New Scientist

WEEKLY January 7 - 13, 2017

RED MIST
Where has Mars's water gone?

SPARK OF LIFE
Electricity zaps body into shape

TRUE LIES
False memory helps you think more clearly

MORAL CAR CRASH Who makes life-or-death decisions for robot cars?

WHEN THINGS FALL UP

If antigravity exists, we'll find it soon

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

No3107 US$6.50 CAN$6.50

CORE BLIMEY Strange goings on in the centre of the Earth

ROBERT INGELHART/GETTY

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

CONTENTS

Volume 232 No 3107

This issue online
newscientist.com/issue/3107

News

8
Early test for genetic disease
Safe blood test can detect disorders in early pregnancy


BSIP/UIG/GETTY

On the cover

28
When things fall up
If antigravity exists, we'll find it soon

Cover image
Alex Staroseltsev/Shutterstock

Features

36
Moral car crash
Who makes life-or-death decisions for robot cars?


BRUNO MANGYOKU

Coming next week...

How clean is too clean?
The truth about hygiene and your health

Hungry tumours
Cancer's greed could be its downfall

Leader

News

Analysis

Aperture

Features

Culture

Regulars

New Scientist events

BECOME AN INSTANT EXPERT IN 2017

If you enjoyed New Scientist Live, come to a New Scientist one-day masterclass next year.

Join six leading experts working at the cutting edge of research, and by the end of the day you'll feel like an expert too.

Saturday 18 February 2017
INSTANT EXPERT:
ARTIFICIAL INTELLIGENCE

Saturday 11 March 2017
INSTANT EXPERT:
THE REVOLUTION IN GENETICS

Saturday 1st April 2017
INSTANT EXPERT:
THE MATHEMATICAL WORLD

Find out more and book tickets:
www.newscientist.com/events

10am – 5pm at:
Royal College of General Practitioners
30 Euston Square
London

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
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

BUBAONE/GETTY

New moral codes needed

Innovators should not reshape society just because they can

SHOULD the wealthy live longer? Of course, they – or rather we – already do. People born in rich countries can look forward to longer lives than those born in poor ones. Now that gap is widening within societies, as well as between them.

If you need drugs to keep you alive, your access to medicine depends on which insurance you can afford, or perhaps on winning the "postcode lottery". That trend is set to accelerate with the advent of medicine explicitly designed to extend life (see page 22). If it is costly, the rich will get to live longer than the poor; if it is cheap, the demographic challenges of greying populations will be exacerbated. Which option – if either – should we aim for?

This is by no means the only epic moral quandary we face as we enter 2017. In fact, they loom everywhere. Should a would-be autocrat be free to broadcast falsehoods directly to millions over social media? Who should design the logic underpinning life-and-death decisions made by self-driving cars (see page 36)? Should a government be able to eavesdrop on every electronic communication its citizens make?

What's notable about these questions is a word that's falling out of public debate: "should". In recent years, most of the running has been made by "can". Creating the ability to do something has become conflated with the right to do it. This is in many respects a good thing: *New Scientist* has long advocated controlled innovation and experimentation as a route to a better world for everybody.

But unbridled innovation leads to social upheaval. Politicians and regulators, dazzled by the pace of innovation and seduced by the megabucks that follow it, have in many areas allowed innovators to "move fast and break things", trusting that common sense and market forces will ensure nothing important gets too badly broken along the way. That trust would appear to have been misplaced. As this attitude has spread from digital technology to transport, healthcare, the environment and beyond, consensus has begun to break down about fundamental precepts of our societies: the equality of human lives, the value of work and wages, the nature of free speech, and so on.

"The ability to do something has been conflated with the right to do it, even if it leads to social upheaval"

Scientists are often accused of trying out things just because they can, but in fact experiments that raise moral concerns are first vetted by ethics committees. Medicine is governed by codes of conduct: first, do no harm. These systems aren't perfect – they can be opaque and overly risk-averse – but they are far more robust and accountable than the ethical void that has opened up in innovation.

There are signs this is changing. An open conversation is emerging about the new rules of the road in the age of self-driving cars. Google has an ethics board overseeing its AI activities – although it is far from clear what this actually does. And politicians have started to call for transparency about how our data is used to make algorithmic decisions about our lives.

The morality of these and many other technologies is in need of urgent discussion: policymakers need to stop dozing at the wheel; and innovators need to listen to ethicists, rather than funders and founders. To be clear, what we need is renewed moral discussion, not "traditional" moral values, which are often not equal to the challenges and opportunities we face today. That will not be easy: millions prefer tradition to new thinking, and turning mores into code will not be easy either. But we can do it if we put our minds to it – and we really should. ■

SAM HOBSON/NATUREPL.COM

Quietly booming

City fox explosion

URBAN red foxes are thriving in England, with populations soaring almost fivefold since the 1990s. The rise seems largely because foxes have colonised new areas or multiplied in small towns, particularly in the north of the country.

Dawn Scott of the University of Brighton, UK, and her team used radio-tagging to understand fox social group sizes and the extent of their territories. From 2013 to 2015, they also asked the public in eight cities to report July and August sightings.

By combining these sightings with models based on the tagging data, the team was able to calculate fox densities in cities across England.

Top of the list was Bournemouth on the south coast, with 23 foxes per square kilometre. Bristol, which had 37 per square kilometre before disease sent the population crashing, now has 16. Newcastle upon Tyne in the north-east is home to about 10 per square kilometre, while London registered 18, Scott told the British Ecological Society meeting in Liverpool, UK, last month.

The team estimates there are now just under 150,000 urban foxes in England. That compares with around 33,000 in the 1990s, and works out at about one fox for every 300 people. However, separate surveys including rural sightings point to a steep overall decline in the past 20 years.

Urban foxes can transmit diseases to humans, although the worst two – rabies and the fox tapeworm – are not present in the UK. On the plus side, they keep rat populations down.

Codeine ban

AUSTRALIA has become the latest country to ban over-the-counter sales of drugs containing the opioid painkiller codeine. The hope is that new regulation, which will come into effect on 1 February 2018, will halt the rise in codeine-related deaths, which have more than doubled in Australia since 2000.

"Codeine is a pretty rubbish drug. It doesn't help people as much as they think it does"

Codeine is used to treat pain and suppress coughing, and can currently be purchased in Australia and the UK without a prescription. Low doses are found in some painkillers, cough syrups, and cold and flu tablets.

However, codeine can become addictive even in small doses, prompting some people to increase their use of codeine-containing medications. The US, Germany and Japan have already banned sales of the drug without prescription.

Since banning such sales, these countries have seen a fall in codeine-related deaths, says Michael Vagg, a pain specialist in Geelong, Australia. "But that's not even the most compelling argument for doing this," he says. "It's also a pretty rubbish drug that doesn't actually help people as much as they think it does."

In its decision to make codeine prescription-only, Australia's Therapeutic Goods Administration noted that the drug doesn't provide effective pain relief at the low doses used in over-the-counter medications.

Virtual witness

COULD your smart home testify against you? Prosecutors investigating a murder case in Arkansas have served Amazon with search warrants for data collected by one of its Echo devices.

Police found an Amazon Echo – a home assistant that responds to voice commands – at the home of James Bates, who is charged with murdering his friend Victor Collins in November 2015. They seized the device as evidence but are now seeking any audio or text records it may have sent to Amazon's servers around the time of the incident. The Echo streams audio to Amazon's cloud, where the data is processed and stored, when it hears its "wake word" – usually "Alexa".

Amazon has been served with several warrants but refuses to provide all of the data requested. "Amazon will not release customer information without a valid and binding legal demand properly served on us," the company said in a statement. "Amazon objects to overbroad or otherwise inappropriate demands as a matter of course."

RADISICS/WILD WONDERS OF EUROPE

Bird paradise: will tourism wreck it?

Lake threat

SOUTHERN Europe's largest lake is under threat from a double whammy. The development of an "eco-resort" on its shores and several hydropower projects on its major tributary could damage biodiversity and harm endemic species unique to the area.

Lake Skadar, shared by Albania and Montenegro, is recognised as an area of international importance for birds. But the Montenegrin government wants

to build several dams on the river Moraca, which provides most of the lake's water, leaving bird nesting sites vulnerable.

The development of an eco-resort, due to be completed in 2019, is also raising concerns. Critics fear tourism will drive birds away and pollute the lake with waste water. The firm behind the resort insists it has carried out impact studies and says that some of the profits can be used to keep the area clean. A number of environmental groups started a petition in late December asking the Montenegrin government to save the lake.

Eco catch-22

WHAT'S good for the ocean could be bad for the planet. Sustainable fishing might use more fuel than vessels that just scoop up all the fish in their vicinity.

Eco-label programmes designed to guide consumers focus mainly on factors such as leaving enough fish in the ocean to maintain populations. But they overlook carbon emissions.

By combing through papers and catch databases, Brandi McKuin at the University of California, Merced, and her team found that tuna vessels using more sustainable methods such as pole and line fishing consume about three to four times as much fuel to land the same catch as boats that use a large net.

The researchers also compared the climate impact of tuna with that of terrestrial sources of protein, like tofu, pork and beef. Sustainably caught tuna has a larger effect than any other protein considered, except beef, for which climate warming emissions are five times those for the same weight of tuna.

The energy needed to freeze fish on its way to the shops might add to its impact, says McKuin.

Psychedelic help

HOW do you recover from a bad trip? A "psychedelics sanctuary" will open in New York this month, the first US therapeutic facility for users of psychedelic drugs.

Current treatments tend to encourage users of such drugs to go cold turkey. But LSD, psilocybin and other psychedelic drugs are not physiologically addictive, and many people who use them don't want to be cured. Instead, some seek help making sense of their experiences, which can sometimes fundamentally challenge how they see the world.

The sanctuary will offer support groups, workshops and training in meditation. Staff will include a doctor, 11 clinical psychologists, plus psychedelic researchers. Preliminary research suggests that group therapy can improve well-being, says Katherine MacLean at the Center for Optimal Living, the clinic that will host the sanctuary.

But while some people may benefit from sharing experiences, others risk more trauma by recalling them, says Elias Dakwar, a clinical psychologist at Columbia University, New York. It's important for therapists who lead group therapy sessions to be properly trained and familiar with psychedelics, he says.

China's ivory trade ends

CHINA has promised to close its domestic ivory market – the world's largest – by the end of 2017.

Conservation groups hope that the announcement, made by the Chinese government on 30 December, will blunt demand for ivory and with it the rationale for poaching elephants.

"This is a tremendous victory for elephants, and we applaud China for showing such decisive action and leadership on this issue," says Azzedine Downes, president of the International Fund for Animal Welfare.

All processing and sales of ivory within China will cease by the end of the year, the government statement said. This will see the closure of 34 registered ivory processing factories and 143 trading venues. Carvers will be redeployed in museums.

Two more of the world's key ivory markets are also taking action. New laws passed in the US last July prohibit almost all domestic ivory trade. Hong Kong, the other key market, announced last month that it would phase out domestic ivory trade by 2021, although a WWF feasibility study found it is possible by 2019.

"Now that three of the world's largest domestic ivory markets are being phased out, we hope other countries will follow suit," said Lo Sze Ping, head of WWF China, in a joint statement with TRAFFIC, which monitors trade in wildlife products. TRAFFIC says that although ivory poaching peaked in 2011, 20,000 animals are still poached each year.

ADAM DEAN/NEW YORK TIMES/REDUX/EYEVINE

No longer for sale

60 SECONDS

Ebola vaccine hope

An experimental vaccine could mean we never see another major Ebola outbreak. In a trial launched in 2015, when the Ebola virus was still spreading in West Africa, 5837 people in Sierra Leone and Guinea received the vaccine. After the first 10 days, there were no Ebola cases in those vaccinated, while 23 people in the control group developed the disease (*The Lancet*, doi.org/bwm9).

Chinese mission trio

China's space agency has revealed plans to soft-land a probe on the far side of the moon in 2018, and to launch its first Mars probe by 2020. It also wants to send a craft to Jupiter by 2030. The missions will reveal new details of the solar system's origins and turn China into a "space power", the agency said.

Cheetahs' decline

Cheetahs could soon be added to the endangered list: there may only be 7100 of them left, confined to only 9 per cent of their former range (*PNAS*, doi.org/bwnc). In Zimbabwe, their numbers have fallen from 1200 to only 170 animals in just 16 years.

North Korea nuke claim

North Korean leader Kim Jong-un has said that the country is close to developing an intercontinental ballistic missile. The claim, made in his New Year address, comes after two North Korean nuclear tests in 2016. US president-elect Donald Trump responded in a tweet that a North Korean weapon capable of reaching the US "won't happen".

Sugary start

Children in England have already had half their recommended maximum daily sugar intake before they get to school. According to dietary data analysed by Public Health England, children consume an average of 11 grams of sugar around breakfast, largely from drinks, cereals and spreads – equivalent to eating three sugar cubes.

BSIP/UIG/GETTY

Testing time

Early fetal gene test

A blood test could let prospective parents safely find out if their fetus has a genetic disorder during early pregnancy, finds **Alice Klein**

A FAST test for genetic disorders means women could learn about the future health of their baby as early as 6 weeks into pregnancy.

The test for single-gene disorders, which are collectively more common than Down's syndrome, could become available within five years. This would enable prospective parents to choose whether to proceed with a pregnancy if conditions like muscular dystrophy or Huntington's disease are detected.

"This is just sensational – I'm completely blown away," says Andrew McLennan, a specialist in prenatal diagnosis at Royal North Shore Hospital in Sydney, Australia.

Many inherited diseases, including sickle cell anaemia, haemophilia and cystic fibrosis, are caused by mutations within a single gene. We know of 10,000 single-gene conditions and together, they affect about one in 100 births.

At the moment, options for prospective parents are limited. Embryos can be screened using pre-implantation genetic diagnosis (PGD), if couples opt for IVF. Those who conceive naturally can have tests like amniocentesis, but these carry a small risk of miscarriage, and detect a limited number of genetic disorders.

"Abortion isn't the only option. Test results could help reduce the effects of a genetic disorder"

But the speed and ease of safer tests is improving. The non-invasive prenatal test (NIPT) for Down's syndrome is available in over 60 countries, including the US and Australia, and it is being trialled in some UK hospitals. Now the team that developed NIPT has found a similar way to detect single-gene diseases.

The test, developed by Rossa Chiu at the Chinese University of Hong Kong, and her colleagues, can detect almost any single-gene disorder in the first 6 to 10 weeks of pregnancy. Guided by DNA from parent blood samples, the test looks for increases in the level of mutations associated with a particular condition in the mother's blood once she is pregnant. In theory, any hospital pathology lab could run the test, producing results in one to two weeks.

In a study of pregnant women at risk of having a child with a single-gene disorder, the test accurately predicted the condition in all 12 fetuses whose DNA they were able to test (Clinical Chemistry, doi.org/bv3h).

In the UK, the Don't Screen Us Out campaign has voiced concerns that NIPT for Down's syndrome could lead to the number of babies born with the condition to decrease by more than 10 per cent. The group says this would have a long-term effect on the Down's community, and will allow an informal kind of eugenics.

