million to a group of physicists, including Rychkov, Komargodski, Poland and Simmons-Duffin, to build on bootstrap techniques. Top of their priorities is a complete catalogue of all theories that have conformal symmetry, which would serve as a road map of unsolved problems the bootstrap could tackle.

Simmons-Duffin also hopes the bootstrap

> "Using the new method is like going from a Mercedes to a Rolls-Royce"

can help to unify gravity with quantum mechanics. So far, no single theory has been able to couch Einstein's century-old general relativity in quantum language, but physicists haven't stopped trying. One of the major breakthroughs came in 1997, when it was shown that some theories of quantum gravity would acquire conformal symmetry if you recast them in one fewer spatial dimension. This result means that such theories could also be studied using bootstrap techniques.

Small wonder, then, that bootstrap researchers feel they could be on the cusp of a new realm of physics. But they are clear-eyed about the scope of their techniques. For a start, in many of the complex problems physicists grapple with now, the 3D Ising model is not enough. Questions such as how supercold fluids begin to flow without viscosity, or how to construct alternative theories of gravity, will require tackling more complicated variants of the Ising model, ones that span more dimensions and that have so far proved resistant to bootstrapping. The connection between boiling water and the forces that hold matter together might not be the only hidden pattern bubbling away beneath the surface of reality. ■

Gabriel Popkin is a freelance writer based in Mount Rainier, Maryland

It was just a dream...

Exploiting our ability to lucid dream could help erase real-life traumas, finds sleep researcher **Michelle Carr**

I WAS scrambling away from a monstrous dark figure when I started to have the sneaking feeling that I had been here before, running from this man. I realised that I was in a bad dream, one I'd had several times recently. Only this time, I stopped mid-stride and turned around to face my attacker. "Who are you?" I screamed. "What do you want?"

I was in a lucid dream, a state of consciousness in between waking and sleeping, in which people are in a dream world but remain aware and able to control their actions. I normally use the dreams for fun – flying, say, or exploring – but sometimes I become lucid within bad dreams or nightmares. At first, I would simply wake myself up whenever this happened, but over time I realised I could change the dreams from within.

Psychologists have long been interested in using dreams to rewrite nightmares or help people overcome persistent fears. But the ability to use lucid dreams has been limited because they are difficult to trigger, and, as with all dreams, memories of them evaporate so quickly upon waking.

That could be about to change, however, as more consistent ways to induce these dreams are uncovered. It is even becoming possible to communicate with the dreamer and record what's happening within dreams. These advances raise the tantalising prospect of unlocking this unique state of mind to create therapies for people with nightmares, anxiety and other conditions. We may soon be able to treat people within their dreams.

I learned to lucid dream several years ago, initially by accident. When I went to bed or as I woke up, I would often get caught in a scary half-awake state where I was alert but unable to move or speak – something called sleep paralysis. To get out of this, I found it easier to fall back asleep than force myself awake. Since I maintained some awareness while drifting off, this often resulted in a lucid dream. It turns out that what I was doing isn't so different from techniques used to induce lucid dreams deliberately (see "Lucid dreaming for beginners", page 34).

"It's a step toward conveying the content of dreams to the outside world – in real time"

People have been experiencing and writing about lucid dreams for thousands of years. Now with the advent of brain imaging, we have been able to learn much more about what goes on during them. Comparing the brain scans of people who were awake, asleep or in lucid dreams revealed what many had long suspected: lucid dreaming is a state in between REM sleep – the phase in which most of our dreams occur – and waking. Unlike regular dreams, lucid dreams involve brain activity in areas associated with working memory and regions thought to play a role in higher cognitive functions, such as planning and behavioural control.

Dreams have long been a focus of psychological therapy, for many reasons. Recurring nightmares can be symptomatic of anxiety, post-traumatic stress disorder and other conditions. Discussing dreams during therapy can provide an insulated way for people to explore traumatic subjects, and attempting to rewrite them can help overcome phobias or grief. For this, patients are encouraged to use a strategy known as imagery rehearsal therapy, in which they rehearse and then try to play out challenging scenarios within their dreams, or change the course of nightmares.

The first hints that lucid dreaming could enhance or even expand on the therapeutic use of dreams came in the past decade, when psychologists found that people who are capable of lucid dreaming may be more resilient to trauma and better able to avoid nightmares. Then, in 2015, Brigitte Holzinger and colleagues at the Institute for Consciousness and Dream Research in Vienna, Austria, showed that lucid dreaming makes therapy for nightmares more effective.

When Holzinger asked people undergoing a variation of imagery rehearsal therapy to try lucid dreaming, those who were successful stopped fearing sleep and began to enjoy their dreaming lives. One person even figured out how, within a nightmare, to go back to a point before a threat had started and continue the dream in another direction. People also found that lucid dreams brought a sense of power and control that translated into waking life, a welcome change from the helplessness often experienced in nightmares. This outcome is the ideal for this kind of therapy: to enable ›

RONALD KURNIAWAN

people to confront the source of their trauma or anxiety by directing or changing the course of their dreams.

But the utility of strategies like these is limited by how well people can learn to lucid dream. Even with the best existing methods, results are spotty. Now, though, researchers have found a way to induce such dreams.

In 2014, Ursula Voss and her colleagues at Goethe University Frankfurt in Germany discovered that a technique known as transcranial alternating current stimulation could spur lucidity in dreams. It involves applying a low electrical current to the brain's frontal cortex during REM sleep, and it works about two-thirds of the time. "Stimulating the frontal area is like putting 'wake' activity into sleep," says Cloé Blanchette-Carrière at the Dream and Nightmare Laboratory in Montreal, Canada.

Blanchette-Carrière is interested in therapies that would trigger lucid dreams instead of relying on people teaching themselves to induce them. "We want to apply this to nightmare sufferers or PTSD patients, to make them able to modify or control their dreams,"she says. She already has promising results from a preliminary study.

The next hurdle in using lucid dreams as a treatment is to communicate with someone once they are asleep, to provide external support as they face a source of trauma, for instance. Many of us have experienced incorporating a noise from the waking world into a dream – a horn honking outside, or music playing on a nearby radio, for instance. But can we deliberately send messages into people's dreams?

To find out, Kristoffer Appel, a sleep and dream researcher at Osnabrück University in Germany, recruited experienced lucid dreamers and monitored their brain waves and eye movements as they slept. When in lucid dreams people are capable of moving their eyes deliberately, so Appel instructed his volunteers to let him know when they were lucid by looking left-right, left-right. Once he got the cue, he tried to send signals into their dreams using audio tones and flashing lights.

Hello in there

Of 10 volunteers, seven reported incorporating the sounds or lights into their dreams. The tone might become a noise from a ship, car or cellphone. Some people registered the flashing lights as the whole dream turning bright and dark; for others, it was the lightning in a thunderstorm, or a lamp that switched on and off. Those who noticed the noises or lights realised that they were messages from the waking world.

But Appel wanted to go further: he wanted to send more complex messages, and he wanted the dreamers to respond. So he asked these same volunteers to learn basic Morse code for numbers. The idea was to use a series of audio tones to send the dreamers simple arithmetic problems, like 3 + 5 or 7 - 2. The dreamers didn't know the numbers in advance, and were told to answer using Morse code eye signals. For instance, a "3" in Morse code is three short and two long dashes, so the subject would look three times to the left and two times to the right.

For Appel and the volunteers, it felt like there was a lot at stake. Many people who can lucid dream have spent months, if not years, teaching themselves how. Although confident it would be possible to communicate from within their dreams, the volunteers feared they might let the side down by waking too soon or failing to find the signals. But it worked, at least for three of them: they not only got the signals, but gave the correct answers. One participant described how he looked around his dream for something that might convey signals from outside. He was in a bus terminal, and spotted a ticket machine. Soon, it began to beep. "I was thrilled to bits… I decoded the first message, confirmed the numbers, solved the math problem, and answered it back to the wak[ing] world: 4 + 4 = 8. I next walked along the street further, telling other pedestrians that I was solving tasks within a lucid dream."

Relying on eye movements limits how much information can be conveyed, however. So Remington Mallett, a researcher then at the University of Missouri–St Louis, decided to try using a brain-computer interface, a device that – as the name suggests – enables the brain to talk directly to an external device such as a computer. Mallett believed lucid dreamers

LUCID DREAMING FOR BEGINNERS

The simplest method to boost your chance of lucid dreaming is to perform "reality checks" during the day. As often as possible, stop to observe your environment and body, and ask yourself: "Is this a dream?" As this becomes a habit, it will be incorporated into your dreams. One night you will find yourself asking, "Is this a dream?" and realise, in fact, it is.

A more direct way is through the "Wake-Back-To-Bed" technique, which is exactly what it sounds like. Ideally, you should set an alarm about 2 hours before you normally wake up, which will put you at a phase in the sleep cycle when REM sleep is longer and more intense. When the alarm goes off, sit up and stay awake for about 20 minutes. During this time it can help to think or write about the most recent dream you remember, noting anything that could have clued you in to the fact you were dreaming. When you go back to sleep, you should soon enter a dream, and your recently awake and intent mind is likely to follow.

Finally, you can complement these effortful techniques with technology. While there are many apps and sleep masks that are supposed to induce lucid dreams via audio and visual signals, most of them simply run on a timer and send signals randomly while you sleep, so aren't that effective.

The most promising are two new devices, the Aurora Dreamband and the iBand+. Both are small headbands that use actual EEG, among other biosensors, to detect when you are in REM sleep and to trigger LED signals at this time to "wake" you up within your dream. What's more, both are paired with an app that tracks your sleep patterns and an alarm designed to wake you at the best point in the sleep cycle.

should be able to use it, since there is an overlap in the way the brain treats activities during lucid dreams and waking. When lucid dreamers imagine clenching a fist, for example, activity in the brain's motor cortex and even muscle twitches in the wrist of that hand can be detected.

To see whether controlling a brain-computer interface from inside a dream was possible, Mallett recruited two self-taught lucid dreamers to try a simple headset, the Emotiv Epoc. It maps the activity of the brain, and then uses these signals to direct different desired outcomes on the computer. So if you imagine moving the cursor on a screen, it moves. "You basically move virtual objects with your mind," says Mallett, like a "Jedi mind trick".

First, Mallett trained the volunteers – awake and lying down with their eyes closed – to move a block on a computer screen using only their minds. Once they reached 75 per cent accuracy, they were ready to try the task during sleep. When they became lucid, they let Mallett know with quick left-right eye movements, and then began the task. Mallett saw the signal from both volunteers, and then the block steadily moved forward on the screen.

One volunteer said that during the waking task, he was imagining a street fighter character moving the block forward. During the dream he did the same thing. So in his sleeping mind was him as the dreamer, and in the dreamer's mind was the mental image of a little ninja moving the block. "It's fairly meta," says Mallett. "You're imagining about imagining something. We're taking this mental cognitive task and observing it objectively." It's a first step toward being able to convey the content of dreams to the outside world, in real time.

"Imagine halting a recurring nightmare by choosing a different ending"

This approach could also help people learn how to control prosthetic limbs. Like moving blocks on the screen, a brain-computer interface can pick up activity in the motor cortex when you imagine moving your arm, sending the signals to the prosthesis. These devices have even been used to restore brain-controlled walking in people who have had a spinal cord injury.

People with lower limb paralysis who must learn to control an exoskeleton face an added barrier, in that the brain may forget how to send motor signals to their legs. In August, the Walk Again Project – an international collaboration led by Miguel Nicolelis at Duke University in Durham, North Carolina – helped people with partial paralysis regain some muscle control in their lower limbs. To do so, they first learned to use brain activity to control an avatar in virtual reality, getting it to walk around a field. This helped the brain relearn how to send motor signals, which meant that when people moved on to using a real exoskeleton they got the hang of controlling it more quickly. With lucid dreaming, people could exercise their mental muscles in their dream world every night, helping them eventually transition to controlling a real exoskeleton.

As well as the many therapeutic applications, looking into our lucid dreams could also enable us to harness our creativity. Many people find inspiration in their sleep. The melody for *Yesterday* came to Paul McCartney while he was dreaming, and Dmitri Mendeleev famously dreamed up the structure of the periodic table of elements. But as we know, when inspiration strikes in this way it is a race to jot it down once you wake up.

New gadgets, like the headset in Mallett's study, could eventually be used to help us record ideas from within lucid dreams. And Appel is developing a sleep mask that could record eye-movement Morse code for people to transfer messages. He is also experimenting with something more of us are familiar with: texting. "We are trying for dreamers to just follow the keys with their eyes and track the movements."

As techniques for inducing and communicating from within lucid dreams improve, the possibilities will only grow. For mental health professionals and those who study sleep disorders, the potential for psychological therapies is most inspiring. Imagine, after prolonged grief, getting to say the final goodbye you hadn't been able to. Imagine overcoming a persistent fear while receiving messages of support from the waking world, or halting a recurring nightmare by choosing a different ending. As Blanchette-Carrière says, "If people are able to control the dream, they will be empowered to modify their behaviour in real life." ■

Michelle Carr is a sleep and dream researcher at the Swansea University Sleep Laboratory in the UK

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

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

Introduction by **Professor Stephen Hawking**

New Scientist

KILLING AMERICA'S GIANTS

Yellowstone's iconic bison are caught in the middle of an economic and ecological battle between cattle ranchers, campaigners and park officials. The result is a controversial and sometimes gruesome scheme to capture and kill one of the country's most treasured animals.

Story and photos by ***Michelle McCarron***

One freezing dawn last March, I stood in Yellowstone National Park's Stephens Creek facility with a small group of journalists and conservationists. We watched as park rangers and biologists went to work on one of the nation's most iconic and impressive animals. It was an uncomfortable scene to watch. One by one, dozens of American bison were forced into squeeze chutes. They roared in pain and fear as their enormous bodies were trapped by a brutish metal clamp called the Silencer. Many bled and their horns were ripped off as they tried to escape.

Methodically, the biologists drew blood samples and weighed the immobilised giants, then sorted them into pens: on one side, animals that would be kept in quarantine for an undetermined period; on the other, those that would be loaded on a trailer. These were the less fortunate ones – their final destination a slaughterhouse in Montana.

The Stephens Creek facility, just inside the park's northern border, near Gardiner, Montana, is infamous among wildlife advocates. Every year since 2000, park authorities have culled hundreds of bison (also known as buffalo) at the behest of the state of Montana. For years, conservation groups and members of the public have been demanding the right to witness the event. Finally, a small group of us was allowed in last year. Fencing and wood boards partially obscured our view. This year's cull will be larger. It's aim: to drastically reduce the size of this last herd of wild bison.

At one time, up to 60 million roamed the plains of the western US. That was before they were brought to the edge of extinction by European settlers in the 19th century: by 1890 just a few hundred remained. Then, their fortunes reversed. Some were protected by private individuals who feared they would otherwise be wiped out. In Yellowstone, a lone herd of 25 wild bison was given reprieve at the turn of the 20th century. Today, that population numbers 5000, the highest it has been in more than a century.

But for all the awe and reverence buffalo inspire – President Barack Obama officially declared them the national mammal last May – American bison have an uneasy relationship with people. They have out-grown the park's winter grazing ranges, says Keith Aune of the Wildlife Conservation Society. As a result, the animals have started roaming outside its borders during the winter months in search of food.

In 1995, the state of Montana sued the National Park Service because buffalo were moving onto its state lands. Agriculture is king in Montana and cattle its biggest commodity, worth $4.5 billion annually. With the

Left: Each year, hundreds of wild bison are prodded through the wood and metal maze of Stephens Creek facility in Yellowstone National Park

Above: The Silencer (centre) is a metal clamp that holds the enormous beasts in place while biologists take blood samples. From here, the vast majority are shipped to a slaughterhouse in Montana

state's blessing, many of the cattle graze on public lands. Roaming bison were competing for the grass. Ranchers say they also spread brucellosis, a damaging and costly bacterial disease (see page 40).

The cull is part of a plan, introduced after the 1995 lawsuit, to control the wild herd. It seeks to bring numbers down to 3000, which park officials say is Yellowstone's carrying capacity. But bison advocates say this number is too low and is politically driven in a state that favours the profits of cattle production over the well-being of a wild species. For Aune, the figure reflects a "human tolerance capacity" rather than the ecological capacity of the landscape.

The International Union for Conservation of Nature (IUCN) has called the American bison "the most neglected icon", and listed it as "near threatened" as a result of habitat loss, genetic manipulation and depopulation – all of which are a direct result of human intervention. Aune and a team of conservation biologists studied the health of eight wild populations in North America for an upcoming report for the IUCN. They found numbers were healthy: according to the IUCN, a bison herd needs at least 400 individuals to be viable, which makes the Yellowstone population demographically viable.

However, only two of the eight populations studied were deemed genetically stable – the wood bison in Canada and the Yellowstone plains bison. Declining diversity as a result of inbreeding highlights the genetic value of the Yellowstone herd and the extent to which the future of the species depends upon it.

Bison campaigners are categorical: "3000 is a politically derived figure," says Dan Brister of the Buffalo Field Campaign, adding that the wider habitat should matter more than the parks' arbitrary borders.

Above: Blood samples are taken from each coralled bison and tested for brucellosis, but the on-site tests can only show if the animal was exposed to the disease, not if it is infected

Right: Bison are an important part of Native American culture. Tribal members are allowed to hunt bison outside national park boundaries

Ranchers on the margins of Yellowstone National Park blame bison for transmitting bovine brucellosis to their cattle herds. This claim is not without irony given studies showing it was probably cattle that passed the disease to wild bison in the early 20th century.

Brucellosis is a bacterial disease which triggers abortions in pregnant females and is highly contagious. It is passed on primarily after birth when other animals in the herd lick the infected placenta. The disease is of such concern to the cattle industry that the US has a programme to eradicate it.

But there is little evidence to support the ranchers' claim that wild bison pose a risk to their herds. Aune says the brucellosis argument is "a regulatory vehicle" which ranchers use to keep bison off state lands. Transmission from bison to cattle has only been demonstrated in captivity, but there are no documented cases in the wild. And last May, a study by the US Department of the Interior and the US Geological Survey looking at 30 years of data on brucellosis concluded that elk are the most likely source of transmission to livestock.

The study found that four of the five strains of the bacteria are mainly associated with elk and originated in the National Elk Refuge in Wyoming, just south of Yellowstone. The fifth strain was linked to the Yellowstone bison, but was found to spread less rapidly than the elk strains.

Nonetheless, blood samples continue to be collected from each animal corralled out of the wild herd at Stephens Creek. The trouble is, the on-site test is for antibodies to the bacterium and so only shows if the animal has been exposed, not if it is infectious. For that, samples need to be grown in the lab, which takes weeks – by which time the animal's fate has already been sealed. Most are killed and their meat is given to Native American tribes.

On the two days I witnessed the sorting at Stephens Creek, 150 animals were processed and two-thirds were taken to be culled. The remaining animals were kept for a new quarantine and relocation programme. None of the animals captured at Stephens Creek will ever roam in Yellowstone again.

Pressure groups working to protect the American bison claimed a victory in December 2015. After two decades of pressure from the Buffalo Field Campaign (BFC) and people living near the park border, the governor of Montana granted bison year-round access to Horse Butte, to the west of Yellowstone. This is an area that herds use for calving, and from 15 May each year, the authorities had been hazing bison back into Yellowstone to stop them eating grass.

BFC welcomed the decision, but is less keen on another initiative. Of the 150 bison I witnessed being captured, park officials held 57 yearlings back for a 50-year relocation plan. After a period of quarantine to make sure they aren't infected, the buffalo will be shipped to other parts of the country, to boost wild or conservation herds. Conservation herds live behind fences and are used for education or tourism. The quarantined animals could also be used for plans to establish fenced-in "cultural" herds on tribal lands and reservations.