Informed choice

Advances in prenatal screening often spark controversy because of concerns that they might promote intolerance of diversity, McLennan says. "But this is not a negative eugenics campaign," he says. "This is about choice. It's about being given the opportunity to have information, to have appropriate counselling, and to make decisions."

"Some of the cystic fibrosis community are very against tests that are post-conception because they say 'my life is pretty good and I wouldn't exist if that test was around when I was born'," says Nettie Burke from Cystic Fibrosis Australia. "But there are mothers who have said to me 'I wish I'd known, because I would have had an abortion'."

But abortion isn't the only option. In some cases, test results could help reduce the effects of a genetic disorder. Congenital adrenal hyperplasia, which can be life-threatening, can be prevented if a mother is given a steroid before 9 weeks of pregnancy. Thalassemia blood disorders can be treated with blood transfusions if given soon after birth. "In the future, some disorders may also be treatable *in utero* using gene therapies," says Chiu.

The test will first be developed for couples with family histories of genetic disorders, but Chiu hopes it will later be incorporated into universal screening programmes. "The potential for this is just phenomenal," says McLennan. ■

Test of modified gravity theory kills dark matter

A CONTROVERSIAL approach to gravity that challenges both Albert Einstein and dark matter has passed its first test.

The vast majority of physicists agree that gravity acts according to rules laid down in Einstein's general theory of relativity. Yet observations of the universe show that the motion of the galaxies can't be explained by the gravitational pull of all the ordinary matter out there – hence the belief in unseen dark matter that exerts its own pull.

Now, a team of astronomers studying the distribution of matter in more than 30,000 galaxies say their observations can be explained by an alternative theory that does away with dark matter. If this "modified gravity" is correct, it would up-end centuries of fundamental physics.

Margot Brouwer at Leiden University in the Netherlands and her colleagues looked at the gravitational lensing of these galaxies – the way they bend the light of more distant galaxies as predicted by Einstein's theory – to measure how much dark matter they contain.

To their surprise, they discovered the observed lensing could just as readily be accounted for by a new model of gravity, without invoking dark matter.

That modified theory of gravity was created by Erik Verlinde at the University of Amsterdam. His calculations fit the galaxy observations without resorting to free parameters – essentially values that can be tweaked at will to make theory and observation match. By contrast, says Brouwer, conventional dark matter models need four free parameters to be adjusted to explain the data (arxiv.org/abs/1612.03034).

Brouwer's team used catalogues of distant galaxies released in 2011 and 2015 to look at regions close to the visible disc of each galaxy, where gravitational lensing should be bending light from distant galaxies beyond.

Using statistical algorithms that consider the shape and colour of the background galaxies, the researchers inferred a lensing profile for the foreground galaxy. It's a bit like projecting an image onto a warped and uneven sheet of glass and then, knowing what the original image looks like, figuring out the optical properties of the glass sheet from what we see on the far side.

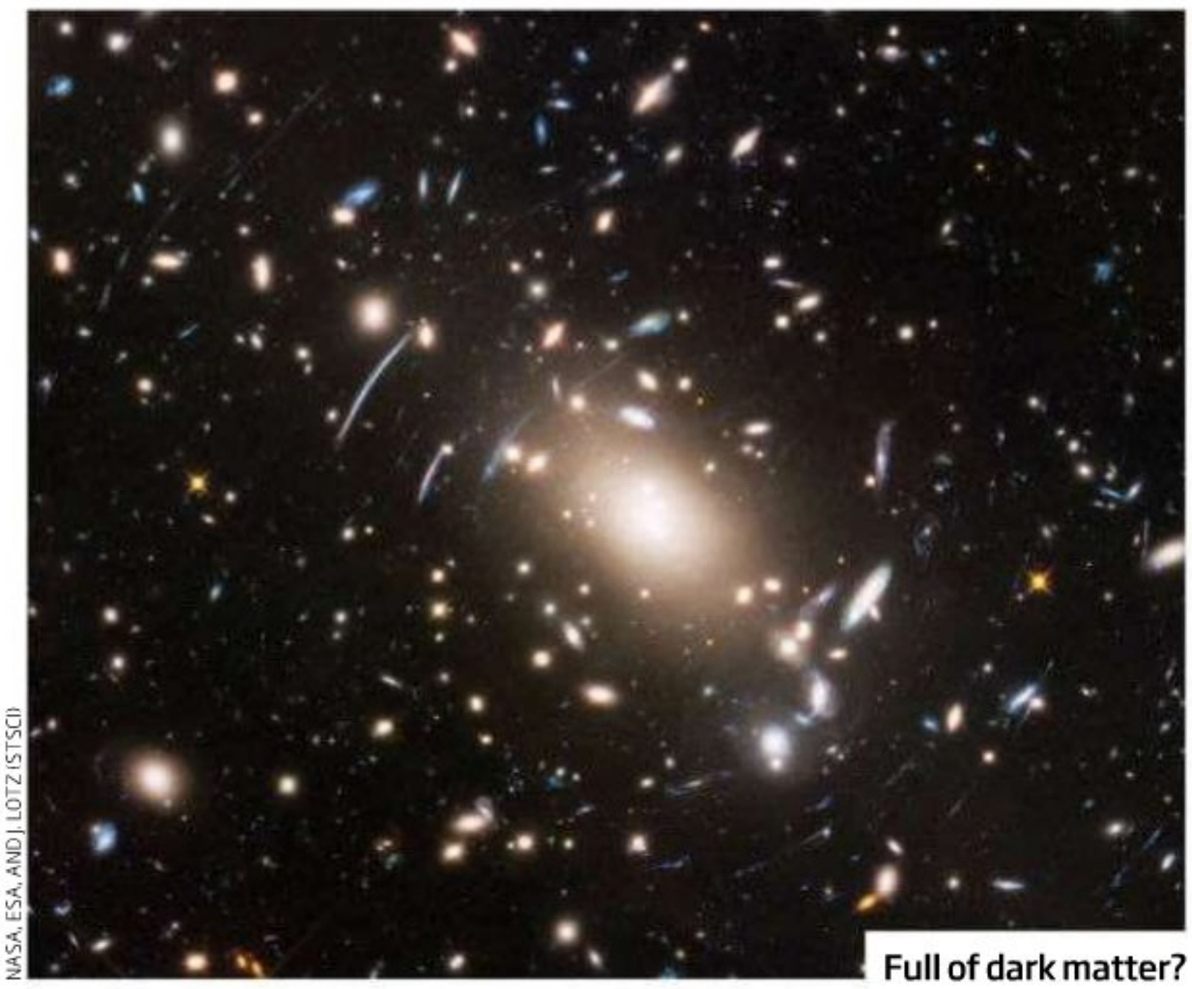
It was from the gravitational distortions inferred for each foreground galaxy that the team devised a lensing profile based on Verlinde's gravitational model, and one based on a conventional dark matter approach.

So if Verlinde's is the better match, what's the problem? Gravitational heresy. Verlinde's gravity is stronger and dies off more slowly with distance compared with the models of Isaac Newton and Einstein.

To most physicists, that's an issue. The current theories of gravity have been so comprehensively validated that it borders on sacrilege to suggest gravity could work differently.

Mordehai Milgrom at the Weizmann Institute in Rehovot, Israel, however, supports the work. Verlinde is building on Milgrom's own theory, Modified Newtonian Dynamics (MOND). Milgrom points out that in his 2013 analysis of gravitational lensing data in galaxies, MOND produces similar results.

"My equations work differently than Milgrom's, and in the case of [galaxy] clusters this can be quite important," says Verlinde. But in the case of Brouwer's work, "They put in the formula I get, and I have to admit it's the same formula that Milgrom would have got, and... they just put it on the data. It looks like a fit." **Mark Anderson** ■



NASA, ESA, AND J. LOTZ (STSCI)

Full of dark matter?

Our brains can't generalise when tired

IT PAYS to have false memories. Our brains use them to generalise new information – but lack of sleep gets in the way.

False memory was discovered in an experiment that asked volunteers to memorise lists of related words and then recall them. When they learned "bed", "drowsy" and "dream", about half later also remembered the word "sleep". That's because well-rested brains normally use "associative memory" to link related concepts together. "There's a lot of evidence that the brain cares less about individual data and more about the gist of it or what it means," says Alex Chatburn at the University of South Australia in Adelaide.

Chatburn and his team have found that sleep deprivation inhibits this. They asked 44 people to memorise lists of words when they were well rested, had slept for only four hours on each of the previous four nights, or hadn't slept at all for the past 30 hours.

Unsurprisingly, when they were immediately asked to recall these words, the volunteers did less well when partially or completely sleep-deprived. But when shown a new list and asked which ones had been on the original list, sleep-deprived people were less likely to misremember (*Neurobiology of Learning and Memory*, doi.org/bvz9).

"Staying up late for several days before an exam is like going into exams without sleep"

"When a tired person came to a word that had the same gist but wasn't entirely familiar, they were inclined to say they didn't remember it," says Chatburn. "This shows that not only were they less able to learn individual items, they were also less able to extract their meaning."

We tend to underestimate the impact of a few late nights, says Andrew Vakulin at Flinders University in Adelaide. "Staying up late studying for several days prior to an exam might seem like an effective strategy, but in the end it is like going into exams without sleep." Alice Klein ■

River of iron flows near Earth's core

Andy Coghlan

DEEP below our planet's surface, a molten jet of iron, nearly as hot as the surface of the sun, is picking up speed.

This stream of liquid some 420 kilometres wide has been discovered by telltale magnetic field readings 3000 kilometres below North America and Russia. It has trebled in speed since 2000, and is now circulating westwards at between 40 and 45 kilometres per year, heading from deep under Siberia towards the underside of Europe (see diagram, below). That is three times as fast as the typical speeds of liquid in the outer core.

No one knows yet why the jet has got faster, but the team that made the discovery thinks it is a natural phenomenon, and can help us understand the formation of Earth's magnetic fields, which keep us safe from solar winds.

"It's a remarkable discovery," says Phil Livermore at the University of Leeds, UK, who led the team. "We've known that the liquid core is moving around, but our observations haven't been sufficient until now to see this jet."

"We know more about the sun than the Earth's core," says team member Chris Finlay from the Technical University of Denmark in Kongens Lyngby. "The discovery of this jet is an exciting step in learning more about our planet's inner workings."

What made the discovery possible was the combined monitoring power of the European Space Agency's trio of satellites, called Swarm, which were launched in 2013. From orbit, they can measure magnetic field variations down to 3000 kilometres below Earth's surface, where the molten core meets the solid mantle.

"Having all three meant we could strip away magnetic fields from elsewhere such as the ionosphere and the crust, providing our sharpest ever image of the fluctuations at the core-mantle boundary alone," says Livermore. The team plugged the data into models to see how the fluctuations change over time (*Nature Geoscience*, doi.org/bv8r).

Earth's magnetic field is generated by the movement of molten iron in the outer core, so examining the magnetic field can in turn reveal details of the core.

Livermore and his colleagues say the jet is created by the movement of molten iron around the inner, solid iron core. There are parallel cylinders of swirling molten iron in the outer core running from north to south. Where these cylinders meet the solid core, and squash against it, they act like a pair of rollers, squeezing out additional molten iron sideways. This produces and moves the two lobe-like magnetic fields, which is what the satellites detected and tracked.

Why the jet is getting faster is more of a mystery. It may be related to the rotation of the inner core, says Xiaodong Song at the University of Illinois in Champaign, who co-discovered in 2005, using seismological data, that Earth's core rotates faster than its crust. "If these seismological and geomagnetic observations can be tied together to a common process in the fluid core, it would be really exciting," he says.

Studying the jet should enable geophysicists to better understand how the planet's core behaves and influences Earth's magnetic field strength. "The more we understand the core's behaviour at various time and spatial scales, the more we can hope to understand the beginnings, renewal and future of our magnetic field," says William Brown of the British Geological Survey.

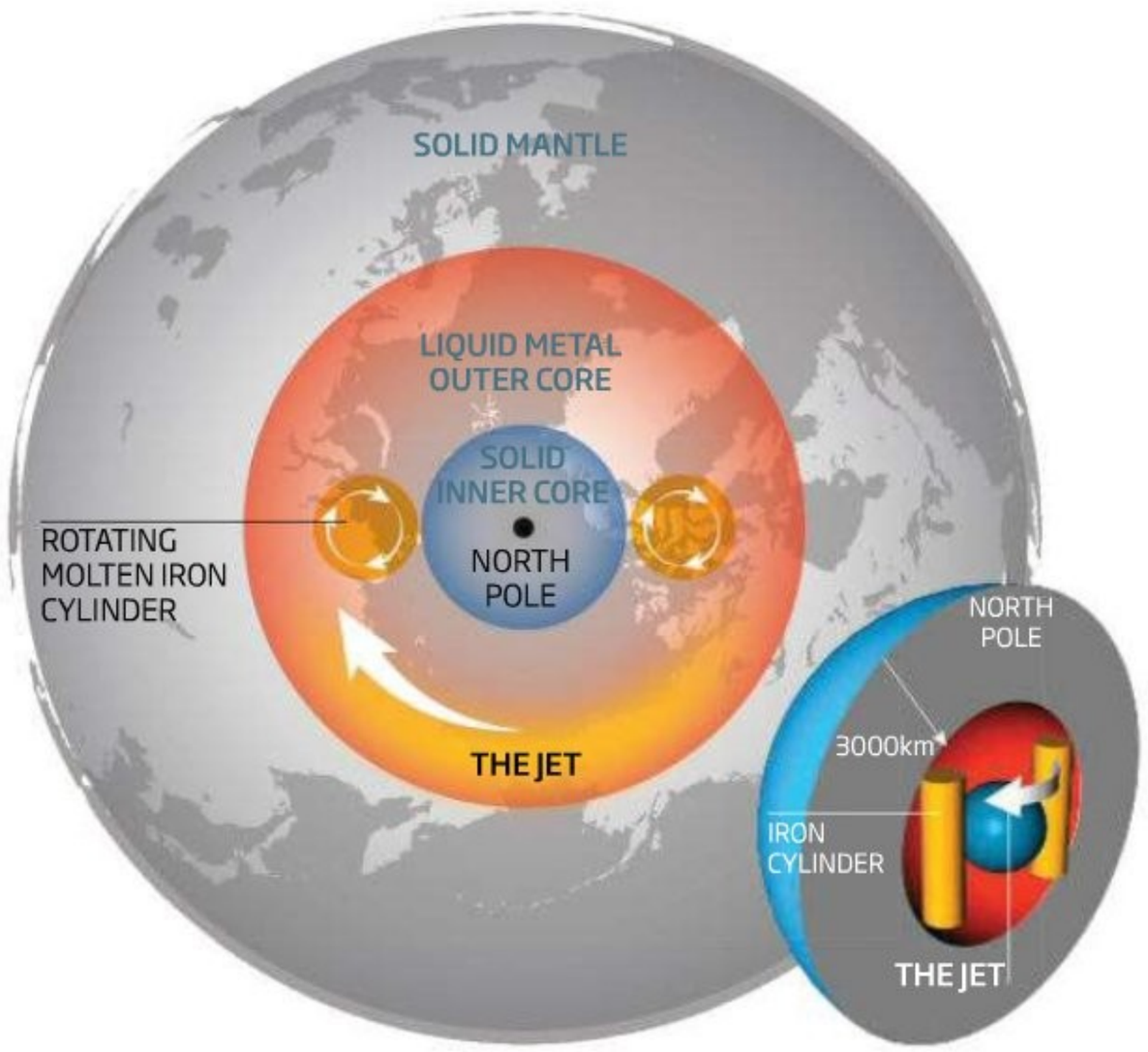
Earth's magnetic field seems to have been weakening, especially since around 1840, at about 5 per cent per century. The molten iron stream should help us predict if and when the magnetic field of the planet's core will flip. And thanks to the satellite monitoring system, says Xiaodong, we have opened a new window to view in real time the activity of molten iron deep in Earth's core. ■

MICK ROESSLER/GETTY

Pretty hot stuff

Mystery molten jet

A massive jet stream of molten iron seems to be circling the northern hemisphere in a westerly direction inside Earth's liquid outer core



Computer spots signs of autism and ADHD

AN ALGORITHM that analyses facial expressions and head movements could help doctors diagnose autism-like conditions and attention deficit hyperactivity disorder.