The BFC and other groups see these plans as a path to domestication. Aune agrees that is likely to happen if the programme runs over generations, but argues that without captive restoration there would be no animals left in the wild. "Wildlife is over if we start saying we can't do this stuff because it domesticates them," he says.

Another option for controlling the population would be to introduce hunting quotas. Hunting is currently forbidden inside the park and there are strict quotas for hunting bison outside its boundaries. Some Native American tribes have proposed that they be permitted to hunt inside the park as well. They say that they do not meet their quotas from the bison that spill out over its borders.

US government services are also testing vaccines, including the RB51 vaccine against brucellosis and another one that sterilises females. But Darrel Geist of BFC is vehemently opposed, not least because the work is run by a branch of the Department of Agriculture which he says should have no role in managing wild buffalo. "Federal livestock bureaucracy is the driving force behind the slaughter of America's last wild buffalo in Yellowstone and Montana," he says.

Eleven months have passed since that cold morning in Stephens Creek. Eleven months during which the cull has continued, as more animals have been herded into the area for testing and sorting. In total, 900 animals were slaughtered last year – short of the annual target of 1000. In September, the BFC and two other wildlife conservation groups sued the federal government for failure to list the Yellowstone bison under the Endangered Species Act. Undeterred, park officials announced the 2017 cull quota would be raised to 1300. It is already under way. ■

How to accidentally save the planet

He is famous for his "Gaia hypothesis", but it's a device **James Lovelock** invented 60 years ago that we should laud him for

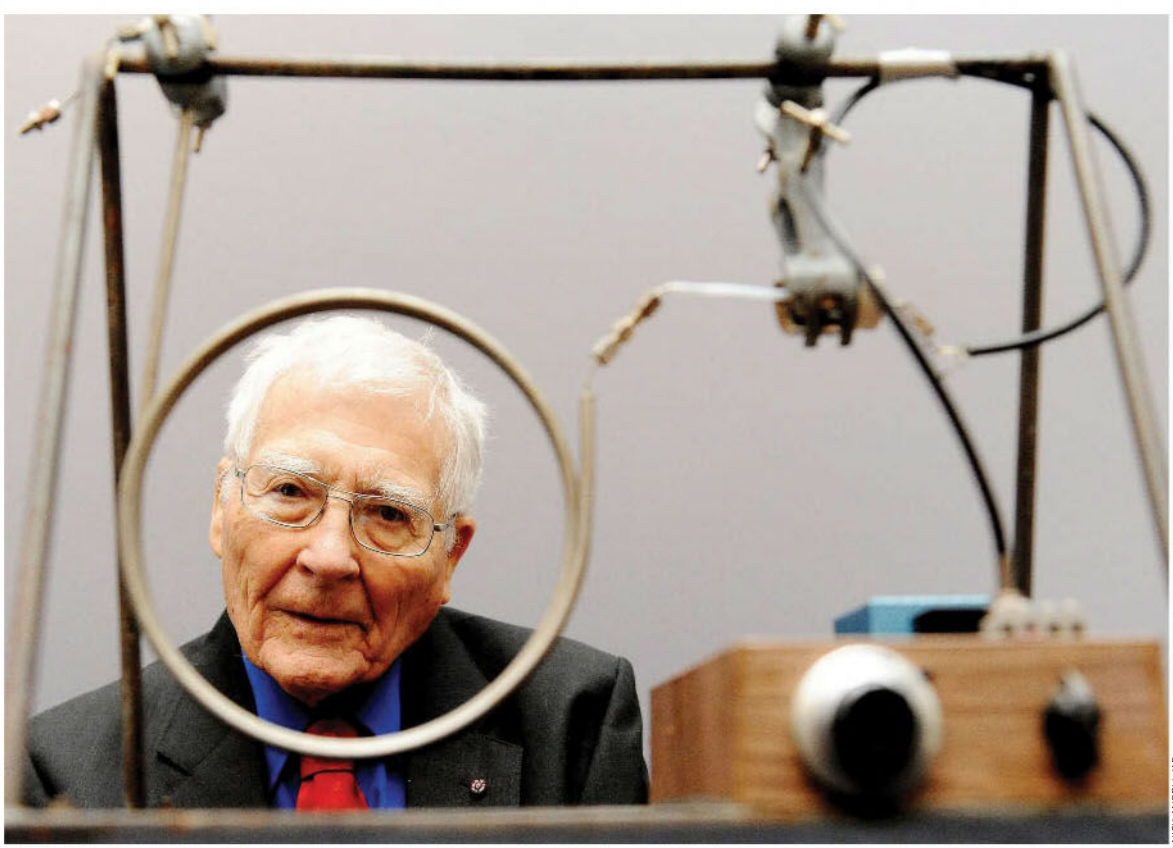
IN 1957, I invented a device that can sniff out poisonous pesticides and ozone-eating compounds at concentrations of just one part per trillion. The electron capture detector, as I called it, boasted a level of sensitivity unheard of at the time and never bettered since.

I made the first one myself on a lab bench. I'm not sure it could happen that way now. For a start, I was working in a government lab in Mill Hill, north London, and I wasn't supposed to be crafting an environmental detector at all – I was a medical researcher. But the boss allowed us to follow our noses.

The lab was a wonderful place, how all research should work. No bureaucracy. And its output was phenomenal, even though there was not much technical back-up beyond a couple of shared technicians and a titled lady who kindly washed the dishes. We invented and made our own equipment. I used to go down to Soho, the red-light district in London, to an army-surplus store, where I bought old Royal Air Force transmitters to cannibalise for electronic parts. The prostitutes always seemed to know what we were after, and ignored us. We were particularly nerdish, I expect.

I had been working on how we could freeze

PROFILE
James Lovelock is an independent scientist and inventor. His most recent book – as editor and co-author – is *The Earth and I* (Taschen, 2016). He is 97



NICK ANSELL/AP

One of Lovelock's early creations – a home-made gas chromatograph

animals and then bring them back to life. During this work I made one of the earliest microwave ovens, which was good for both reviving hamsters and heating my lunch.

An important part of my work was looking at why the fatty-acid composition of cell membranes determined their resistance to damage by freezing. Cells with unsaturated fatty acids did best, and I wanted to analyse them better. So I went to see Archer Martin, a Nobel laureate, who was two doors down the corridor. He was a pioneer of gas chromatography, the only technique that would separate my membrane acids. Unfortunately, his equipment, which could find organic compounds at concentrations of less than one part per million, was still not sensitive enough for my purposes. So he challenged me to invent a better detector.

I loved a challenge, and within about three weeks, through pure serendipity and with the help of little more than a soldering iron, I came up with what became the electron capture detector. Small enough to hold in my palm, it had a chamber coated with a radioactive foil. The radiation freed electrons from a gas in the chamber – initially argon and later nitrogen. That set up an electric current. My idea was to add tiny quantities of the stuff I wanted to analyse into the chamber, and measure the effect it had on the electron flow. I figured that organic compounds would react with the free electrons and so reduce the current, and that different compounds would produce a different signal.

At first it didn't seem to work reliably. One day, I injected a tiny amount of carbon tetrachloride, about 0.1 microlitres, into the chamber. The whole thing seized up, and it was a week before I could use it again. I thought it was broken. But as I eventually worked out, the device was so sensitive to the compound that, even after I cleaned it out, it was completely saturated. Blinded by it, you might say,

> "I must have been a bit thick, because at first I didn't realise its potential"

That was my Eureka moment. The device turned out to be amazingly sensitive to other compounds too, particularly chlorinated ones. I had inadvertently made something that could measure critical human-made poisons at concentrations as low as one part per trillion – a million times better than anything before. With some refinements I made later at Yale University, it has never been bettered.

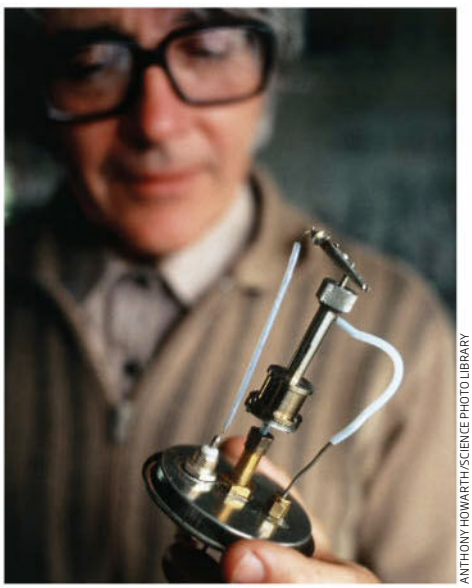
I must have been a bit thick, though, because at first I didn't realise its potential. But word spread and shortly afterwards a researcher from the petrochemicals company Shell, which manufactured chlorinated pesticides, contacted me. He said they found it very difficult to measure low levels of pesticides in field trials, and asked if my device might be useful. I said yes, of course.

This was before the great hoo-ha created by the publication in 1962 of Rachel Carson's book, *Silent Spring*. She wrote that our countryside was awash with pesticides that were destroying nature, such as DDT. Some people say my device provided the data that resulted in Carson's book. In fact, she hadn't heard of the device, and nor had the researchers whose work she used. They could only measure down to one part per million. But research using my gadget did provide the proof that these poisons were present virtually everywhere in the environment – as Carson had claimed but couldn't prove.

Without the electron capture detector, large chemicals companies would have been able to dismiss her findings. The reason I know that is because by then I was an adviser to Lord Victor Rothschild, a biologist in charge of science at Shell. When Carson's book came out he was furious. He told me if what was in the book was true, it could destroy the entire pesticides industry. I had to tell him that my gadget confirmed she was right. He took it very well, considering. The pesticides industry has survived, but it is no longer based on organochlorine compounds.

The device started to be manufactured commercially soon after. I got no income from the patent, which the US government ended up owning because of the work done at Yale, but I have been giving advice to its manufacturers and users ever since. In 1961, I worked with NASA on plans for tiny gadgets that could analyse the chemistry of the atmosphere on Mars or Venus. But apart from pesticides, the biggest impact of my electron capture device was in providing the data used to predict that chlorofluorocarbons (CFCs) could harm the ozone layer.