There is no simple test for autism or ADHD, but clinicians usually observe someone's behaviour as part of the assessment. "These are frequently co-occurring conditions and the visual behaviours that come with them are similar," says Michel Valstar at the University of Nottingham, UK.

His team used machine learning to identify some of these behaviours. The group captured video of 55 adults as they read and listened to stories and answered questions about them. "People with autism do not always get the social and emotional subtleties," says Valstar.

The participants fell into four groups: people diagnosed with autism-like conditions, ADHD, both or neither.

The system learned to spot differences between how the groups responded. For example, people with both conditions were less likely to raise their eyebrows when they saw surprising information.

The team also tracked head movement to gauge how much the volunteers' attention wandered. Using both measures, the system correctly identified people with ADHD or autism-like conditions 96 per cent of the time (arxiv.org/abs/1612.02374).

Eric Taylor at King's College London welcomes the potential of this as a diagnostic tool for these conditions. But he says the best approach is still observing children in everyday surroundings.

Algorithms won't take over from doctors any time soon, says Valstar. "We are creating diagnostic tools that will speed up the diagnosis in an existing practice, but we do not believe we can remove humans. Humans add ethics and moral values to the process." Matthew Reynolds ■

DEREJE BELACHEW / ALAMY STOCK PHOTO

Got the maths, not the meaning

Physicists cannot agree about quantum world

IF YOU find the quantum world confusing you're not alone. A recent survey shows that physicists disagree over the picture of reality that quantum mechanics describes – and that many of them don't even care.

There was no consensus among the 149 survey participants. While 39 per cent supported the so-called Copenhagen interpretation, the conventional picture of quantum mechanics, 25 per cent supported alternatives and 36 per cent had no preference at all. In addition, many weren't sure they understood what certain interpretations described.

"I don't think the debate will resolve soon," says Sujeevan Sivasundaram, a recent graduate of Aarhus University in Denmark who conducted the survey. "I could see us still discussing this 100 years from now."

The conventional interpretation, which is often the first and only one a physicist is taught, may have been the most popular in the survey, but that doesn't indicate it's right, says Charles Sebens at the University of California, San Diego. "It's what physicists go on believing because it's the first way they're introduced to the theory," he says. "But it's a disservice to only learn one interpretation."

This interpretation uses the Schrödinger equation to accurately predict the results of quantum experiments. But it includes a problem: if you measure or observe a particle, you abruptly change its trajectory in defiance of this equation.

Critics point out that nothing else we know of makes such a weird instant switch, and it seems to be inconsistent with other established laws of nature. In addition, making "measurements" is poorly defined, says Aephraim Steinberg at the University of Toronto, Canada. "If a fly looks at it, if a bacteria interacts with it, if a dog looks at it – what constitutes a measurement?" he says.

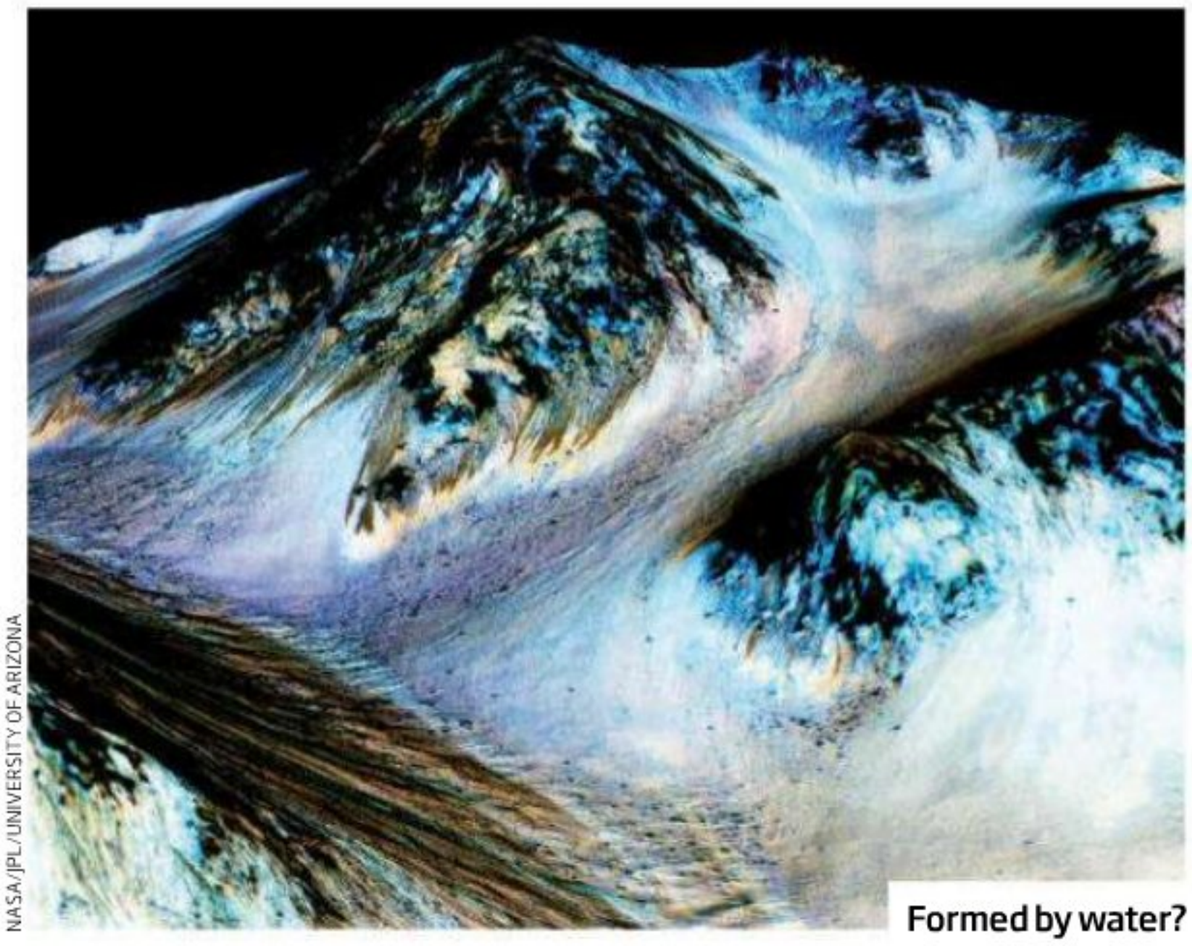
"In a survey, 32 per cent of respondents didn't understand enough to have an opinion"

Alternatives approach things differently. For example, the many interacting worlds interpretation, published by Howard Wiseman at Australia's Griffith University and colleagues in 2014, says quantum phenomena arise from multiple universes interacting with each other under consistent physical laws. "It's very strange, I admit," says Wiseman. But to him, parallel universes that consistently obey a set of laws are far less strange than a single universe with exceptions to the rules, as with Copenhagen.

Despite some enthusiasm for alternatives, 32 per cent of respondents didn't understand the interpretations enough to have an opinion, and 23 per cent thought interpretations were irrelevant. "One physicist wrote in the comments that he found the survey a complete and utter waste of time," says Sivasundaram. Furthermore, some thought that certain interpretations couldn't be experimentally verified, and thus belonged more in philosophy than physics.

The number of diverging ideas suggests that maybe all of them are off the mark, says Sabine Hossenfelder of Germany's Frankfurt Institute for Advanced Studies. "There doesn't seem to be two people who can come to any agreement on anything," she says. "It seems to me that they're just discussing the wrong things or in the wrong way." **Sophia Chen** ■

Where did all the Martian water go?



NASA/JPL/UNIVERSITY OF ARIZONA

Formed by water?

Lisa Grossman

MARS has a real water shortage. It seems we have either misunderstood what its early years were like – or vast amounts of water are hiding beneath its surface.

A lot of evidence points towards Mars being warm and wet early in its history; features that look like rivers, lakes and outflows have been spotted both from orbit and by rovers on the surface, and a lot of the planet's minerals contain water.

So where did all this water go? The Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft was sent to find the answer. Since its arrival at Mars in 2014, it has been measuring how much atmosphere Mars is losing to space. From that, we can figure out how much it had in the past.

The orbiter keeps track of both the activity of the sun and the ions streaming away from the planet's atmosphere to build up an inventory of everything that enters and leaves over time. It also estimates the total loss by measuring the fraction of heavier isotopes of certain atoms versus their lighter counterparts. As the lighter versions are easier to knock out into space with a stray cosmic ray or extra energy from solar photons, a higher fraction of heavy isotopes remaining in Mars's present-day atmosphere means much of the original atmosphere has been lost.

MAVEN focuses on hydrogen and oxygen as ways to trace water and carbon dioxide, and neutral argon as a way to measure the sheer volume of atmosphere loss. Based on measurements of these taken over a full Martian year, the team concludes that about 4 billion years ago, the Red Planet's atmospheric pressure – currently less than 1 per cent of Earth's – was up to 1.5 times what Earth's is today. They also found that it could have had the equivalent of a global ocean between 2 and 40 metres deep in its distant past.

"It's a consistent story," said team leader Bruce Jakosky at the Laboratory for Atmospheric and Space Physics in Boulder, Colorado, who presented the findings at the American Geophysical Union meeting in San Francisco in December. "Loss of gas to space is likely a major if not the major process for changing the Mars climate through time."

The trouble is, that's less water than expected. In 2015, James Head at Brown University and Michael Carr at the US Geological Survey estimated that the equivalent of a global ocean a few hundred metres deep was needed to explain all the geological features that look like they were formed by water.

"We were counting on their loss rate to explain it," Head says. "And they didn't come through."

One possible reason for the discrepancy is that the long-held

"Loss of gas to space is likely a major process for changing the Mars climate through time"

notion of Mars being like Earth in the past is wrong. One theory has it that the planet was actually cold and dry, and that streams and rivers formed underneath the ice pack instead of via water flowing on the surface. All that would be needed is a slightly denser CO_2 atmosphere – which MAVEN's measurements suggest you had.

The other option is that the water is hidden away somewhere, maybe underground. Dark streaks recently spotted on crater rims that look like they could be liquid water may be fed by underground aquifers, for instance.

"Either it's hidden somewhere, or there wasn't that much to start with," says Carr. ■

Orcas seen hunting rare beaked whales

ORCAS off the coast of Australia have been seen killing and eating rare beaked whales – a behaviour never observed before.

Since 2014, a small team including Rebecca Wellard at Curtin University in Perth have joined commercial whale-watching trips to study orcas, or killer whales, off Australia's south coast. On four occasions, they photographed groups of up to 20 orcas attacking lone beaked whales. Those whales were similar in size to the orcas hunting them.

The hunts lasted an hour or two. The orcas chased the whales and eventually killed them by biting them and forcing them underwater to drown them. On two occasions they were seen stripping carcasses of skin, suggesting these are predatory attacks (*PLoS One*, doi.org/bvzt).

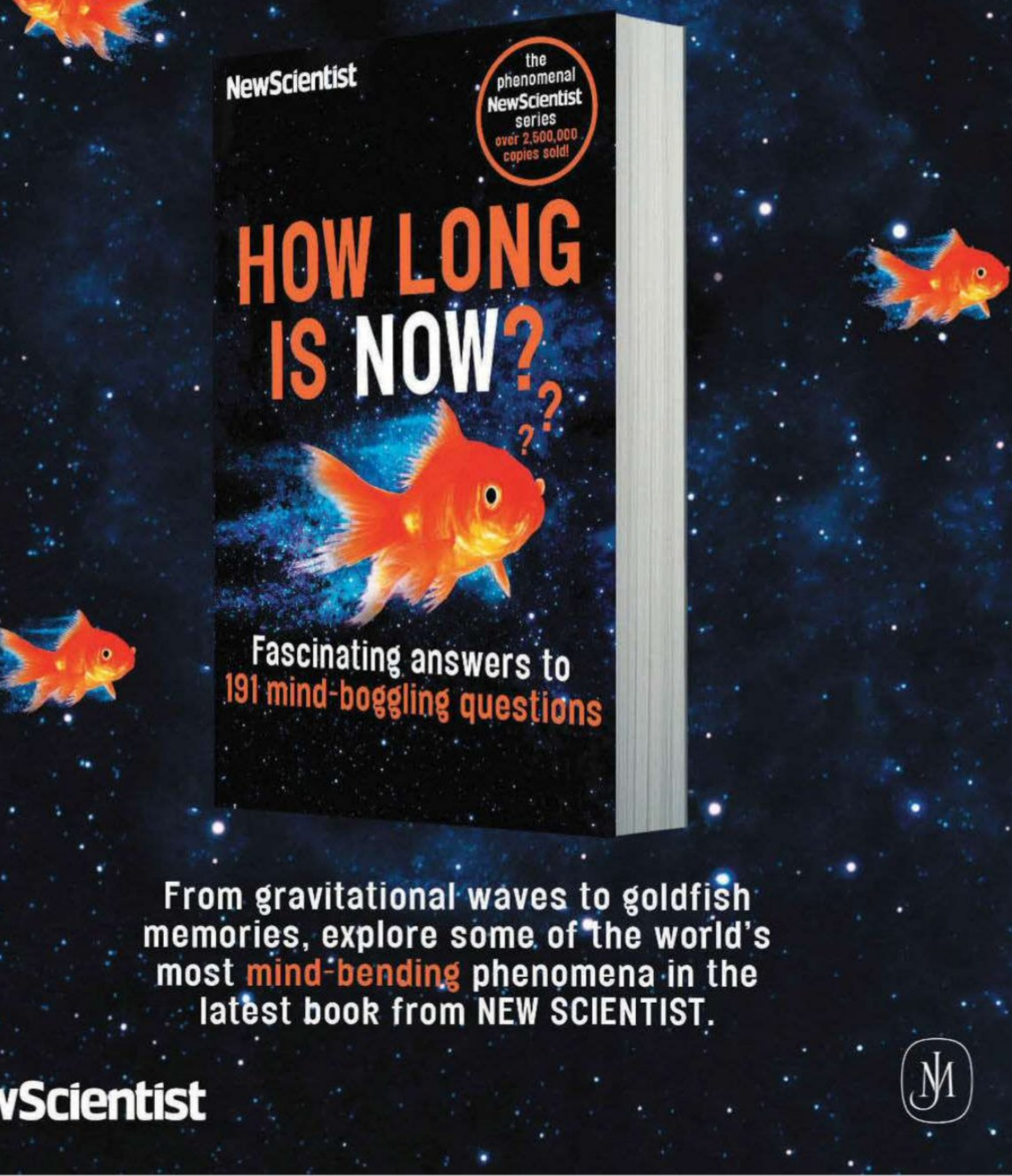
Little is known about the orcas that live around Australia. But it is known that populations elsewhere in the world have their own distinct cultures and specialise in particular prey. Some feed on fish such as herring, while others hunt mammals such as seals, dolphins and the calves of large whales. The 2001 BBC documentary *The Blue Planet* famously featured footage of orcas pursuing and killing a grey whale calf despite the mother's efforts to protect it.

REBECCA WELLARD

Killer whales are whale killers

Little is known about beaked whales. They are rare, hard to spot on the surface and feed in deep waters. The species preyed on in Australia is thought to be young or female strap-toothed whales (*Mesoplodon layardii*). Michael Le Page ■

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

TIMOTHY REVELL

AI is ahead of the game

Robot game arena puts AIs to the test

Timothy Revell

THE race is on. Two miniature cars are zooming around a loop of track in a new robotics arena. I'm driving one via remote control. The other is controlled by artificial intelligence – and it's kicking my ass.

From August 2017, the University of Essex's robotic games laboratory will pit AI systems against each other in robot challenges, starting with these remote-controlled cars. The AI I'm racing has been honed to complete the track in super-quick time, but the real competitions won't be so straightforward. The rules will change between heats: in one, the cars' brakes might be disabled, in another, obstacles could be added to the track. The AI developers won't know in advance what challenges they will face. Instead, their systems will have to figure out for themselves how to win each time.

"The challenges will be wide and varied, so the entries will have to be able to adapt to whatever tasks we present to them," says Simon Lucas, the head of the lab.

For the past three years, Lucas's department has hosted the General Video Games AI Competition, which is sponsored by Google's DeepMind. This pits research teams against each other to develop intelligent systems that can take on a variety of different video games, from puzzles to platformers

"Now they are not just playing with pixels; they are controlling physical robots"

like *Super Mario Bros*. This new lab takes the concept out of simulated environments and into the real world.

Now the AIs aren't just playing with pixels; they are controlling physical robots. The arena has 26 infrared cameras that track movements at a rate of 250 times a second, allowing the competing systems to know the precise location of the robot they are controlling at any given time.

The systems that do well will need skills that are in high demand in everything from video games to autonomous cars.

The idea is to use robot games to develop AI systems with more general capabilities. Plenty of AIs excel at very specific tasks, like beating a human at chess or recognising a car in an image, but they fall to pieces if asked to do something outside of their training. An ability to adapt is especially important for systems with applications in real-world environments, where situations are often unpredictable.

"Games are great at challenging our brains and forcing us to learn certain skills," says Julian Togelius at New York University. "The same goes for AI. With the right games it can slowly figure out how to do more complex tasks."

Toy cars are just the beginning. The arena can also handle other types of robot. In the future, Lucas plans to have an aerial event in which AIs will control drones.

The stakes are high. "The AIs in the robotics competition will have to learn very quickly," says Lucas. "If you make a fatal mistake in a video game you can just hit reset. That's not true in the real world." ■

Synaesthesia shifts then goes back as before

ONE woman's unique experiences are helping us understand the nature of synaesthesia.

We don't know yet what causes synaesthesia, which links senses and can enable people to taste words or smell sounds, for example. There's some evidence that it can change or disappear, and a detailed assessment of one woman's experiences is helping Kevin Mitchell at Trinity College Dublin in Ireland and his team investigate.

The woman, referred to as "AB", sees colours when she hears music, linked to pitch, volume or instrument – higher notes have more pastel shades. She also associates colours with people, largely based on personality. Green is linked to loyalty, for instance.

But several experiences in her life have caused her synaesthesia to change. "To say she had a series of unfortunate events would be an understatement," says Mitchell. As a teenager and young adult, AB sustained several concussions, had migraines, contracted viral meningitis and was struck by lightning.

For a month after meningitis, the colours she associated with musical notes changed. One concussion moved her colours from the centre of her vision to the periphery. Migraine medication and the lightning strike both stopped her synaesthesia.

But it quickly returned to its standard state. When the team compared a synaesthesia test she took before meningitis with a test done after these experiences, they found that her synaesthesia was nearly exactly the same (*bioRxiv*, doi.org/bv3j). This suggests it is hard-wired into some people's brains, says Mitchell. "Whatever is causing synaesthesia, it's long-lived and stable," he says.

"It's a configuration of the brain," says Veronica Gross at Rosalind Franklin University of Medicine and Science in Chicago. "There's almost no way to get rid of it – it's just something the brain does." Jessica Hamzelou ■

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

Insects give flying lessons to drones

ANDREW MOUNTCASTLE

This is how you do it

Nicole Kobie

DRONES could learn a thing or two from the birds and the bees.

If an aerial robot loses a part mid-flight, you would expect it to crash. But it could stay airborne by mimicking fruit flies, which can keep flying even after a catastrophic loss of limb.

To uncover the insects' secret, biologists placed flies with a clipped wing into a wind tunnel and analysed their movements using high-speed cameras. They used this data to run simulations of the flies' wing motion.

They then programmed a robotic fly to mimic the insects with different levels of wing damage, which allowed them to explore movements beyond the range of a real fly's normal behaviour. "We cannot ask the fly, 'can you flap your wings a little bit faster or in a different way'," says Florian Muijres at Wageningen University in the Netherlands. "But we can ask that to the robot."

With a wingspan of 50 centimetres, the robotic fly is larger than a fruit fly, which means the team also had to scale up its movements – and the "air" it moves in. To keep the same ratio between the size of the wing and the viscosity of the medium around it, they replaced the air with mineral oil. "It sounds a bit weird," says Muijres, but, "as a result, the aerodynamics around the wing are the same."

This means the robot can't actually fly – to do so, it would need air as viscous as mineral oil. However, the lessons gleaned from its oily swims could help other robots with flapping wings overcome damage. Muijres and his team produced an algorithm based on their experiments to help drone developers keep their creations going after an accident (*Interface Focus*, DOI: 10.1098/rsfs.2016.0103).

It's not only fruit flies that have lessons for drones: finding out how bumblebees fly through turbulent skies could improve their stability. "One reason we were interested in bumblebees is they're the tankers of the flying insect world," says James Crall at Harvard University. "They're pretty incredible flyers in the natural environment."

By enticing trained bees into a wind tunnel with fake flowers, Crall and his colleagues found that they compensate for higher winds by beating their wings more quickly and at different angles (*Interface Focus*, DOI: 10.1098/rsfs.2016.0086).

"Understanding how insects solve this problem will be very useful for drone design," says Crall.

Meanwhile, other researchers have examined how stick insects right themselves in the air after a fall, how owls fly silently and how pigeons navigate turbulence to pick up some aerodynamic tricks for flying robots.

Nature can provide clues to improve robotic flight systems, says Stephen Prior at the University of Southampton. But he points out that most commercial drones have fixed or rotary wings rather than fluttering insect-like wings. ■

Antihydrogen sets a shining example

HYDROGEN'S antimatter counterpart has shown its true colours, and they are just what physicists ordered.

Antihydrogen atoms are made of a positron (a positively charged version of the electron) orbiting a negatively charged antiproton. According to the standard model of particle physics, these anti-atoms should absorb and emit light at the same wavelengths as hydrogen. Now antihydrogen's spectrum has been measured at last, and it confirms the prediction.

Antimatter is notoriously difficult to work with, because the moment it touches normal matter both annihilate in an explosion of smaller particles and radiation. To scrutinise antimatter, physicists have to keep it as cold as possible and trap it using powerful magnetic fields.

Jeffrey Hangst and his colleagues in the ALPHA collaboration, based at CERN near Geneva, Switzerland, managed to trap 14 antihydrogen atoms at once – a dramatic improvement over the one or two atoms of previous experiments. To peek at the spectrum, they shone an intense laser on to the antihydrogen atoms, so that the beam's energy could be absorbed and re-emitted.

The team found that the lowest-energy photons in the antihydrogen spectrum had the same wavelength as for hydrogen (*Nature*, DOI: 10.1038/nature21040.)

"Even the smallest discrepancy in the atoms' spectrum would violate the standard model"

Because no one has persuaded an atom of antimatter to interact with a laser before, the measurement is still vastly less precise than our best observations for hydrogen. Improving the accuracy might flag up any possible discrepancies in energy levels between the two, which would undermine the standard model of physics. Hangst also wants to check how antimatter responds to gravity (see page 28).

"This is really a milestone that they have achieved," says Michael Doser of CERN's AEgIS collaboration, one of ALPHA's competitors in the race to probe antimatter. Leah Crane ■

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

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**

* BAGGAGE COSTS ARE NOT INCLUDED ON INTERNAL FLIGHTS

INTREPID real life experiences...

CHIP SOMODEVILLA/GETTY

NATUREPL.COM/WILD WONDERS OF EUROPE/ZANKL

Baby turtle eggs leave brief oases on beach dune deserts

BABY turtles that fail to make it to the sea help fuel life on otherwise deserted sandy beaches in the tropics.

The remains of turtle eggs that have been attacked by predators lead to a short pulse of life in what are normally deserts, boosting the abundance of small invertebrates fourfold, a study has found. These bursts peak at seven days after the eggs become available and are all but gone in just 20 days. "This discovery affirms the role of sandy beaches as unique ecosystems," says Ronel Nel at the Nelson Mandela Metropolitan University in South Africa, whose team studied the Maputaland beaches in the iSimangaliso Wetland Park, in Kwa-Zulu-Natal. "They are not deserts, as many seem to think."

Traditionally, we think of beaches being important to the fate of turtles, but the findings now highlight the importance of turtles to beaches where the ecosystem capitalises on this nutrient pulse, she says. Her team sampled sand in naturally predated nests and set up experiments to track changes in microscopic life, known as meiofauna, as compared with control sites nearby that didn't have eggs.

The boost in meiofauna was especially pronounced in the abundance of nematode worms. Their densities increased from a single worm to 10,000 worms per cubic centimetre in just 10 days (*Journal of Experimental Marine Biology and Ecology*, doi.org/bvwq).

Ants use tools to transport honey

ANTS may be smarter than we give them credit for. We think of tool use as something brainy primates and birds do, but even the humble ant can pick up the right tool for the job.

István Maák at the University of Szeged in Hungary and his team documented two species of funnel ants using tools to transfer liquid into their nests – and selecting the most appropriate one.

The ants were offered liquids containing water and honey along with a range of potential tools. They experimented with the tools and chose those with better ease of handling and soaking capacity, such as bits of sponge or paper, despite them not being found in the insects' natural environment.

This suggests ants can take into account the properties of both the tool and the liquid they are transporting. It also indicates they can learn to use new tools (*Animal Behaviour*, doi.org/bvw6).

Motherhood wires brain for empathy

NEW mums experience many changes – including dramatic ones in the brain.

Elseline Hoekzema at Leiden University in the Netherlands and her team compared brain scans of 25 first-time mothers with those of childless women.

After having a baby, the mums showed shrinking in the frontal and temporal cortex – areas vital for understanding other people's mental states and emotions (*Nature Neuroscience*, DOI: 10.1038/nn.4458). This was probably because of fine-tuning of neural connections there.

"The changes could confer an advantage for the mother by strengthening her ability to read the needs of her relatively helpless infant," says Hoekzema.

Secure connection is a walk in the park

WEARABLE gadgets such as smartwatches or fitness trackers could use the characteristic way you move to securely pair with other devices on your person.

"The authentication key is in your gait," says Stephan Sigg at Aalto University in Finland. His team analysed people's gaits with accelerometers. Using a technique called fuzzy cryptography, they created gait "fingerprints". Sensors on different parts of the same body recorded fingerprints that were 82 per cent similar, whereas fingerprints from different bodies were only 50 per cent similar (arxiv.org/abs/1612.03472).

The fingerprints could be used to pair wearable devices. If two devices pick up a gait fingerprint that is similar enough, they know they are being worn by the same individual and can automatically connect to each other without the user needing to enter a password or even unlock their smartphone.

A perk of the method is that it happens in the background, says René Mayrhofer at Johannes Kepler University in Linz, Austria. But it is not as secure as fingerprint or iris scanning. "Gait authentication is more comparable to face or voice recognition," he says.

Invasive parakeet displaces hoopoes

THERE just aren't enough palm tree homes to go round. Invasive ring-necked parakeets have prompted a rapid decline in Israel's native hoopoe population, probably because of their aggressive takeover of nesting cavities in palm trees.

Reuven Yosef at Ben Gurion University, Israel, and colleagues followed densities of hoopoes in four palmeries in rural areas over a period of 10 years. In the two that were invaded by parakeets in 2000 and 2006, the team found a significant decline in hoopoe population density. By contrast, in the two palmeries without parakeets the hoopoe density remained unchanged (*Annales Zoologici Fennici*, vol 53, p 281).

These invasive parakeets usually nest in existing tree cavities. But in Israel they were observed digging new cavities, which suggests there is a lack of nesting sites. Parakeets start breeding earlier in the season than hoopoes do, and may use up all nesting sites before hoopoes can get to them, the team says.

Originally from Africa and South Asia, parakeets have spread globally, probably after individuals kept as pets escaped or were released into the wild. But hoopoes in Europe may be safe for now: parakeets only tend to live in cities there, so there isn't the same competition for nesting holes.

CULTURA CREATIVE (RF) / ALAMY STOCK PHOTO

Tiny wires monitor brain without damaging it

ELECTRODES so thin they are barely there could make brain treatments safer.

Wires are sometimes implanted in the brain to treat epilepsy and Parkinson's disease by stimulating malfunctioning nerve cells. They can also be used to record electrical signals inside the brain – a useful tool for neuroscience.

But these electrodes are wide – around 1.5 millimetres in diameter – and kill brain cells and sometimes hit blood vessels when they are inserted. Because they are stiff, they cause inflammation in the brain and gradually become covered with immune cells that reduce their efficiency.

A better alternative would be thinner, softer electrodes such as carbon nanotubes, a thousandth of the diameter of regular wires. But how do you stick something soft into the brain? "It's like trying to stick a wet noodle into a bowl of Jello," says Jacob Robinson of Rice University in Houston, Texas.

Now Robinson's team has found a way to temporarily make a nanotube behave more like a stiff knitting needle than a noodle. They have built a device with a tiny channel of flowing water to stiffen the wire. As the nanotube is pushed into the brain, the surrounding tissue stops it from crumpling.

The device was used to insert electrodes that record brain activity in mice, seemingly without causing any damage, the team told an IEEE workshop in San Diego in November. The nanotubes should enable researchers to study brain activity over much longer periods.