In my work for Shell, I was looking at long-range air pollution. I knew that my detector could sniff out tiny amounts of CFCs and, because they are inert, I thought they might be accumulating in the air. When I looked, I found them even in the supposedly clean air over the Atlantic. I hitched a ride on a research boat to Antarctica and found them there too.



ANTHONY HOWARTH/SCIENCE PHOTO LIBRARY

Lovelock in 1980, with his serendipitous creation, the electron capture detector

I subsequently did a similar trip on a German research ship. Unlike British researchers, who were not fussy about personal hygiene, the Germans used aerosol deodorants. The CFC propellants messed up my readings, so I had to get the captain to cut me adrift on a small boat before I could find suitable air to analyse. My readings led directly to warnings about CFCs eating the ozone layer. The researchers involved subsequently won the Nobel prize in chemistry.

The UK gave me the freedom to do my research, but it was Americans who usually spotted its importance. One exception, however, was the UK secret service. This was the height of the cold war, and they were trying to keep track of the KGB's activities in London. The KGB had all sorts of sophisticated gear to sweep their cars for electronic bugs when they went about their clandestine business, but they never knew that we could use chemical tracers. My gadget had the scent-following powers of a bloodhound, and I was happy to put it at our guardians' disposal.

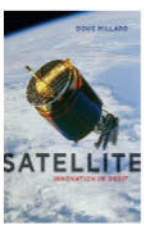
Of course, a lot of people have criticised me for teaming up with Shell, the secret service and so on, but such collaboration has allowed me to be an independent scientist for the past 60 years. Like my first boss, my only interest is in doing good science and going where my curiosity and intuition takes me. That kind of approach to is all too rare these days. ■

As told to Fred Pearce

Connecting the world

From cold wars to hot junk, satellites extend human reach in all directions, finds **Andrew Robinson**

Satellite: Innovation in orbit
by Doug Millard, Reaktion Books



IN 2002, two NASA satellites nicknamed "Tom" and "Jerry" were charting Earth's gravitational field, as part of the Gravity Recovery and Climate Experiment. As they moved in the same polar orbit, the distance between them was monitored to an accuracy of 10 micrometres, a tenth of the width of a human hair. When either satellite flew over an area of increased gravity, it would speed up slightly and the distance would increase or decrease.

The experiment's vital result is recounted in *Satellite,* Doug Millard's accessible and superbly illustrated book, which tracks the history of this amazing extension to our lives. By combining the changes in distance between the satellites with their respective positions – measured by GPS – it was possible to build a detailed map of Earth's gravity field, writes Millard, deputy keeper of technologies and engineering at London's Science Museum.

Satellites have a long history, with Isaac Newton the first to imagine one in *Principia Mathematica* (1687). He envisioned a cannon projecting a ball from a mountaintop with ever more force. In the end, noted Newton, the ball would reach beyond Earth's circumference, retain its velocity and "describe the same curve over and over".

But Newton had no concept of a satellite's usefulness. That came in 1869, when Edward Everett Hale suggested in his story, *The Brick Moon,* that they could be used as an orbiting reference point for measuring longitude.

By the early 20th century, rocket pioneers like Robert Goddard, Hermann Oberth and Konstantin Tsiolkovsky were showing how satellites could be launched, and in 1944, a German military team led by Wernher von Braun fired a V2 missile to an altitude of some 180 kilometres. Inspired by the V2, in 1945 Arthur C. Clarke, then a Royal Air Force radar engineer, predicted that it would take only three satellites in geostationary orbit, 36,000 kilometres above the equator, to handle Earth's communications.

In the 1950s, the US and Soviet Union raced to launch a satellite. The Soviets won in 1957, marking the start of the space age. The name of their satellite, Sputnik, translated into "fellow traveller", or companion to Earth. Fellow traveller was also cold-war speak for Communist sympathiser.

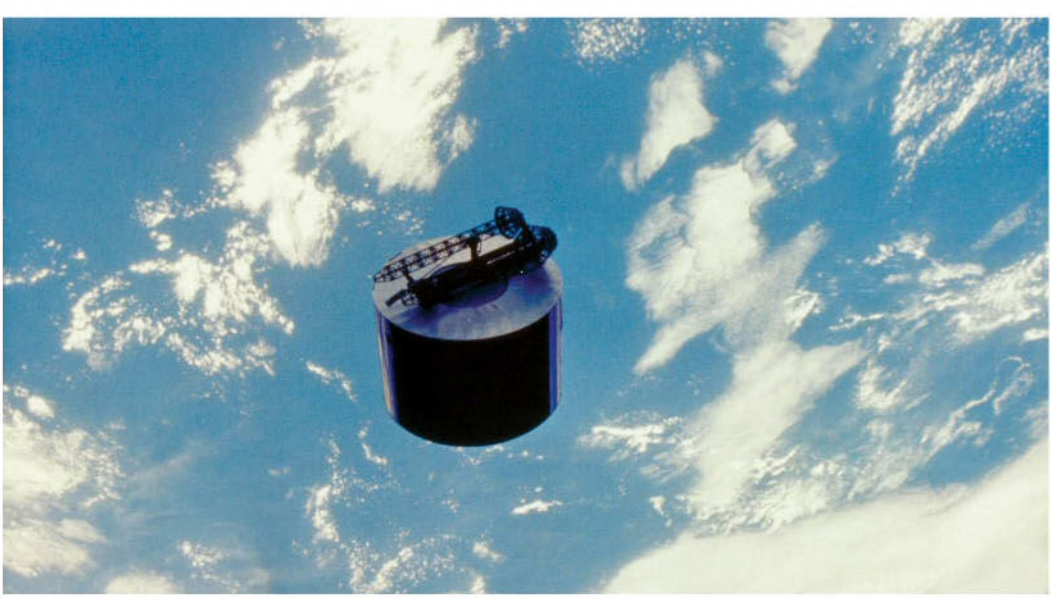
The triumph humiliated the US, provoking the country to set up NASA, launch Explorer (its first satellite) in 1958, establish the Apollo space programme in 1961, and Telstar, the first commercial communications satellite, in 1962.

Millard, who curated the Science Museum's 2015 hit Cosmonauts show, mixes technology with Russian, US and European politics to great effect. For example, his book includes an early 1960s photo of a US aircraft that could capture a capsule dropped by a US satellite, containing film of Earth's surface. He quotes an off-the-record comment by President Lyndon Johnson about the secret film's value: "We were building things we didn't need to build... Because of satellites I *know* how many missiles the enemy has."

"Isaac Newton imagined satellites in *Principia Mathematica,* but had no concept of their usefulness"

Today, everyone has access to detailed images of Earth's surface. More than 1400 satellites, some 500 in geostationary orbit, predict weather and handle navigation, communications and TV broadcasting. But, says Millard, we must not depend on them completely. In 2009, a retired Russian satellite crashed spectacularly into a working US communications satellite. Indeed, tonnes of space junk threaten to degrade all satellite services.

Then there are solar flares, which caused electrical disruption in 1859 and 1921. In 2012 , one just missed Earth. The price of our connected world is that the next big flare will produce chaos. ■



Connecting you now: LEASAT satellite orbits the Atlantic in 1984

GRANGER HISTORICAL PICTURE ARCHIVE / ALAMY STOCK PHOTO

Andrew Robinson wrote *Earth-Shattering Events* (Thames & Hudson)

Space, the final holiday frontier

Don't even think of leaving Earth without this book, says **Mick O'Hare**

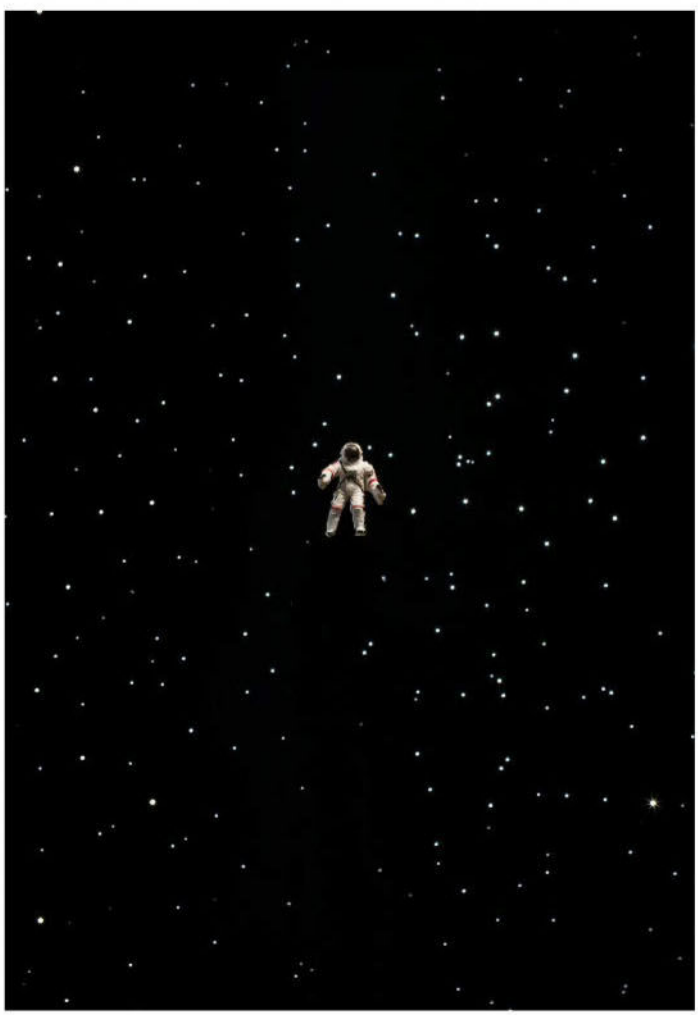
The Traveler's Guide to Space: For one-way settlers and round-trip tourists by Neil F. Comins, Columbia University Press

THERE are some journeys that, although you are aware they exist, you don't ever expect to make. Diving to the bottom of the Mariana trench, perhaps, or circumnavigating the world. And then there are some you probably have no desire to undertake. Travelling alone across the ice by sled to the South Pole in midwinter, maybe, or crossing the Sahara on foot. But if you really, really had to go ahead with any of them, you would want to know you were in very safe hands.

Fortunately Neil F. Comins has such hands. He is at the University of Maine's department of physics and astronomy, and what he doesn't know about space travel and its effects on the average human isn't worth a handful of stardust.

If space travel is to become commonplace, trippers will be keen to know what to pack, the kind of experiences they are likely to face and how it will feel. Key among the last of these is adapting to weightlessness, which gets a whole chapter. This may be just as well since there's a lot to learn about the topic: eating, moving around and having sex are all very different in space. And, of course, you have to go to the toilet. As Comins says, "urine and feces don't [just] go down", they go everywhere. Be careful.

Then when you've finally got used to doing what once came naturally, the trip will be over. Thankfully, the final chapter offers hints and tips about adapting to life back on Earth, where you'll find it difficult to stand and tricky talking to family and friends who haven't been through what you have – it's psychologically and socially disorienting, and deeply disruptive. As for sex, up there, the lack of weight means more positions are comfortable; on Earth, it's back to the boring old ways, presumably.



CHRIS PARSONS/GETTY

Space: great sex and sport, but the psychological re-entry is tricky

"Space travellers revert to childhood, becoming as territorial as they might have been with siblings"

In addition to the erotic and the exotic, Comins covers sleep disturbance (space travel is way noisier than you might expect) and problems with smells (plastics really leach gases – recall that "new car smell" and decide if you can cope with it, not to mention the odours of your fellow travellers, for months). And then there's the sheer boredom of being somewhere with so little to do: space travel sounds exciting, but there's a hell of a lot of sitting around while you do it.

The chapter on making the most of experiences in space tells you what to look out for on Mars as you pass by, why you should do a crash course in geology before you go (Apollo 15 astronaut David Scott discovered moon rocks that were 4.5 billion years old because he paid attention in class), and which sports are best played on the moon. Here, golf and soccer work well because, despite the balls going higher and further than on Earth, they still return to the surface.

Comins also covers things you would never have considered. For example, space travellers tend to revert to childhood, becoming as territorial as they might once have been with their siblings. Disputes can break out if one person inches their gear into another's personal, er, space, so demarcation zones should be clearly assigned before launch.

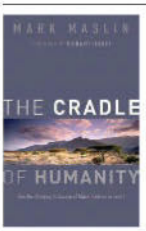
The Traveler's Guide to Space is a delight, and the fact that few of its readers will ever need to use it doesn't diminish its pleasures. Difficult terrestrial journeys will remain just that. However, after reading this guide, space will sound far more fun than our planet's offerings – but also more challenging and perplexing than you could have expected.

Don't leave Earth without it. ■

How the world made us

Adrian Barnett explores chance and climate in the human story

The Cradle of Humanity: How the changing landscape of Africa made us so smart by Mark Maslin, Oxford University Press



THE story of our 2-million-year journey towards becoming human has been told so often it's almost a cliché. But despite a vast stack of books and papers, there are still questions to which the answers are sketchy or controversial.

It has, for example, never been made clear why it all began in east Africa, not elsewhere. After all, Europe and Asia both had apes too, so why did they not start the transition to something human, allowing us to descend not from *Australopithecus*, but from *Gigantopithecus*, the 3-metre-tall distant relative of the orangutan?

Enter Mark Maslin, professor of climatology at University College London and his new book, *The Cradle of Humanity*. In it he addresses many outstanding questions, while showing what was going on in the world at the time. As a climatologist, he looks at the ecological consequences of the great dry-out that occurred not only in east Africa but also in primate-rich Europe and primate-free North America.

In most accounts these events receive the broadest of historical brushstrokes, with just enough detail to lend a plausible inevitability to whatever process is under discussion. *The Cradle of Humanity* is more textured and subtle, showing not only how such changes altered any meat-giving prey, but how both climate and new mammalian fruit eaters changed the suite of plants available to our early ancestors. Only then does Maslin tackle the probable consequences of this for the social systems and mental development of proto-hominins.

But this book offers far more than a palaeoanthropological cocktail with a twist. Maslin dedicates whole chapters to the history of Earth and its climate, as well as showing how the interaction of wobbles in the orbits of our planet and the moon create climatic cycles. Then there are the effects of plate tectonics, rain shadows and lakes of varying ephemerality and salinity.

All this allows Maslin to buttress his central contention, that human evolution as we know it wouldn't have occurred without the uplift of the Tibetan plateau and the formation of the Great Rift valley. These events, and the cycling between salt flats and shallow sea that mark the history of the Mediterranean, are the great drivers of human evolution – the climatic starting gun that set off the human race.

Maslin also provides a fine overview of the evolution of evolutionary thinking over the past 150 years, to the point where we now see it less as an orderly march towards an inevitable

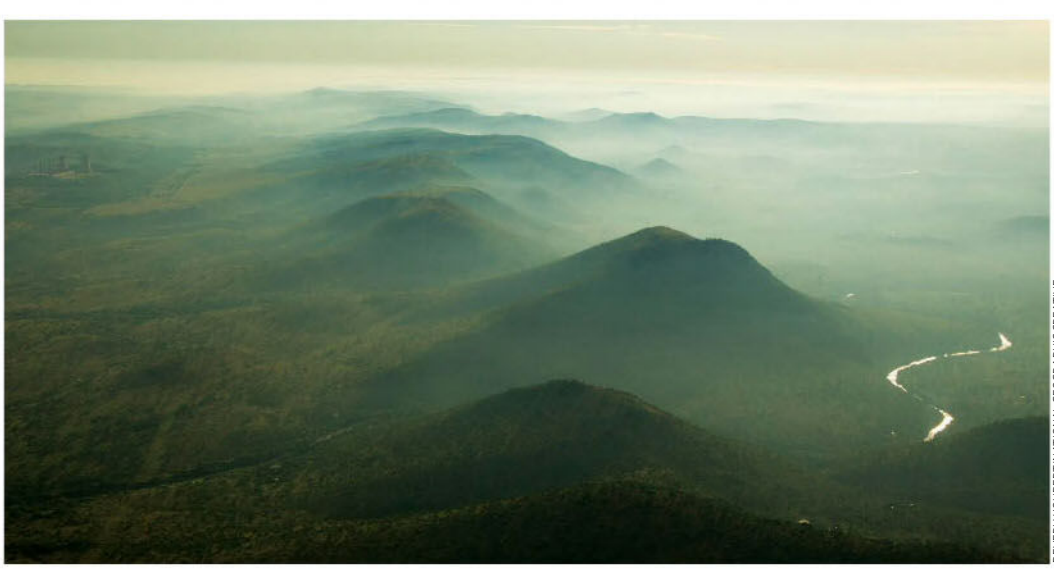
"Europe and Asia both had apes too, so why did they not start the transition to something human?"

Homo sapiens and more of a random stumble to now. He is clear that while the appearance of a smart, tool-using primate is no major surprise, the presence of this particular smart, tool-using primate, arising as a result of that exact evolutionary trajectory, owes much more to chance and contingency than previous popular perspectives allowed.

For much of early human history, for example, there was another smart bipedal ape on the African savannah: *Paranthropus*, a heavy-jawed grinder of nuts, seeds and tubers. Even a tiny disaster could have wiped out the protohuman's prey base, leaving only *Paranthropus*. Similarly, the cycles of aridity and plenty could have been very different, given a greater or lesser slippage of ice fields into the ocean, say, or a change in when the Strait of Gibraltar closed and the Mediterranean experienced death by evaporation. Such shifts might have had us reading this on Mars, or squatting round a cave fire.

In synthesising the most recent research in palaeoanthropology and giving the ecology of our ancestors a climatological twist, Maslin has produced a book that is fascinating, humbling and informative. ■

Adrian Barnett is a rainforest ecologist at Brazil's National Institute of Amazonian Research in Manaus



Humans were shaped by climatic events, geography and chance

BEVERLY JOUBERT/NATIONAL GEOGRAPHIC CREATIVE

EXPAND YOUR MIND

From the multiverse to travelling through space-time to changing the laws of physics - explore the most incredible concepts in science.

Buy your copy from all good magazine retailers or digitally.
Find out more at **newscientist.com/theCollection**

NewScientist

East Coast Office
50 Hampshire Street
Cambridge, MA 02142
Email NSSales@NewScientist.com
Phone 781 734 8771

NIH National Institute on Aging
Intramural Research Program

Department of Health and Human Services
National Institutes of Health
National Institute on Aging

The National Institute on Aging (NIA), a major research component of the National Institutes of Health (NIH) and the Department of Health and Human Services (DHHS), is recruiting for a postdoctoral position in The Section on DNA Helicases, Laboratory of Molecular Gerontology. Research in the Laboratory of Molecular Gerontology involves the study of genomic stability maintenance. The focus of our group is to investigate the functions of DNA helicases defective in premature aging and cancer disorders. The objective of this research is to understand the molecular and cellular roles of human DNA helicases in pathways that are important for the maintenance of genome stability. Genetic and biochemical approaches are used to characterize the roles of helicases in cellular DNA metabolic pathways and the mechanisms of unwinding by human DNA helicases.

Interested candidates must have a Ph.D. or M.D. with less than five years of postdoctoral experience and research experience in molecular biology, and training in mammalian cell culture techniques. Salary is commensurate with experience and accomplishments. Submit letter of interest, curriculum vitae, and references to:

Robert M. Brosh, Jr., Ph.D., Senior Investigator NIA-NIH,
Laboratory of Molecular Gerontology,
251 Bayview Blvd., Suite 100, Baltimore, MD 21224 USA.