Selfish black holes kill host galaxies

GREEDY black holes may suffocate their host galaxies by hogging the gas needed to make stars.

There are two main types of galaxies: "blue", star-forming galaxies and "red and dead" galaxies that no longer form new stars. Blue galaxies seem to evolve into red ones, but nobody is sure how or why. Simulations now suggest black holes at the centres of galaxies may be the cause.

The biggest galaxies are also the most stagnant. Once galaxies reach a mass threshold of about 30 billion times the mass of the sun, they almost completely stop making new stars. To find out why, Richard Bower at Durham University, UK, simulated the balance of gas entering and leaving the galaxy.

His team found that once a galaxy gets massive enough, its central black hole ramps up the rate at which it devours the gas around it. This releases a blast of heat, pushing away the cool gas needed to build stars and preventing new material from flowing in (*MNRAS*, doi.org/bvv6).

"All the gas inside the galaxy flows out into the universe, and there's nothing left to form stars anymore," says Bower.

BURKART/PLAINPICTURE

Night vision shades are a step closer

EVER wish you could don a simple pair of specs to see in the dark? Nanocrystals that turn heat into visible light could make your wildest spy dreams come true.

Made from aluminium gallium arsenide, the nanocrystals are 500 times narrower than a human hair and can be applied to ordinary glass as ultra-thin, lightweight films. Each crystal acts like an antenna that concentrates incoming infrared radiation (*Nano Letters*, doi.org/bssr).

Dragomir Neshev at the Australian National University in Canberra and his colleagues have shown that the nanocrystals can emit the absorbed infrared energy within the visible spectrum – a property called second harmonic generation. But this only works with high-intensity radiation from a laser. Converting the heat emitted by warm bodies would be trickier because it is so much weaker.

Aside from the obvious military applications, the team envisages more frivolous uses. "There's the possibility of playing night golf," Neshev suggests. The aim is to build a successful prototype within five years.

HERO IMAGES/GETTY

Time to stop getting old

The race is on to develop anti-ageing treatments. Will they work and can you afford them, asks **Jessica Hamzelou**

FEEL that? It's your body, slowly degrading. Ageing affects us all, and it leads to diseases that eventually kill most of us. No wonder so much research is going into creating an antidote.

If we come up with a way to slow, halt or even reverse the ageing process, we could potentially protect people from cancer, heart disease and Alzheimer's. The idea is to extend "health span", the number of years of good health a person enjoys. Extra birthdays are simply a bonus.

Where philosophers once pursued outlandish schemes for eternal youth, researchers now believe there are plenty of worthwhile options to investigate. But do any hold water, and will they be for all, or only the rich?

Take the young blood plasma theory, for example. The idea is that there's something in the blood of people aged under 25 that keeps them youthful, although we don't yet know what it is.

Old mice injected with plasma from young mice, or even from human teenagers, appear rejuvenated – they are healthier, more active and show fewer signs of ageing. There's also anecdotal evidence that people who get blood transfusions from under-25s feel better than those who receive blood from older donors.

Teams around the world have started trials of blood plasma transfusions to treat age-related diseases, but Jesse Karmazin is taking a different approach. His company, Ambrosia, based in Monterey, California, is offering them to anyone – providing they can afford the $8000 price tag.

Karmazin hopes to treat 600 people and record their health before and after a transfusion. So far, Ambrosia has signed up 40 people and treated 20 of them. "They're all over 35, and are in relatively good health," he says, although some have chronic fatigue syndrome or Alzheimer's. Most are in their 60s and 70s and have a variety of reasons for wanting to stay young. Not all are rich – some see the experiment as a worthwhile investment.

The people who have been treated are already reporting benefits in cognition, muscle strength and energy levels, says Karmazin. But this clearly isn't a rigorous clinical trial with placebos, so as of yet, we can't be confident of any benefits.

"Old mice that get blood plasma from young mice or from human teenagers appear rejuvenated"

Karmazin says it's ethical to offer the treatment and that it is cheap and safe, meaning it could quickly enter mainstream medicine. He buys the plasma from blood banks, where he says it is often a by-product of blood prepared for transfusion.

Others are yet to be convinced, and think other treatments show more promise. They are aiming to

ALDO SPERBER/PICTURETANK

Grey days can be averted

enhance DNA protectors known as telomeres, an idea backed by decades of work in mice and other animals.

Telomeres are the "caps" on the ends of chromosomes, and plenty of evidence links their length with ageing. The caps shrink every time a cell divides, until they are too short to protect chromosomes from damage. Next comes either a straightforward cell death, or a slow process called senescence that leads to inflammation and surrounding cells being damaged.

Both animals and people who start life with short telomeres tend to develop age-related diseases earlier in life, and to have shorter lifespans.

Genetic gamble

Maria Blasco at the Spanish National Cancer Research Centre in Madrid has spent much of her career studying telomeres. A few years ago, Blasco and her colleagues found a way to extend the telomeres of mice using gene therapy. The animals lived 40 per cent longer as a result.

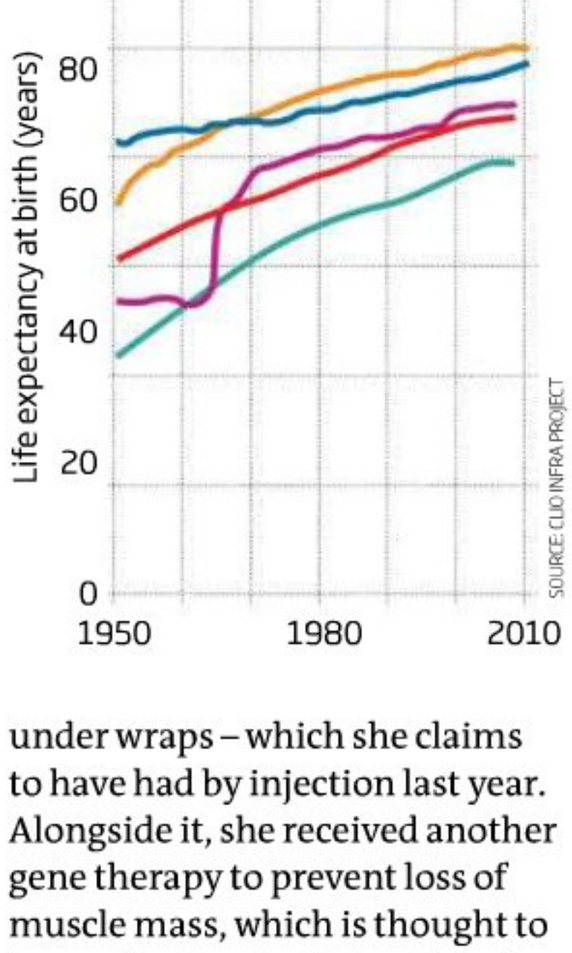
This therapy is not yet ready to roll out, as we don't know if it will work in humans. There are safety issues, too. Some researchers worry that maintaining telomeres could help damaged cells survive, leading to cancer, although Blasco found that her mice seemed to be protected from this.

But that hasn't stopped Liz Parrish from trying the treatment on herself. Parrish, who is not a scientist, launched her company, BioViva, based near Seattle, to explore and test new treatments that target the processes underlying ageing. "We can't really create preventative medicine if we don't address biological ageing," she says.

After surveying existing work, Parrish felt that the telomere extension findings were the most convincing. She says she worked with scientists to develop a modified version of Blasco's gene therapy – the details remain under wraps – which she claims to have had by injection last year. Alongside it, she received another gene therapy to prevent loss of muscle mass, which is thought to be another cause of age-related disease and frailty.

On the up

Life expectancy is rising around the world, but average lifespans still widely vary between nations



Parrish says she wasn't scared to try the treatment. "My grandmothers had died of Alzheimer's, and my grandfather died of heart disease. I thought, if I don't do something, I know what I'm likely to die of."

Parrish says she has felt "fantastic" since the treatment, and that her telomeres have grown by a length equivalent to wiping 20 years off someone's age. That in no way amounts to a proper trial, of course, so this year, Parrish plans to launch clinical trials of her gene therapy outside the US, in people with various age-related diseases.

A few other anti-ageing approaches are also showing promise. Senescent cells that pump out chemicals damaging to their neighbours could be targeted, by either preventing their development or periodically killing them off. One team is probing the use of heavy fats – so named because they contain a heavy isotope of hydrogen – to protect cells from the wear and tear associated with ageing. And others are trialling the diabetes drug metformin (see "A disease staring us in the face?", below).

Treatments still in development aside, many people already take supplements in the belief they might stave off ageing. Unfortunately, even those with a little evidence in their favour probably aren't helpful on their own or at the small doses usually taken, says John Ramunas at Stanford University in California.

"I've tried so many supplements, just because I'm curious," he says. "But the number one thing that we know can protect your telomeres is exercise."

In fact, there's a lot we can do to extend our health span without anti-ageing treatments, says Craig Venter, who recently launched Human Longevity Inc (HLI) to offer its customers reams of personalised health data. The most popular package, at $25,000, sequences your genome and microbiome and provides scans, blood tests and more.

"My grandmothers died of Alzheimer's. I thought, if I don't do something, I know what I'm likely to die of"

Venter wants to help people identify which diseases they are likely to develop, or are already developing, while the conditions are still easy enough to prevent or treat. "This is a healthy cohort, but we're finding that around 40 per cent of them have serious underlying disease," he says. His own results encouraged him to lose weight. "I've lost 43 pounds since finding out things about my metabolic condition."

Venter thinks a full medical assessment and personalised health advice will be more beneficial than any anti-ageing treatment. "I don't think you need some magic elixir," he says.

But the vast amount of data collection performed by HLI is simply not feasible for many hospitals, and most people won't be able to afford such health checks. The increased life expectancy in rich countries (see graph, above) shows that money already buys you more years on earth, so only a low-cost solution will make longevity available to all. Until that arrives, your best options are boring old diet and exercise. ■

A DISEASE STARING US IN THE FACE?

Getting old puts you at risk of a host of diseases likely to end your life. But is ageing itself a disease?

Some say it can't be. For a start, ageing is a natural process that happens to even the healthiest. We'll never be able to eliminate it entirely, and we don't have clear ways to measure it. Describing it as a disease, which suggests it could potentially be cured, allows us to give in to wishful thinking and unfounded claims for anti-ageing treatments.

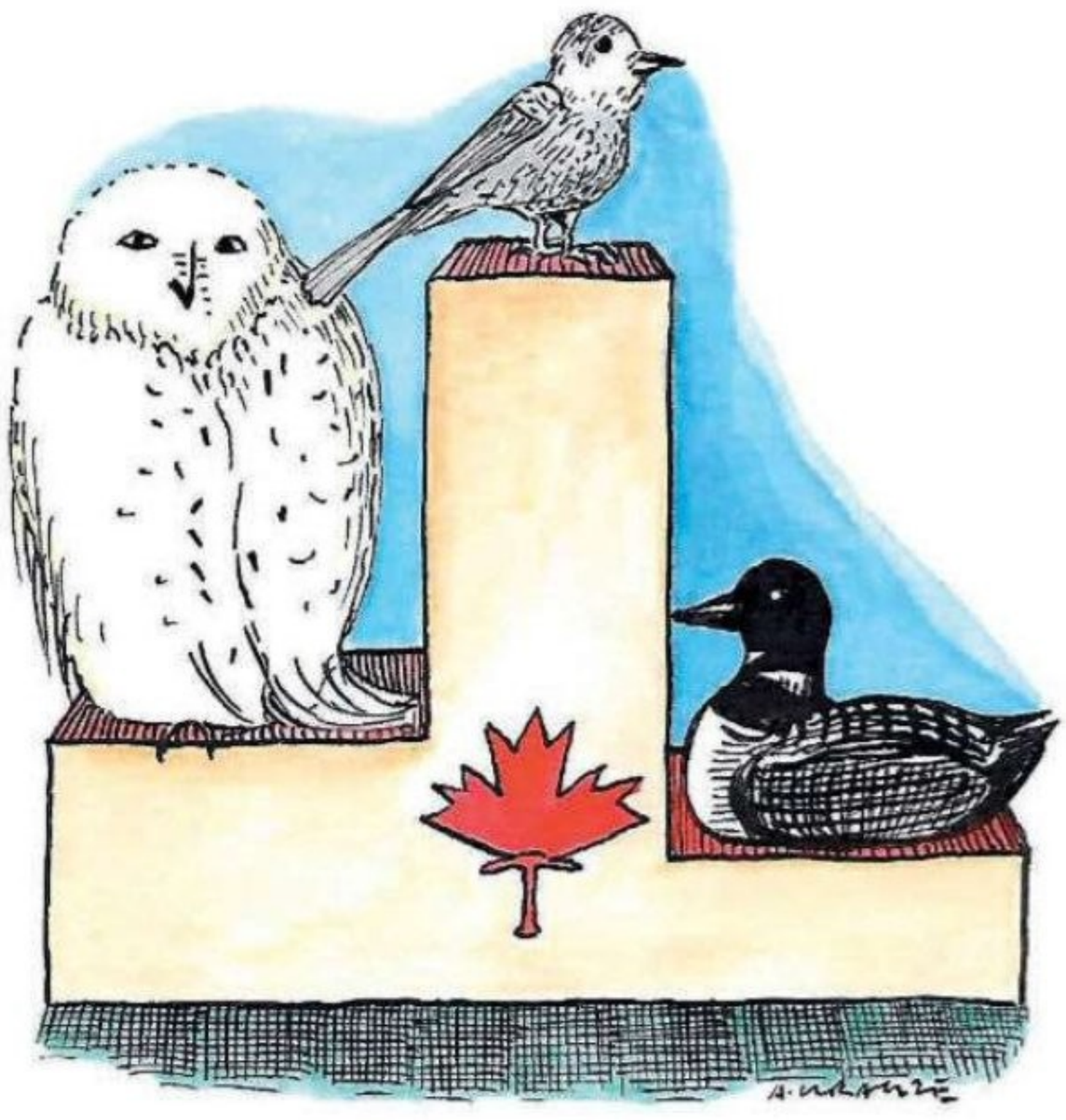
But Nir Barzilai of the Albert Einstein College of Medicine in New York says that kind of thinking prevents us developing evidence-backed treatments for ageing.

His team are running a five-year clinical trial of metformin, a diabetes drug that has been found to boost longevity in a range of animals (*Cell Metabolism*, doi.org/bvwn). They are measuring the effect of the drug on ageing itself, including general health and cognition, rather than on a specific, age-related condition, in the hopes of convincing the US Food and Drug Administration to recognise ageing as a disease.

If they succeed, it could mean this approach makes more sense than thinking about individual age-related diseases. We know that old, worn-out cells put us at risk of Alzheimer's, cancer and heart disease, for example – why not try to prevent all of them with a single therapy?

Mine's a whiskey jack

Feathers flew when Canada's geographical society named its choice of national bird, but it was spot on, says **David Bird**



THE icing on the cake for Canada's celebration of its 150th birthday this year would be for the government to officially adopt the gray jay as our new national bird.

After a vote to allow the public to help choose a bird to represent the country, the Royal Canadian Geographical Society stunned many by choosing the third-place gray jay over the first-place common loon. The excrement hit the fan with an online backlash.