Phone: **410-558-8578**, or E-mail: **BroshR@mail.nih.gov**

For additional information on this position, visit
https://www.irp.nia.nih.gov/branches/lmg/rbrosh.htm

HHS and NIH are Equal Opportunity Employers

FDA U.S. FOOD & DRUG ADMINISTRATION

Regulatory Pharmaceutical Analysis Program
OFFICE OF REGULATORY AFFAIRS (ORA)

The FDA's Office of Regulatory Affairs is seeking PhD-level scientists with experience in chemical analysis of complex pharmaceutical products to work at ORA's field laboratory located in Irvine, CA. Candidate must have a PhD in a mainstream technical field such as chemistry, biochemistry, and physics. The preferred candidate must have extensive experience in the mass spectrometry analysis/characterization of complex pharmaceuticals such as protein-based or nanotechnology drugs; and must be an expert in mass spectrometry, including method development, troubleshooting, and maintenance.

Candidate must be able to independently execute defined projects, develop new methods to meet agency needs, and serve as an expert in area of specialty. Candidate must possess excellent written and oral communication skills. Must be able to engage with other experts in industry, academia, other parts of FDA, other federal, state and local agencies; establish collaborations when necessary; and represent ORA in field of expertise. Only US Citizens and Permanent Residents are eligible to apply and candidate must be willing to relocate to Irvine, CA.

Salary range: $75,000 – $120,000 per year and will be commensurate with experience.

Interested persons can send curriculum vitae or resume with cover letter to: **ORSJOBSEARCH@FDA.HHS.GOV**

Help Government Regulations Keep Apace with Biomedical Advances

BURROUGHS WELLCOME FUND

Regulatory science is an underserved area of research, and academic researchers can help government agencies bridge existing knowledge gaps,
writes Rusty Kelley of the Burroughs Wellcome Fund.

Who informs the regulations of the regulators?

The U.S. Food and Drug Administration (FDA) defines "regulatory science" as the science of developing new tools, standards, and approaches to assess the safety, efficacy, quality, and performance of FDA-regulated products. Indeed, to craft policies which secure the welfare of citizens against the risks of untested therapies, government regulators must rely on rigorous research to properly evaluate novel treatments and the evaluation methodologies and standards themselves.

But regulatory science itself is an underfunded area of research. National policies and regulations on new biomedical therapies should be supported by state-of-the-science data. Yet given the unpredictable fiscal realities of government research, agencies often lack the resources to fully address each and every emerging regulatory question, even as the rapid pace of industry innovation pushes forward.

Academic researchers can help agencies bridge this gap in knowledge. Recognizing the need and the opportunity, the Burroughs Wellcome Fund has elevated the importance of regulatory science through a first-in-its-kind funding initiative.

Our Innovation in Regulatory Science Awards (IRSA) specifically funds university researchers who can leverage their institutional resources towards new approaches for vetting novel therapies, developing new diagnostics, evaluating food safety, and other needs. The goal is for IRSA awardees to produce timely and implementable strategies that can directly assist U.S. and Canadian agencies in making regulatory decisions.

Such innovations informing regulatory science necessarily require multidisciplinary thinking, and awarded IRSA proposals have been as varied as their investigator's expertise. Rustem Ismagilov, the Director of the Jacobs Institute for Molecular Engineering for Medicine at Caltech, tinkers with microfluidic diagnostic platforms. Mary Labbé, the Chair of Nutritional Sciences at the University of Toronto, sought to evaluate nutrient profiling methods for nutrition regulation. While Sara Lynn Van Driest, Assistant Professor of Pediatrics at Vanderbilt University, applied her MD-PhD training towards analyzing "big data" to predict and improve children's response to medication.

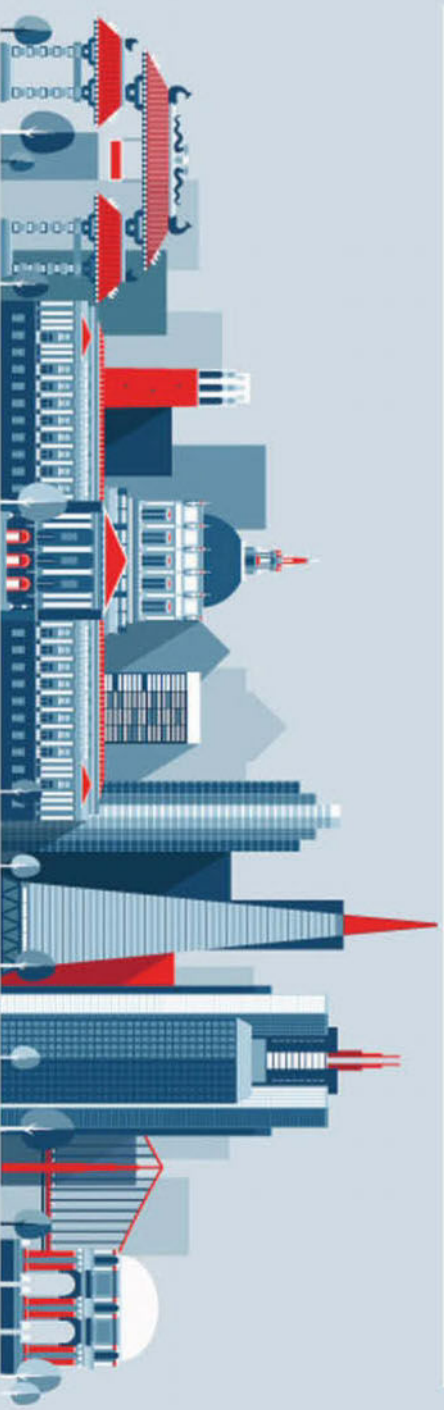
As the FDA writes in their 2010 report, *Advancing Regulatory Science for Public Health*: "Without advances in regulatory science, promising medical therapies may be discarded during the developmental process simply because we lack the tools to recognize their potential, or outdated evaluation methods may unnecessarily delay their approval."

The demand for informed FDA policymaking is as limitless as the frontier of medical therapies – and investigators seeking to advance their career while making far-reaching, practical impact would do well to consider regulatory science as a research focus. We can ensure that research by academic institutions helpfully complements that of government agencies and industry – and together, we can strengthen the biomedical knowledge needed to inform our national regulatory decisions.

–Rusty Kelley

Rusty Kelley, PhD, MBA, is a Program Officer with the Burroughs Wellcome Fund.

U.S. and Canadian citizens or permanent residents who have a faculty or adjunct faculty appointment at a North American degree-granting institution are invited to apply for the Innovations in Regulatory Science Award (IRSA). The program provides up to $500,000 over five years for investigators to develop innovative and implementable solutions to regulatory science questions in U.S. and Canada.
***Proposals are due March 15th, 2017**. Visit **www.bwfund.org/IRSANS** to apply.*



NPA 2017 Annual Meeting

15th Anniversary

March 17-19 ○ San Francisco, CA

Keynote Speaker

Peter Fiske, Ph.D.
CEO, PAX Water Technologies, Inc.

REGISTRATION IS NOW OPEN!

REGISTER BY MARCH 3, 2017

www.nationalpostdoc.org/2017AnnualMeeting

DON'T LET ZIP CODE DETERMINE DESTINY.

Heading into it's 10th year of public service, the EnCorps STEM Teaching Fellowship prepares STEM professionals, military veterans, and retirees to explore a career transition to teaching in a highly supported way.

Now accepting applications for the 2017 Cohort.

www.encorps.org/apply

EnCorps
STEM TEACHERS PROGRAM

EDITOR'S PICK

AI challenges our basic idea of science

From Nello Cristianini, Bristol, UK
Malcolm Shute suggests that if all the old attempts at performing natural language translation using grammar-based sentence analysis have failed, and the statistical analysis of translated documents found on the internet has been a resounding success, that "may speak volumes about how natural language works" (Letters, 4 February). This is an important point, and is becoming the object of philosophical discussion.

Shute's question implies deeper questions about the very purpose of scientific investigation. It is a shame that there was no space to address this in my article on artificial intelligence (26 November 2016, p 39).

Do we build models of reality in order to predict it, or in order to explain it? And what are we to make of models that make good predictions, but make no sense to us?

Our need for causal explanations seems to be similar to our need to tell stories about what we perceive.

More work is needed to understand what role machines can play in the future of the scientific method.

The stranger results of infinite multiverses

From Bob Watts, Bristol, UK
Shannon Hall explores the implications of everything allowed by physics happening (21 January, p 28). But I conjecture events with non-zero probabilities that will surely not happen anywhere. Is there a civilisation like ours but where every fair dice throw is a six for every person every time? Probabilities that tend to zero, with opportunities that tend to infinity, should maybe be treated like multiplying zero by infinity: the result is undefined.

A world where the least likely has always occurred is interesting to think about, though.

From Jeremy Greenwood, Bacup, Lancashire, UK
If there is an infinite multiverse, I would argue that somewhere there will be at least one god. On account of being consubstantial, coeternal and so on, once She, He or It appears they immediately pervade space-time, always and already having been everywhere, unconfined by the speed of light.

This theory seems as valid as the idea that we live in someone else's virtual environment, or are figments in the imagination of a Boltzmann brain (25 May 2013, p 12). I accept that this notion also predicts the existence of the Flying Spaghetti Monster.

From David Wilson, Stroud, Gloucestershire, UK
OK, so I'm prepared to swallow this multiverse business, but an infinite multiverse? Surely that way lies utter madness.

If there are infinitely many universes, then among them there is one identical to our own in every single respect but one:

"Dolphins are a hoax created by China to defeat the freedom to drill and overfish"

Kevin Russell responds to the news that there are only 30 vaquita porpoises left (11 February, p 5)

in that universe you chose not to publish this letter – but otherwise it made absolutely no difference.

My purpose here is to say that we don't know

From Alfred Zarb, Leura, New South Wales, Australia

Teal Burrell purports to deal with a sense of purpose and the meaning of life (28 January, p 30). But how does she know the "harsh reality" that "as far as the universe is concerned, we are nothing but fleeting and randomly assembled collections of energy and matter"? How does she know that "life is ultimately meaningless"?

If that were the case, why do we still read Plato, Shakespeare and Dostoyevsky; or listen to Mozart, Mahler and Wagner; or look at Michelangelo, Caravaggio and Picasso; or take notice of Euclid, Galileo and Darwin? Yes, they all turned to dust, like the rest of us will. But their memory lives on.

From Annemieke Wigmore, Cudworth, Somerset, UK

Burrell tells us that Victor Strecher is developing "an app called Jool that he hopes can eventually serve as a kind of 'purpose pill'... tested by companies to help employees hone their sense of purpose – and boost productivity". Personally, I'd rather die miserably and before my time than be trained by a cutely named app to line my employer's pockets.

The question is not about humanity, but suffering

From Ingrid Newkirk, People for the Ethical Treatment of Animals, Washington DC, US

Clare Wilson asks whether pigs that are manipulated to possess human brain cells merit "greater moral consideration" (28 January, p 8). The presence of human brain cells is a faulty criterion. Moral consideration must be afforded to all beings that are able to suffer.

As the utilitarian philosopher Jeremy Bentham wrote in 1789: "the number of legs, the villosity of the skin, or the termination of the *os sacrum* [tail bone], are reasons equally insufficient for abandoning a sensitive being to the same fate... the question is not, Can they reason? nor, Can they talk? but, Can they suffer?"

Can free-range planets solve a cosmic mystery?

From Bruce Denness, Whitwell, Isle of Wight, UK

You suggest that the Milky Way – and by analogy the universe – may abound with free-floating planet-sized bodies (14 January, p 20). The elusive dark matter?

The editor writes:

■ Perhaps sadly, there wouldn't be enough of them to account for all the missing mass that dark matter is invoked to explain. Other evidence, such as that from gravitational lensing, suggests dark matter has a particle nature.

You think antimatter is weird? Look here...

From Sam Edge, Ringwood, Hampshire, UK

Joshua Howgego says "the antimatter realm is so bizarre... particles that destroy themselves and normal matter whenever the two come into contact" (7 January, p 28). Antimatter isn't of itself any more bizarre than matter, apart from its rarity in our neck of the multiverse.

We have a habit of classifying anything that is rare in our experience, such as metallic ›

hydrogen, as "special". This just shows that the environment we live in is itself rare compared with the bulk of the universe.

The imbalance between matter and antimatter in the observable universe is a puzzle, but the stuff itself is no weirder than any other type of mass-energy – which is all weird enough already.

The danger zone half way to automation

From Nicholas Thomas, Revelstoke, British Columbia, Canada

Sandy Ong worries about the "ethics" that will be programmed (or not) into fully autonomous vehicles (7 January, p 36). But there is a far more urgent issue that needs to be dealt with first.

Before vehicles become fully autonomous there will be a time when they handle routine driving but occasionally require the human behind the wheel to take control. These drivers will have little training in the capabilities of their vehicles' automation. How many will study and understand the owner's manual?

Drivers who are not paying full attention will be surprised when their vehicle suddenly demands they take control.

Partially autonomous vehicles are likely to reduce the toll of accidents now caused by drivers who aren't paying attention. But I expect some very sad results from passing control to a "driver" who must suddenly wake up and react.

Preserve fragile treasures of space flight

From Rod Cripps, Parkdale, Victoria, Australia

Kate Becker's article on the women behind space exploration in the 1950s and 60s was uplifting and inspirational (21 January, p 40). Another aspect of the space-race is in danger of being lost.

Because digital computers of the time were so slow, much of the trajectory calculation was done by analogue or hybrid digital/analogue electronic computers. A few remain in museums. But their really valuable intellectual heritage is the "programs" they used, and the mathematical techniques behind them. These are being lost as engineers and scientists of my generation die.

In the US, most of NASA's analogue computers were made by Electronic Associates (EAI). I urge anyone with copies of any of these programs, for space applications or others, or knowledge of their whereabouts, to pass them on to one of the analogue computer museums, or to contact me care of this page.

Give credit for pioneer computing work

From Crispin Piney, Mougins, France

Much as I enjoyed your recent crossword (14 January), I must comment on one clue. It asked for the name of an "MIT/IBM educational computing project" and required the answer "Athena".

This overlooked the fact that the Digital Equipment Corporation (DEC) was the main donor to this collaboration of skills, personnel, equipment, technology and money (estimated at $50 million in the year 2000). The memory of DEC's achievements lives on with its past users and employees. Its contributions to the evolution of computing and to information technology cannot be overstated.

How does dust hide gravitational waves?

From Frank Seymour, Wimbotsham, Norfolk, UK

You report the BICEP2 telescope at the South Pole detecting noise created by dust inside our galaxy (14 January, p 6). How does this or any cosmic dust create a noise?

The editor writes:

■ It would have been clearer to say that BICEP2 detected a signal, confusingly similar to the signature of gravitational waves, that turned out to be emissions from warm dust ejected by supernovae (26 April 2014, p 14).

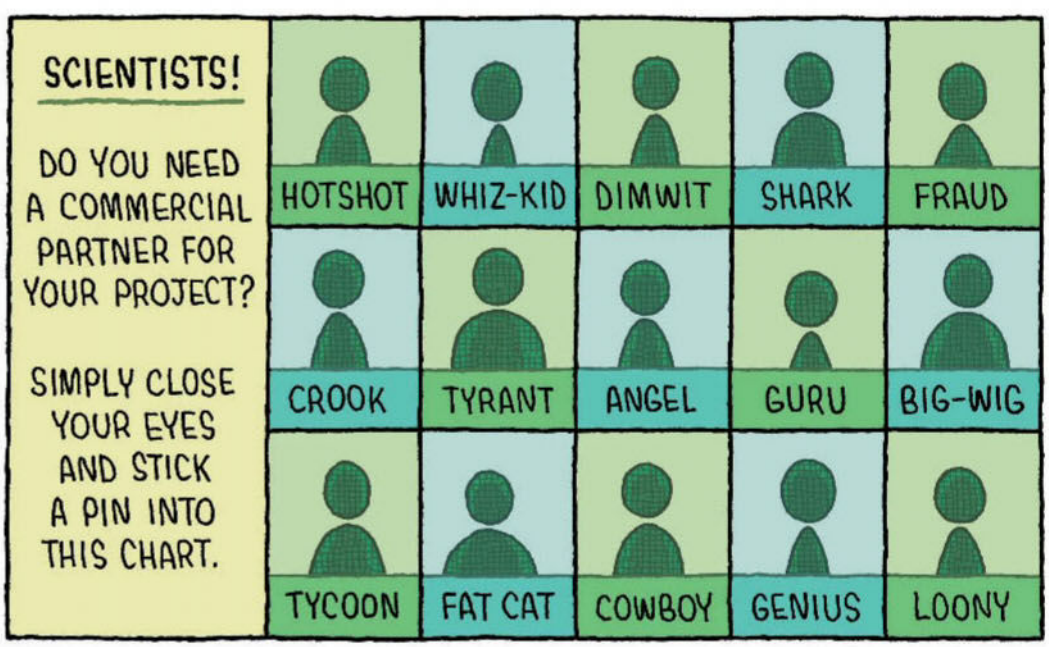
Primatology in surprise anthropology meeting

From Garrick Alder, London, UK

I was captivated by how chimps dealt with the return of a "tyrant" (4 February, p 9). In 1890, James Frazer in *The Golden Bough* proposed that prehistoric "kings" would reign in good times and later serve as scapegoats and sacrifices to ensure fertility.

The parallels made me sit up straight and rub my eyes. Might Frazer's work now bear respectful re-examination by students of the rational sciences, alongside students of the irrational ones?

TOM GAULD



For the record

■ **"PM2.5" particles of air pollution are defined as being 2.5 micrometres in diameter or less (4 February, p 22).**

Letters should be sent to:
Letters to the Editor, New Scientist, 110 High Holborn, London WC1V 6EU
Email: letters@newscientist.com

Include your full postal address and telephone number, and a reference (issue, page number, title) to articles. We reserve the right to edit letters. Reed Business Information reserves the right to use any submissions sent to the letters column of *New Scientist* magazine, in any other format.

SIGNAL BOOST

Offering your projects a helping hand

Fighting infection in babies

DID you know the UK doesn't test for the most common cause of life-threatening infection in newborn babies? Most people will never need to know about Group B Strep, also known as GBS or Strep B, even though 25 per cent of us carry the bacteria. It's living in and on us, without causing harm or symptoms.

But 21 years ago this March, my middle child, Theo, died from GBS infection, aged 17 hours. I was unlucky – most babies recover with no ill effects. But sadly, even with the best medical care, approximately one baby a week dies from GBS in the UK. A similar number recover but with a life-changing disability.

Yet most GBS infections in newborn babies are preventable by offering women carrying the bacteria a course of intravenous antibiotics during labour. Narrow-spectrum penicillin, costing mere pennies, would treat it.

Within a few months of Theo's death, I set up a national charity, Group B Strep Support. Its objective is to prevent GBS infections in babies and it provides support to families affected by GBS and their healthcare providers, and raises awareness of the infection.

In the UK, GBS infections in babies are increasing. But unlike so many developed countries including the US, France, Germany, Canada, Poland and Switzerland, it's not in official guidelines to tell pregnant women about GBS nor is it standard practice to offer them a test, which only costs a few pounds. Instead, the UK adopts a risk-based approach that was rejected by the US in 2002. This looks at things like a woman's previous pregnancies.

Raising awareness among parents and health professionals is vital. A survey we carried out found that 98 per cent of midwives knew about GBS, but only around 50 per cent said they had adequate information about it to give to women in their care. This must change. **Jane Plumb, Group B Strep Support**

If you're interested in sharing information about GBS with parents and health professionals, or can help to produce accessible information and educational materials, contact me at **jplumb@gbss.org.uk** or on **01444 416176**

Signal Boost is your chance to tell our readers about a project that needs their help. We're looking for campaigns, programmes or ideas from non-profit or voluntary enterprises based in the UK. Send a proposal, together with images and information about yourself, to signalboost@newscientist.com. *New Scientist* does not endorse any claims made in this donated advertising space. We reserve the right to edit contributions for clarity and style.