So why the gray jay? First, this little bird is in every province and territory in Canada, and, save for small incursions into the US, its distribution practically mirrors our borders. Second, it was not already claimed as an official bird for any other geographical entity.

The common loon has been Ontario's official avian for years, the second-place snowy owl is Quebec's, and the black-capped chickadee (fifth place) represents New Brunswick. When we selected our Canadian flag on 15 February 1965, we did not elevate the flags of these provinces to national status – we chose something new.

As for the character and quality of the gray jay, you could not find a more Canadian bird. First, as a member of the corvid family, it is arguably one of the smartest birds on the planet. Second, it is tough and hardy. By staying year round, it has adapted to not only survive our harsh winters but is able to incubate its eggs at –30 °C.

Third, gray jays are friendly, coming to perch on open hands and ski poles without training. Fourth, unlike most birds, these jays are not promiscuous and mating pairs do not cheat on one another. They remain together year-round, often flying together and perching side by side touching one another. So we've got "smart", "hardy", "friendly"

Give it a rest

Time to get smarter about overuse of digital devices at night, says **Martin Lee**

IF YOU are thinking of giving up something in January, consider a late-night digital detox. Why? I fear our obsessive love affair with smartphones is affecting sleep, especially among the young.

Last year's Deloitte UK mobile consumer survey reported 91 per cent of 18 to 44-year-olds in the UK own a smartphone. These are clearly desirable devices but less desirable is the way many people, especially the young, use them. That same survey showed half of 18 to 24-year-olds check their phone in the middle of the night.

Likewise the Headmasters' and Headmistresses' Conference, which represents the head teachers of independent schools, surveyed 2750 pupils aged 11 to 18 and found 45 per cent checked mobile devices during the night. Of these, 23 per cent did so more than 10 times and a quarter spent more than an hour on mobiles after going to bed; 68 per cent said this affected schoolwork and a quarter said it left them tired during the day.

A meta analysis last year of studies involving 125,198 children suggests use of portable devices with screens is responsible for

"A recent analysis suggests that night-time phone use is behind a shift to poorer sleep patterns"

a shift towards poorer sleep patterns and daytime sleepiness.

There are various theories on smartphones' role in slumber. Sleep could simply be displaced by phone use, leaving less time for rest, or fiddling with your device at bedtime might prompt increased mental, emotional or physiological arousal, meaning it takes longer to get to sleep. Then there is the screen light especially at the blue end of the spectrum, which may interfere with melatonin secretion (our body's "sleep hormone") or circadian rhythm (our in-built clock). Finally, incoming messages, emails, status updates or calls can

and "loyal". What greater way to describe the typical Canadian?

It gets better. Many Canadians best know this bird by its First Nations name, the whiskey jack – nothing to do with the beverage, but an anglicisation of the indigenous word *Wisakedjak* meaning "mischievous prankster". Yes, it does have the cheeky, cute and opportunistic habit of pilfering food from bags, pantries and picnic baskets, but First Nations people revere it as an omen of good fortune and for its call warning of predators. In the end, we can call our bird whatever we like, even the Canada jay, its former common name.

Maybe part of the reason for the backlash is that the gray jay is not immediately identifiable to most Canadians. Rather than feeding in gardens, it is a denizen of our boreal forest. To meet it, Canadians simply have to get out in our national and provincial parks.

To top it off, because the gray jay is dependent on cold winters to keep its stored food from rotting, you could not find a better poster child for the need to stave off climate change. This year, let's give it the status it deserves. ■

David Bird, emeritus professor of wildlife biology at McGill University in Montreal, led calls to select the gray jay

disturb sleep and reduce quantity and quality of "restorative" sleep.

My worry is that as well as daytime doziness, such sleep loss could also be a potential factor in mental and physical illness.

For example, a recent meta-analysis of the relationship between sleep and depression concluded that sleep disturbance might be a precursor to the condition in adolescence.

If you think your night-time phone habit is out of hand, now is the time to consider a change. ■

Martin Lee is a UK consultant rheumatologist. He has set up the advice site nophonezone.co.uk

INSIGHT New year's resolutions

CAVAN IMAGES/PLAINPICTURE

Achievable goals: that's key

Want a new you in 2017? Here's how

Frank Swain

WE TRADITIONALLY greet the new year to the strains of *Auld Lang Syne*, and with rash promises of self-improvement, such as giving up alcohol for a month. I'm no different – over the last few years I've set myself new year's resolutions with mixed results. Some, like my oath to visit the gym 100 times over the course of the year, were successful. Others, such as keeping on top of my taxes, were not.

In fact, only 10 per cent of resolutions made in January will survive until December. Why do so many of us struggle to keep promises to ourselves? And can we do better?

"As a species we tend to be biased to overconfidence and optimism," says Keith O' Brien at the Centre for Behaviour Change, University College London. "Come January, people tend to tick off all the things they want to do, and as a result try to do too much."

So what separates the successful from the rest of us? O'Brien says that setting goals without planning how you will achieve them is a recipe for failure. "If you have a goal for January 1st, you should prepare in advance with smaller changes," he says, such as removing unhealthy snacks from the house if you want to give up eating junk food.

That's because willpower is like a muscle, and exercising it can give you a better chance of resisting the temptation to eat that second biscuit.

Research also shows those who prepare for the worst are more successful in the long run. So always have a backup plan – if you know

"Only 10 per cent of resolutions made in January will survive until December"

you can't go to the gym in the morning, schedule an evening workout in advance.

Although people assume big, distant goals will inspire them to put in a lot of effort, the inverse is actually true. Last year Kaitlin Woolley and Ayelet Fishbach at the University of Chicago published a study on the best predictors for adherence to long-term goals. They found people were more successful at sticking with resolutions when there was an immediate reward involved (*Journal of Consumer Research*, doi.org/btbc).

"People say they exercise for a long-term health goal," says Woolley, "but it's not the importance of their health goal that predicts how long they exercise for – it's whether their workout is fun." She suggests finding ways to make your new year's resolution more gratifying if you really want to stick with it.

Another key plank is to break big goals down into smaller, discrete steps. This is popularly known as the SMART goals method – ensuring you are working toward milestones that are specific, measurable, agreed-upon, realistic and time-sensitive.

So instead of resolving to "learn Spanish", I can reframe it in terms of the SMART criteria: in 2017 I'll sign up to a language class and practise at least three hours a week, and sit for an official language proficiency certificate by August.

But what about the "agreed-upon" part? O'Brien says that building a support network around yourself can help meet your goals. By making friends and family aware of your resolution, you can increase the chances that you'll stick to them.

"It takes up to 65 days to break a habit," says O'Brien, "You need that reinforcing power for that long." With less than 100 days to go before the deluge of chocolate eggs at Easter, it's never too soon to start your own self-improvement programme. ■

APERTURE

Glow in the dark

IT'S like a message scrawled in light. This time-lapse image, taken over 30 seconds in a Costa Rican cloud forest, shows a headlight beetle's meandering path along a leaf.

The insect's "headlights" – two bioluminescent spots just behind its actual head (see inset image) – gleam steadily as it wanders undisturbed, as does a third, hidden bright area under its abdomen.

The largest and brightest of the bioluminescent insects, headlight beetles can reach 4 centimetres in length and glow with a brightness of around one-fortieth that of a candle. If anything gets too close, it can brighten its light to try to scare away the possible predator. This ability to dial its luminescence up and down can also be useful for luring prey. Grown headlight beetles are mostly vegetarian (with the exception of the occasional aphid), but larvae often devour other insects attracted to their gentle glow.

Brightness isn't always safe for a headlight beetle, though – trap enough of them and you can light a whole room. Leah Crane

NATUREPL

Photographer

Cristobal Serrano

cristobalserrano.com

Upwardly mobile

If anything ever fell up, it would rewrite the textbooks. Antimatter might be that thing, says **Joshua Howgego**

ON 11 November last year, a small birthday party was held in an apparently unremarkable hangar onthe outskirts of Geneva, Switzerland. Nothing too fancy, just a few people gathered around a cake. The honourees were there. Well, sort of – they were still locked in the cage where they had spent their first year. But then again, there is no other way to treat a brood of antimatter particles.

The antimatter realm is so bizarre as to be almost unbelievable: a mirror world of particles that destroy themselves and normal matter whenever the two come into contact. But it's real enough. Cosmic rays containing antiparticles constantly bombard Earth. A banana blurts out an anti-electron every hour or so. Thunderstorms produce beams of the stuff above the planet.

Making and manipulating antimatter ourselves is a different kettle of fish. Hence that birthday party held at the particle physics centre CERN, celebrating on behalf of a quadruplet of antiprotons. There's a lot we would like to learn from these caged beasts and their ilk, not least this: do they fall up?

Cards on the table, few physicists believe that such "antigravity" effects exist – that if you released one of those antiprotons and somehow ensured it free passage through the hostile world of matter, it would magically float up. But the recalcitrant nature of antimatter means we've never done the experiments, and until we do, we simply don't know. "Progress is often made by asking the questions we think we already know the answer to," says Daniel Kaplan of the Illinois Institute of Technology in Chicago.

The scepticism about all forms of antigravity dates back to the 1950s, when the physicist Hermann Bondi was pondering the implications of general relativity, Einstein's theory of how gravity arises from warping the fabric of the universe. Gravity is an odd sort of force, not least because it only ever works one way. With electromagnetism, say, there are positive and negative charges that attract and repel. With gravity, however, there are only positive masses that always attract.

Bondi showed what a bizarre world it would be if this were not the case, demonstrating how negative mass would end up pursuing positive mass across the universe (see diagram, page 30). This sort of "runaway motion" does not appear to exist – but we should be careful about what we draw from that, says Sabine Hossenfelder of the Frankfurt Institute for Advanced Studies in Germany. "People who speak of the runaway problem often jump to conclusions from Bondi's argument and conclude that anti-gravitation itself is inconsistent," she says. "But it merely requires a modification of general relativity."

And here's the thing: general relativity is probably due a modification. The theory is incompatible with quantum mechanics,

LI WEI/SOLENT NEWS/REX/SHUTTERSTOCK

the other great pillar of modern physics, and if we are to find a way to make a unified description of the universe, that must change. Then everything is up for grabs.

So in a few labs around the world, the search for negative mass and its associated effects goes on (see "Losing weight", page 31). Antimatter is a particularly promising place to look. It is just like normal matter but with the opposite electric charge and a few other mirrored quantum properties. There's no reason to think it has the opposite mass and anti-gravitates, and some good reasons to think it can't have.

But if antimatter did anti-gravitate, that might help with another of its central mysteries: where most of it is. Our theories say matter and antimatter should have been created in equal proportions in the big bang, and yet we live in a matter-dominated world.

The emptiest box

Explaining this glaring inconsistency has largely been a case of trying to find asymmetries in the processes of particle physics that favour normal matter. Such asymmetries do exist – but they are about a trillionth of the size needed to explain matter's supremacy. "People have been trying to make it work – and it doesn't work," says Kaplan.

Antigravity could provide a better explanation. A repulsive gravitational interaction could have driven matter and antimatter away from each other so they never had the chance to annihilate in the early universe. Since then, the ongoing expansion of the universe would have driven the twain ever farther apart – and the antimatter might eventually have created its own galaxies in other corners of the universe. "Then the missing antimatter would be hiding in plain sight," says Kaplan's colleague Thomas Phillips.

Add to that the technological possibilities that levitating matter away from Earth's surface might bring, and even the US air force wants in – it has given millions of dollars to antimatter researchers over the years. Unfortunately, doing the experiments turns out to be quite an ask.

The problems start with needing a home for antimatter that is almost entirely free of normal matter. That requires some of the emptiest boxes on Earth, containing just hundreds of gas molecules per litre (there are about 10^{22} in a typical litre of air). But even these boxes have sides. To stop the ›

antimatter banging into them and instantly annihilating, you must slow it down by cooling it to within a few degrees of absolute zero and then catch it in a vortex of electromagnetic fields. Little by little, we've been perfecting these arts, holding antimatter particles for seconds, minutes, days – and for a year, as celebrated at November's party.

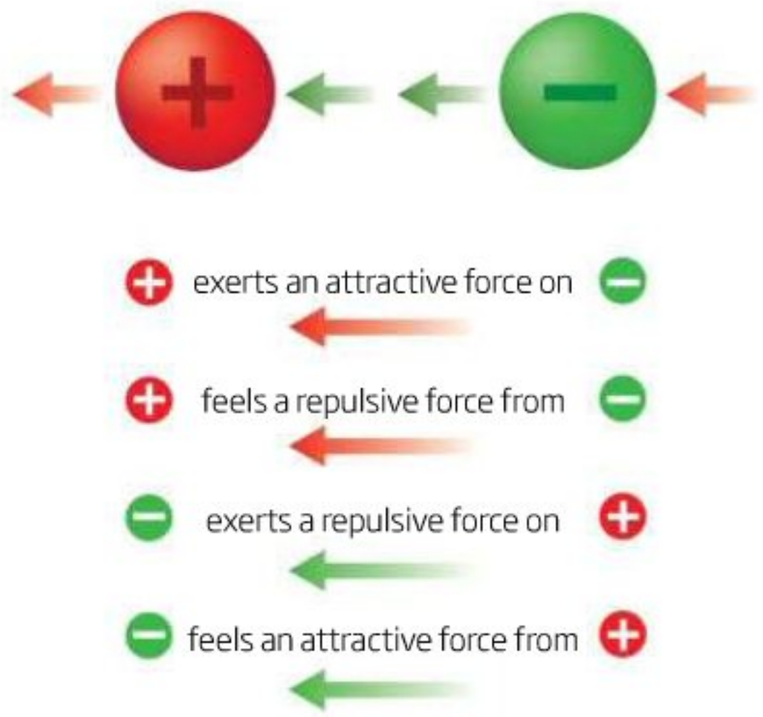
That milestone was reached by CERN's Baryon Antibaryon Asymmetry Experiment (BASE), one of six experiments competing to measure antimatter's fundamental properties that are all housed in CERN's vast Antimatter Deceleration Hall. Inside, past a sign marked "Antimatter factory", the most noticeable things are the bright yellow cranes, swinging around the vats of liquid nitrogen required for cooling. Somewhere below, a beam of particles from CERN's Proton Synchrotron accelerator smashes into a block of metal, creating a plethora of particles. A system of magnets selects the antiprotons and funnels them into a ring of more magnets that keep them on course as they are decelerated for trapping.