PAUL MCDEVITT

READERS may be familiar with the Erdös number, a description of how far removed a researcher is from famously prolific mathematician Paul Erdös. His immediate co-authors earn a score of 1, anyone who co-authored a paper with one of those researchers is scored 2, and so forth.

A similar system measures connectedness in Hollywood via the degrees of Kevin Bacon. And in the music industry, Black Sabbath are at the centre of the collaborative Venn diagram. So it was only a matter of time before somebody combined all three, giving rise to the Erdös-Bacon-Sabbath (EBS) project.

The authors of erdosbaconsabbath.com say: "Anyone with a well-defined EBS number must have many talents and a fascinating backstory, but they turn out to be more numerous than you might think."

Never mind well-known polymaths such as Brians Cox and May. Who knew, for example, that Colin Firth (E6, B1, S4) co-authored a paper on the neuroscience of political leanings (doi.org/bk4) or that Condoleezza Rice (E6, B3, S4) abandoned a career as a pianist to pursue politics? And how delighted we are to discover that Terry Pratchett has the very respectable score of E4, B2, S3, thanks to his Discworld series spanning literature, film and music.

PREVIOUSLY Feedback mulled the issue of ocean acidification or, as UKIP's Roger Helmer would have it, ocean de-alkalinisation (4 February). Dominic Burrow spies an opportunity to pour oil on these troubled waters with technology from Echo Elemonics, a company selling a device that adds hydrogen molecules to your drinking water.

The firm's homepage takes pains to point out that the device doesn't produce the alkaline water you may have seen peddled with dubious health claims, but is a machine for adding a "symphony of balanced trace elements", which will increase your fitness, support weight loss and balance "energy fields and environmental harmonics" for more "harmonically tuned experiences".

Incredibly, the machine can add hydrogen molecules "without substantially altering the pH of the water in the process". Feedback suspects that if this property could be applied to the world's oceans, we might save the coral reefs with a large-scale anti-de-alkalinisation programme.

MEANWHILE, Ian Nelson finds a surprising revelation nestled in a story from the *Daily Mail* about a roofer in The Hague, Netherlands, who is plagued by a dive-bombing gull. Commenting on the motives for the attack, the paper concludes that "the bird was acting defensively because it was giving birth to chicks".

MIKE LAVAN previously challenged readers to find celebrities whose names can be constructed using single-letter symbols from the periodic table (7 January).

Andy Ward writes to complain that "if the International Union of Pure and Applied Chemistry hadn't changed the symbol for argon from A to Ar in the early 1960s, the task would be easier". But he offers leeway in that fusion scientists and cosmologists "often use the symbols D and T for the heavier isotopes of hydrogen".

Finally, he notes that it is possible to make several phrases ending with the symbols for oxygen, fluorine and fluorine. Be OFF with you Andy, that's no way to behave in Feedback.

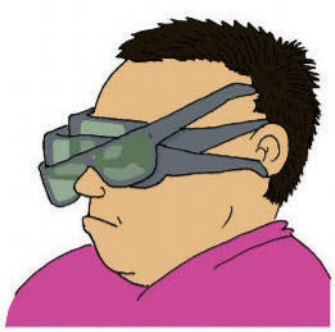
THE insatiably curious Hillary Shaw writes to say she was searching for web hits for the date 12 October 1399 "to see if there were any historic events that happened". Surprisingly, the top result was a link to the BBC Sport schedules for Sunday 12 October 1399. Her initial excitement was soon deflated, however, when she realised that the given page only declares, "There is no schedule for today. Please choose another day from the calendar."

"Perhaps the time-travelling BBC sports schedulers have omitted to include the medieval jousting tournament for that day, or maybe it was just another religious holiday and all the knights had a day off," says Hillary. "Perhaps BBC sports correspondents can clarify?"

Feedback thinks she'd be better off asking Tony Robinson of *Time Team*.

DEMAND for much-vaunted 3D television has proved rather flat, and manufacturers such as Sony, Panasonic and LG are quietly dropping the feature from their latest models.

Nobody, however, told residents in Bukhara, Uzbekistan, where Anthony Wheeler spotted a cinema offering an even-more-extravagant 5D show. "I would certainly have paid the price of



admission just to experience these added dimensions, but sadly our train was about to depart," he says.

Which makes Feedback wonder if three simply wasn't the magic number for TV buyers. Could 66.7 per cent improved 5D sets be what's needed to convince consumers? And how many pairs of glasses would we need to watch shows on them?

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

Andrew Tucker is informed by an ITV News report on nail bars that "the work is mostly manual". "I suppose it would be," he says

High flyers

In the spring and summer, I see swallows swooping in the air, presumably to eat flying insects – so why are the insects way up there?

There may be several reasons why insects fly high and risk predation from birds, rather than staying close to the ground.

One is that insect migration is easier higher up – potentially 6000 metres or more above ground – where the wind is stronger. Leafhoppers, for example, exploit this. In the southern US, these insects use the temperature to gauge their migration, flying upwards when it is warm (implying a southerly wind) but staying closer to the ground in colder conditions (implying a wind from the north).

"Moths and butterflies may be able to locate potential mates more easily the higher up they are flying"

Another reason is that some insects may be able to locate potential mates more easily the higher up they are flying. This is particularly true of lepidopterans – moths and butterflies – which release chemical attractants, or pheromones, to entice individuals of the opposite sex to join them. Impressively, many lepidopterans can detect pheromones from more than 10 kilometres away.

Lastly, most insects are so light that a gust of wind or a thermal current can accidentally lift them high into the air – and unwittingly into the beak of a hungry swallow.

Sam Buckton
Chipperfield, Hertfordshire, UK

Thermals – rising air currents – draw small insects upwards. Glider pilots know only too well about bugs being squashed on the leading edge of wings and degrading performance. Sophisticated gliders even have bug scrapers.

Swallows tend not to use thermals but stay relatively low. House martins, on the other hand, regularly congregate in thermals under developing showers or thunderstorms; I recently spied a flock as a storm was brewing.

Swifts go even higher, but don't flock in quite the same numbers. When I used to spend time in gliders, I often encountered swifts near the cloud base at 1500 metres above ground. I even met a peregrine falcon at that height, obviously looking for easy pickings.

Jack Harrison
Nairn, Highland, UK

On the farm

It always seems that, in any wind farm, at least one of the cluster of turbines isn't turning. What is the reason for this? Is it undergoing repair or are there other, more interesting, factors at work?

Wind turbines are complex pieces of machinery, but are generally very reliable: their availability is typically around 97 per cent. Needless to say, regular maintenance is necessary, and some of this requires individual turbines to go offline.

One notable cause is that the blades accumulate minor damage from stones peppering them in high winds. Blade inspection and repair is usually carried out in the gentler weather of summer, and this provides a major source of employment in areas where there are lots of turbines.

Other components of the turbine can fail and need repair too, such as the gearbox, which is a heavily stressed component.

Turbines may also be turned off in times of turbulence or (often) at night, because of the noise they make. This sort of downtime is normally programmed into the wind farm's computerised management system.

"If one or two turbines are not turning, it's probably maintenance. If more, then it's to do with the grid"

If just one or two turbines are not turning, then, that is probably down to maintenance issues. If the whole site is idle, then the most likely reason is "grid curtailment", which occurs when too much electricity is being generated for the grid to make use of it all.

One of the joys of wind turbines is that they can respond very quickly to a request to stop generating power. This gives a measure of flexibility to the grid.

Eric Billett
Director of the Kilbraur Wind Cooperative (Scotland)
Chellaston, Derby, UK

This week's questions

NUDGE FACTOR

My 8-year-old son is very worried about the Earth being destroyed by the sun when it becomes a red giant billions of years from now. I have tried to comfort him by suggesting we could shift Earth's orbit by hurling asteroids towards the planet on trajectories that will gradually move it away from the sun. Is this feasible?

Steve Dalton
Chipstead, Kent, UK

FEEL THE HEAT

On a beautifully sunny, windless day last summer, I sat in my back garden and felt very warm indeed. The air temperature was 16 °C, but there is no doubt that it felt more like a day when the thermometer read 25 °C. Why the discrepancy?

Simon Silver
Hayes, Middlesex, UK

PURR FACT

Do cats that are looked after by profoundly deaf people meow and purr less than cats looked after by people with hearing? In other words, do they recognise that their human can or can't hear them, and behave accordingly?

Perry Bebbington
Kimberley, Nottinghamshire, UK

The writers of answers that are published in the magazine will receive a cheque for £25 (or US$ equivalent). Answers should be concise. We reserve the right to edit items for clarity and style. Please include a daytime telephone number and an email address if you have one. New Scientist retains total editorial control over the published content.

Reed Business Information Ltd reserves all rights to reuse all question and answer material that has been submitted by readers in any medium or in any format and at any time in the future.

Send questions and answers to The Last Word, New Scientist, 110 High Holborn, London WC1V 6EU, UK, by email to lastword@newscientist.com or visit www.newscientist.com/topic/lastword (please include a postal address in order to receive payment for answers). Unanswered questions can also be found at this URL.

The government measures survival rates for six critical medical conditions.

Only one hospital in the nation outperforms on all of them: NewYork-Presbyterian.

NewYork-Presbyterian is the only hospital in the nation with statistically better mortality rates in all six of the Centers for Medicare and Medicaid Services (CMS) 30-day mortality measures: heart failure, pneumonia, COPD, heart attack, stroke and coronary artery bypass graft.

While these statistics are only for Medicare patients, they tell a compelling story: a combination of clinical excellence, dedicated patient care, and the experience and resources of two great medical schools. We invite you to learn more at **nyp.org/amazingadvances**

Weill Cornell Medicine | NewYork-Presbyterian | ColumbiaDoctors