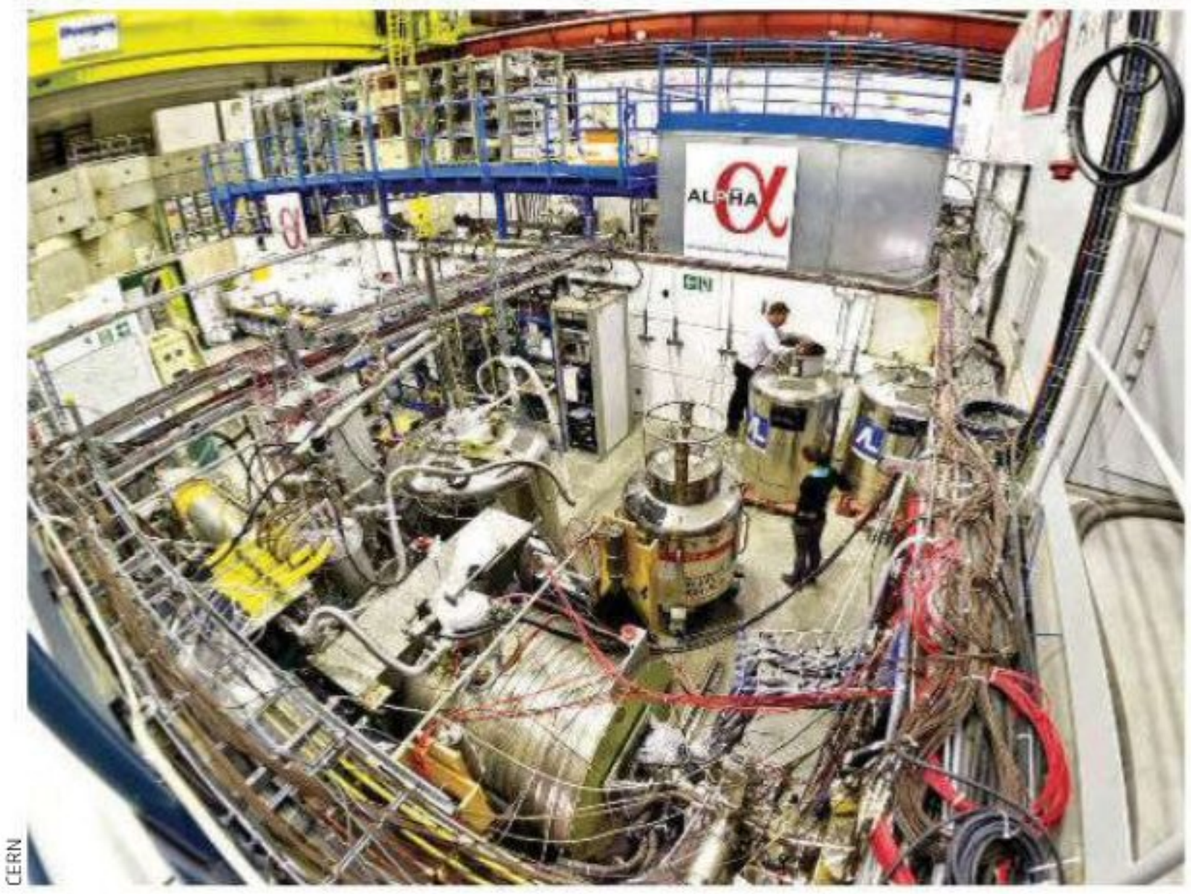
Experiments have been running here since the 1990s, studying whether antimatter and matter particles truly are as close to identical as we think. In 2015, by measuring how antiprotons danced around in a magnetic enclosure known as a Penning trap, BASE produced the most precise measurement yet of their mass-to-charge ratio. They showed it was the same as a proton's, to about 69 parts per trillion, four times more precise than the previous best value (*Nature*, vol 524, p 196). Last November, the neighbouring ASACUSA experiment produced the most accurate measurement yet of the antiproton's mass, finding no evidence of a different value from the proton's (*Science*, vol 354, p 610).

The same value – but is the mass positive or negative? That is the multimillion dollar question, and it takes the experiments to a new level of fiddliness. Gravity is weak and easily overwhelmed by the electromagnetic force, so using charged particles such as antiprotons and controlling them with magnetic fields won't do. You could try getting an antiproton in position and shutting off the magnets to see which way it falls, but the antimatter's electrostatic interactions with its surroundings would overwhelm any gravitational push or pull it might feel.

Runaway problem

Standard positive masses attract each other, giving rise to gravity. But if negative mass exists, the combination of attractive and repulsive forces would cause negative masses to chase after positive ones





The ALPHA experiment is one of six at CERN studying antimatter's properties

A better bet is neutral atoms of antimatter, such as antihydrogen. Making these is no cakewalk, but they have a tiny electric polarity that makes it worth going the distance – their electrostatic interaction isn't strong enough to swamp gravity, but very strong magnetic fields will still hold them in place. CERN's Antihydrogen Laser Physics Apparatus (ALPHA) experiment has been doing this since 2005, and now routinely traps and holds bunches of antihydrogen atoms for about 15 minutes. "Just the other day we trapped 350," says Jeff Hangst, head of ALPHA.

Not up, just less down

In 2013, ALPHA published a proof of principle measurement, briefly collecting a cloud of 434 antiatoms, turning off the magnets and tracking their subsequent motion by where they annihilated. It was a crude test, and inconclusive – the final answer was compatible with the antiparticles having either negative or positive gravitational mass.

Work on a souped-up version that gives the particles more space to fall should start this year. "We're going to knock out a wall and build a vertical version of the experiment next door," says Hangst. Getting the necessary accuracy won't be easy, because the antiatoms ALPHA uses are relatively hot and so jiggle around, which clouds the issue. But large enough numbers of antiatoms should help us answer the central question. "Up or down – that should be possible," says Hangst.

A further CERN experiment, AEGIS, also aims to perform tests within a few years. Kaplan is planning experiments with muons, heavier cousins of the electron, and a team led by David Cassidy of University College London is planning to use positronium, an "atom" consisting of an electron and its antimatter partner, a positron, orbiting one another.

Back at CERN, the Gravitational Behaviour of Antimatter at Rest, or GBAR, experiment intends to tackle the question using a single antihydrogen ion, a combination of one antiproton and two positrons. In theory, it should be easy to hold this charged speck in place with magnetic fields and cool it with lasers. The idea is then to knock off a positron using another laser, making the antiatom neutral. At this point it would cease to feel the effect of the trapping field and fall – up or down. GBAR's head, Patrice Perez, says they expect to make measurements sensitive to detect even a 1 per cent deviation from the gravity felt by normal matter.

LI WEI/SOLENT NEWS/REX/SHUTTERSTOCK

LOSING WEIGHT

Is it crazy to think something might have less than zero mass? It seems like it, but Martin Tajmar, a physicist at the Dresden Institute of Technology in Germany, is not so sure. "It's a bit like walking on top of a mountain and seeing the ground beneath you," he says. "You think, 'hey I'm on the ground'. But there are lower bits of ground that are not up a mountain."

The question isn't necessarily the same as whether anything can anti-gravitate (see main story). There are two types of mass: gravitational mass quantifies how strongly an object feels the force of gravity, whereas inertial mass quantifies an object's resistance to acceleration. Experiment after experiment has shown that these two quantities always have the same value – a mysterious equivalence that lies at the heart of Einstein's description of gravity, general relativity.

Break the equivalence principle and you could have an object with normal gravitational mass, but a negative inertial mass. Such a body would fall normally in a gravitational field, but give it a push and it would accelerate towards whatever is pushing it, not away from it. Pair that with normal mass and you could create a system that self-accelerates. "My motivation is to build something like a warp drive," says Tajmar.

There are a few theoretical avenues for creating negative mass, says Tajmar. One comes from the US historian and physicist James Woodward, who proposes that by cobbling together bits of general relativity you can make particle masses fluctuate, even into negative territory. Woodward has been trying to experimentally verify this effect since the early 2000s.

Tajmar is working to test this too, as well as investigating another proposal. This hinges on a theory called Weber electrodynamics that is viewed with narrowed eyes by most theorists – a position Tajmar's latest unpublished results seem to support. "What I can say, is that if it is there, the effect is very small," he says. Plus, he thinks it could only be turned into a propulsion system inside a charged cage. "So that's not very useful."

Construction of the experiment won't start until later this year, and requires new lasers and an extra antiproton decelerator called ELENA. Hangst is confident of beating the upstart to the punch. "I view GBAR as a case of five miracles happen and then it works," he says. One telling fact is that GBAR plans on using only one detector, below the trap. "We really do not expect antimatter to fall up," says Perez.

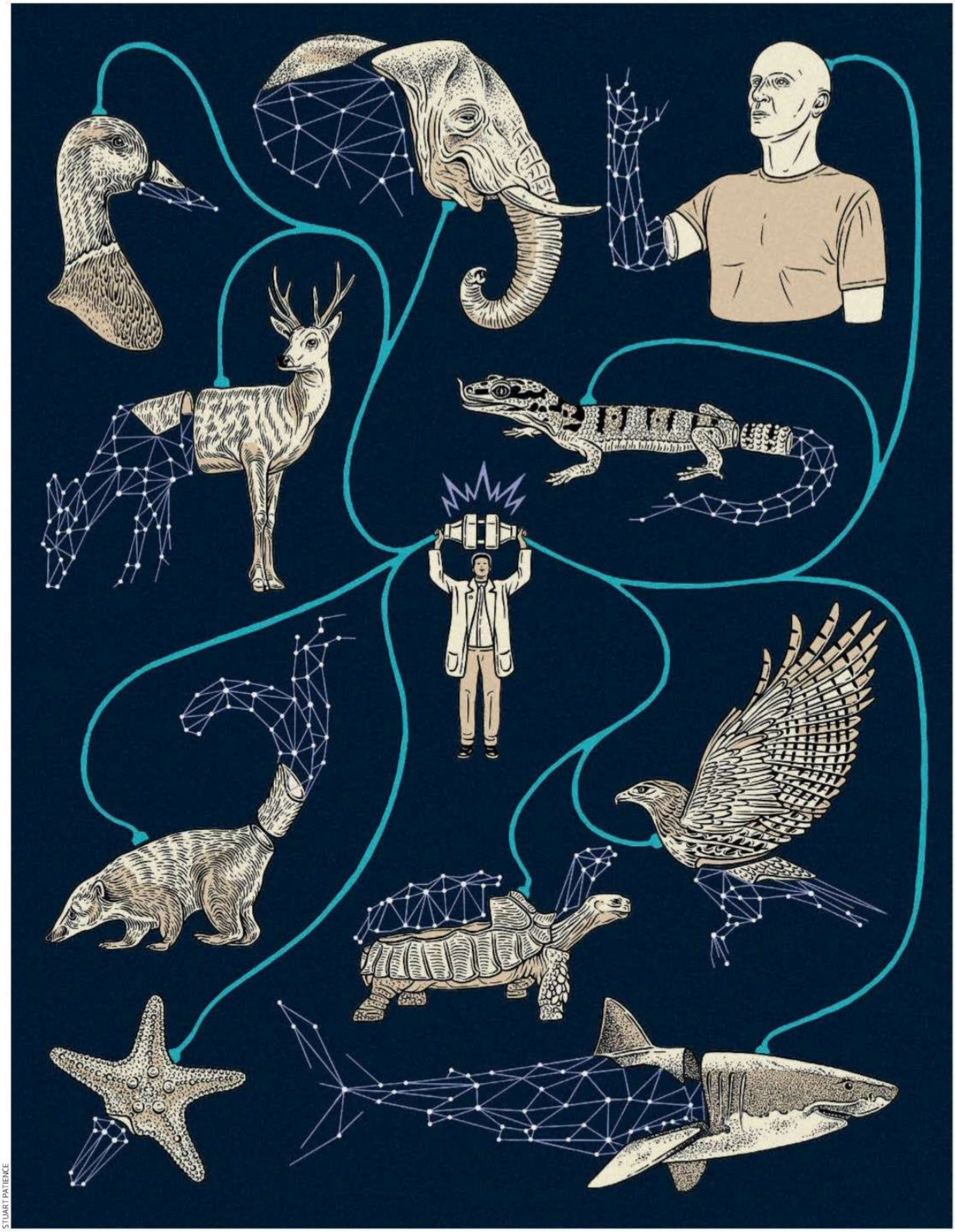
Even if it falls at all differently, however, that would still be hugely interesting. "In all the descriptions I know, antimatter cannot antigravitate," says Sergey Sibiryakov of CERN. What's more plausible, he thinks, is that there might be other forces that modify gravity whose effects cancel out on normal matter, but not on antimatter. In that case, antimatter might not fall up – just less down. "Now, that's not natural, but it is logically possible," he says. Similar gravity-modifying effects might be produced if the graviton, a quantum particle proposed to carry the force of gravity, has a small mass, rather than being massless as is usually assumed.

Even so, we probably shouldn't be holding our breath for amazing self-levitating machines any time soon. A more immediately practicable way of using antimatter to beat gravity might be to harness the energy released when it annihilates. One firm, Positron Dynamics in Livermore, California, has been developing the idea with financial support from PayPal co-founder Peter Thiel, among others.

Positron-fuelled rockets could power spacecraft much further and faster than is currently possible, according to Positron Dynamics co-founder Ryan Weed. "Our vision is to create technology that allows humanity to venture outside of our solar system," he says. The company's patented system involves harvesting positrons from radioactive sodium-22 and using these to start off a nuclear fusion reaction that generates thrust. Weed says the team is set to test the device in a lab and wants to test it in orbit in the next few years.

But experience makes Stefan Ulmer, the head of the BASE experiment, cheerfully sceptical of immediate progress. Antimatter won't be easily tamed. "In the whole history of the CERN Antimatter Deceleration Hall, we've produced about enough to heat up a cup of water by about 5 °," he says. Not even enough, in other words, to make a pot of tea to wash down that birthday cake. ■

Joshua Howgego is a feature editor at *New Scientist*



STUART PATIENCE

Grow with the flow

Bioelectricity shapes anatomy – and it could spark a medical revolution, finds **Jason Bittel**

FROM the tail of the leafy sea-dragon to the toucan's beak and the human hand, each and every one of the myriad forms assumed by living things starts out as an amorphous blob of cells. It's one of the biggest mysteries of life: what choreographs billions of cells to create so many intricate anatomical patterns, what Charles Darwin preferred to call "endless forms most beautiful"?

It's all in the genes, of course. Except that it's not. These days, biologists are investigating a long-overlooked aspect of shape control: the electrical signals that constantly crackle between cells. Whether in embryonic development or repairing parts of the body, bioelectricity seems have a big say in telling cells how to grow and where to go. It also appears to play an important role in the astonishing knack some creatures have to regrow lost or damaged limbs.

If we can figure out precisely how it encodes patterns of tissue formation – if we can crack the "bioelectric code" – the possibilities would be startling. Not only will we get a deeper understanding of evolutionary change, we could revolutionise tissue engineering and regenerative medicine. "Once we know how anatomy is encoded, we will be able to make shapes on demand," says Michael Levin, a developmental biologist at Tufts University in Medford, Massachusetts.

We've known for a while that when it comes to development, the process that takes you from a single cell to a fully fledged organism, DNA only goes so far. "If you were to show someone the completed genome of a creature, and you didn't allow them to compare it with the genome of something they were familiar with, they would have absolutely no idea what that creature would look like," says Levin.

In that sense, DNA is less like a blueprint and more like a list of materials, only without a set of instructions for how to use them. Some direction comes in the form of chemical cues such as morphogens, which influence gene expression, and physical forces that guide migrating cells. But Levin and others think there is something else going on.

They are not the first to suspect as much. In the 1700s, Italian physician Luigi Galvani observed that dead and disarticulated frogs' legs could be made to kick as though they were still alive when he connected them to a source of electrical charge. Later, in the 1930s, Yale University's Harold Saxton Burr proposed that bioelectricity is the "organising principle" that kept living tissue from descending into chaos. Despite what we know about the power of electricity in the brain, however, his ideas were largely ignored – until recently.

If the idea of bioelectricity calls to mind sparks flying between neurons, you're not far off. In fact, the brain's electrical circuitry probably evolved from the simpler, slower bioelectrical connections found between cells elsewhere in the body. Every biological cell has a voltage, which changes depending on the balance of charged atoms called ions on either side of the cell membrane. These differences in electrical potential, governed by ion channels and pumps on cell membranes, carry information.

For a long time, we thought this intercellular chit-chat was mostly concerned with banal housekeeping duties: "Send this waste over there!", "More fuel needed here!". ›

What we're learning now, however, is that it is much more important than that, says Nestor Oviedo at the University of California, Merced. "In a way, bioelectricity tells the cells whether to divide, whether to differentiate, whether to migrate," he says.

That much is clear from a series of experiments that give a whole new meaning to the question "heads or tails?". The most striking have involved planarians, otherwise known as flatworms – simple, squiggly organisms that resemble a 5-millimetre-long smear of snot with crossed eyes.

Caught in two minds

Like salamanders, planarians are remarkable regenerators – slice off a tail and it will quickly grow back. But unlike salamanders, planarians can also survive decapitation. In fact, you can cut a planarian into 200 pieces and each will grow into a new, perfectly healthy whole animal over the course of a few weeks.

In 2010, Levin and Oviedo lopped off planarians' heads and tails, and treated the remaining fragments with a chemical bath known to inhibit the flow of ions between cells. Rather than regrow replicas of the parts that had gone missing, in the normal way, these planarians grew heads on both ends. "That showed, for the first time, that these electrical synapses are important for deciding head versus tail," says Levin.

And here's where things get really kooky. In follow-up experiments, the team put the two-headed worms in plain water for a few weeks, with no electricity-tampering chemicals. They then hacked off each end again. When the flatworms regenerated, they didn't revert to their original programming, but instead grew two new heads.

This doesn't make sense, says Levin – at least not without the bioelectricity's influence. The experiments did nothing to alter the planarians' genomes and so, after all the chemically altered tissue is cut off, one might assume that the worm would go back to building the same body plan it has always built. But it doesn't. Instead, the cells somehow remember the new instructions.

Even when the researchers allowed their creations to reproduce asexually, as they would in the wild, they produced offspring with two heads. So it seems that simply by altering its bioelectric signalling patterns, you can permanently rewrite an organism's body plan.

MICHAEL DURHAM / MINDEN PICTURES

You can also get it to regrow body parts resembling those from other species. Last year, Levin and his colleagues disrupted electrical signalling between cells in decapitated specimens of the planarian *Girardia dorotocephala*. Instead of making a new version of their own heads, they regenerated heads with a distinctive shape and brain anatomy that belonged to a different, albeit closely related, species.

Levin is not the only one revealing the power of bioelectricity. Min Zhao at the University of California, Davis, is investigating the role bioelectricity plays in wound healing. We previously thought that cell movements in response to injury were dictated by chemical cues. But Zhao has demonstrated that electric fields can mobilise and guide sheets of cells towards a wound.

To begin with, Zhao's results met with some scepticism. Josef Penninger at the Institute of Molecular Biotechnology in Vienna, Austria, was one of the doubters. "I was sceptical because to me, it was an entirely new concept," he says. However, that changed when Zhao travelled to Penninger's lab and showed him a video of sheets of skin cells migrating in the same direction when exposed to an electrical field. "I and everyone in my lab was mesmerised," Penninger says.

Zhao understands the scepticism because there is still so much to learn. We don't know how patterns of flickering electrical potential translate into patterns of tissue formation, for

Salamanders can regrow limbs time and again, so why can't we?

a start, although Levin suspects there are parallels with the brain or some forms of computer memory.

What is obvious, though, is that all this could have far-reaching implications for our understanding of evolutionary change. Imagine a scenario in which the lab-built two-headed flatworms were released into the wild: a biologist could stumble on them and think they were a new species, and yet they would find that these worms and their one-headed kin are genetically identical.

According to Levin, this suggests evolution may not be limited to genomic mutation. If environmental stimuli can produce worms with two heads or the heads of other species in the lab, then perhaps such things can happen in nature, too. "This is a potentially whole new way of entering body plans into the evolutionary record."

Others are more cautious. We already know that the same genome can produce strikingly different body shapes, says Mary Jane West-Eberhard at the Smithsonian Tropical Research Institute in Costa Rica: it's called phenotypic plasticity. "Consider the larval and adult forms of a butterfly," she says. "The differences are due to gene expression."

Levin argues that what we're seeing with the two-headed planarians is different. "It's a new type of phenotypic plasticity, one that resides

M. SCOTT BRAUER

Tweaking electric signals can make eyes grow in strange places

"Bioelectrical signalling could have far-reaching implications for our picture of evolution"

not in the cascade of molecules that regulate gene expression but in bioelectric networks and their ability to compute and remember."

Wresting control of this voltage-based communication might also have a big impact on human health. If we can understand how the body creates its structures in the first place, and how some creatures can repeat the process, then perhaps we can commandeer the process in humans. "At this point, it's dreaming about what the application could be," says Emily Bates, a geneticist at the University of Colorado in Denver.

Several developmental diseases are caused by channelopathies, or malfunctions of our ion channels. They include Timothy syndrome and Andersen-Tawil syndrome, rare diseases that cause neurological, heart, and skull and facial defects. Even fetal alcohol syndrome, which can develop if a woman drinks during her pregnancy, can produce similar defects because alcohol blocks many of the same ion channels.

Bates says it may never be possible to treat these disorders given the way they manifest in embryonic development, but she is confident that bioelectricity will have practical applications elsewhere.

Reversing cancer

It could help us tackle cancer. Earlier this year, Levin and his colleagues took advantage of a technique called optogenetics, which involves genetically engineering cells to respond to a flash of laser light. When they hacked a particular set of ion channels in this way to alter bioelectrical signalling in tadpoles that were engineered to develop cancer, the team were able to reduce the incidence of tumour formation. But they didn't just shrink the tumours; they made more tumour cells return to their original healthy state, like the monstrous Mr Hyde turning back into mild-mannered Dr Jekyll. So instead of trying to kill cancer cells as you do with chemotherapy and radiation, which both have unpleasant side effects, you might hack bioelectricity to "normalise" them.

Rehabilitating cancer cells would be impressive; regenerating limbs or organs would be astonishing. That has to be most exciting prospect raised by our new insights into the ways that bioelectricity controls pattern formation.

Humans' regeneration abilities pale in comparison to those of the planarian, of course, but just the ability to mend a fractured finger is an amazing feat. It relies on bone morphogenetic proteins (BMPs), which help stimulate new growth. The trouble is that the body seems to prioritise BMP production in bones that support weight, like the tibia, so lighter bones like the jaw sometimes don't heal well.

We can make these proteins in the lab, but it's expensive. What's more, BMPs can cause problems when injected, such as stimulating too much bone growth – "kind of like a tumour", says Bates. But there might be a better way. Bates has shown in fruit flies that electrical activity plays a role in the release of BMP. If you could selectively target the relevant ion channels, says Bates, you could potentially deploy a person's own molecules to fix their bones – even if their body is stingy with BMP.

What are the chances we could regenerate human limbs, or even grow organs on demand? In 2013, working with froglets, Levin and his colleagues used a chemical cocktail to induce the flow of sodium ions, and thereby increase the biolectrical chit-chat between cells. The animals were past the age at which they can regenerate full limbs, and yet that is exactly what they did after treatment.

"Plasticity definitely varies," says Levin. Salamanders and planarians seem to retain their regenerative abilities for life, while tadpoles lose their superpower somewhere

"The frogs were past the age where they can regrow limbs, yet they did"

JUNJI MOROKUMA

Two-headed flatworms are proof of the body-shaping power of electricity

along the way to becoming frogs. Humans lose the power early on too. Split a fertilised egg cell down the middle when it is a few days old and it will form two genetically identical twins. Try a similar splitting feat a few weeks later, and you'll get a tragically different result.

It's one thing to take a trial-and-error approach to determining the bioelectrical pattern behind an ability animals already have: building a limb, for example. It's quite another to load that pattern into animals that lack that ability. But the fact that humans have regenerative capabilities, even if only briefly, is suggestive. If we can identify what suppresses them, Levin argues, we could potentially unlock that innate repair apparatus.

Identifying such patterns and translating them into something we can use is a tall order. It's not enough to work out bioelectricity's secrets at the cellular level – we must decipher its rhythms and logic if we want to build a structure. If Levin is right that bioelectrical information is analogous to computer memory or brains, then tools from computational neuroscience should help. Artificial intelligence might also come into play.

"Once we crack the code, we will know precisely how we have to rewrite the default electric patterns, so as to make the anatomy we want," says Levin. Even early sceptics like Penninger are excited by the potential: "I think it's a field waiting to explode," he says. ■

Jason Bittel is a science writer based in Pittsburgh, Pennsylvania

To do the right thing, autonomous cars need to be programmed with human ethics. But how do we even get started, asks **Sandy Ong**

Auto correct

ON THE night of 3 September 2010, 33-year-old Brian Wood was driving along a highway in Washington state. Asleep in the passenger seat was his wife Erin, seven months pregnant with their first child. The couple were on their way from Vancouver, Canada, to spend time at her parents' vacation home by the picturesque Puget Sound.

Out of nowhere, a Chevy Blazer came hurtling towards them. By the time Wood saw it, it was too late. He braked hard and swerved right to take the brunt of the impact. He died instantly, but his wife and their unborn daughter survived.

We hope it never happens to us, but any driver might find themselves making such a split-second, life-and-death decision. They are part rational, part reflex, and draw on a delicate balance of altruism and self-interest programmed into all of us. To his wife, Wood was a hero – but indisputably he was a human.

As our cars edge towards making these decisions for us, cases like this raise profound ethical questions. To drive safely in a human world, autonomous vehicles must learn to think like us – or at least understand how humans think. But how will they learn, and which humans should they try to emulate? "We're talking about self-driving cars, up to two tonnes of steel and machine that could crash into homes and people," says ethicist Patrick Lin of California Polytechnic State University in San Luis Obispo. "We definitely can't leave it up to manufacturers to do what they want." It's time to engage low gear – we have a moral mountain to climb.

The most advanced cars of today boast systems to help you cruise down a motorway (Tesla's Autopilot), creep along in bumper-to-bumper traffic (Mercedes-Benz's Distronic Plus with Steering Assist) or detect hazards in poor light using thermal imaging (Audi's Night Vision Assistant). Some cars can even do the dreaded parallel parking (Ford Fusion) or prevent you from rear-ending the vehicle in front (Infiniti Q50). They still can't take your non-driving grandparent to bingo, pick the children up from school or let you work peacefully in the back – but with the world market for driverless tech projected to grow 16 per cent per year over the next decade, that's probably only a short ride away (see "Into fifth", page 38).

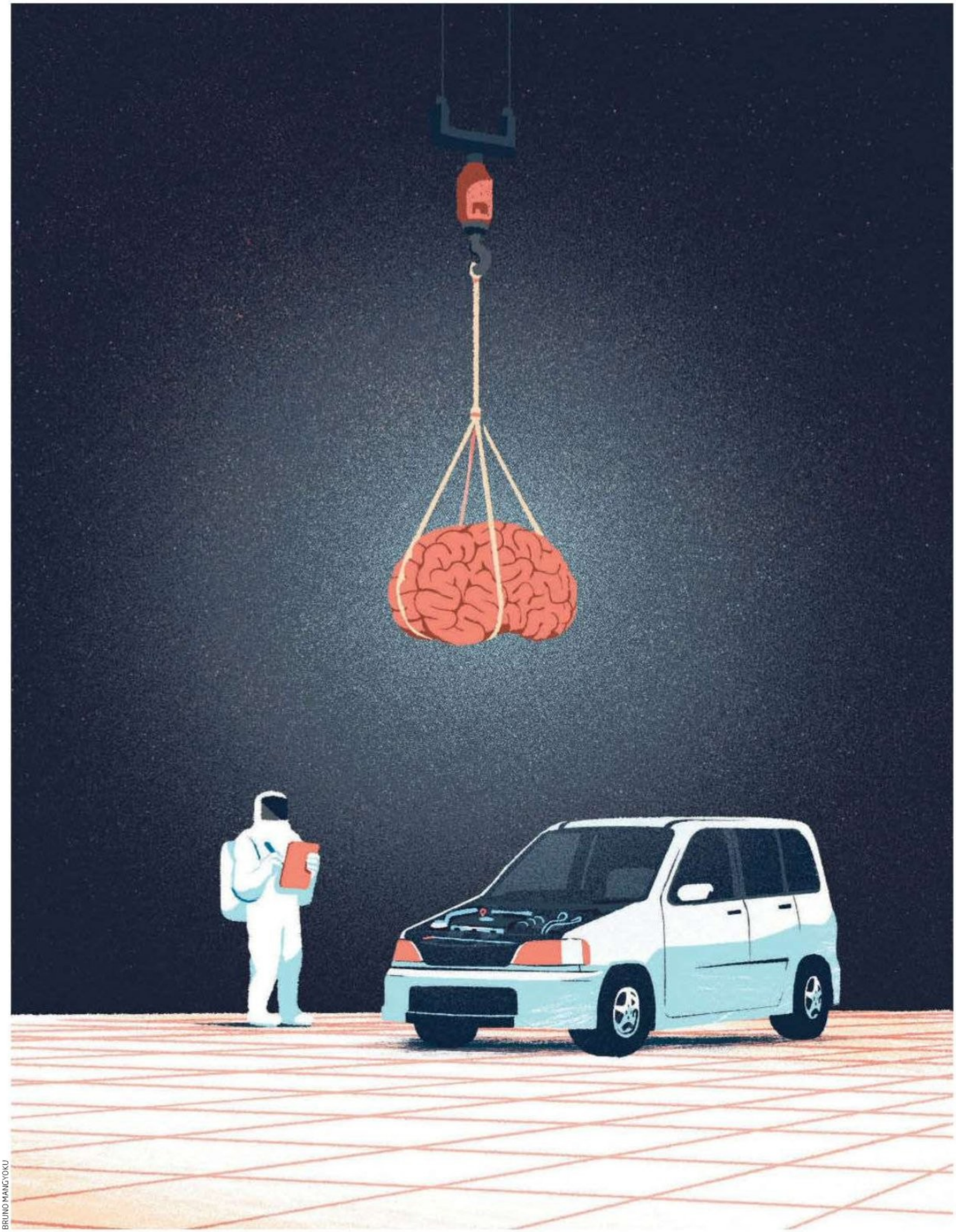
The ethical challenges raised by driverless cars can often be reduced to the trolley problem, a thought experiment familiar to philosophy students. Imagine a trolley car out of control, and five oblivious people on the track ahead. They will die if you do nothing – or you could flip a switch and divert the car to a different track where it will kill only one person. What should you do? In a similar spirit, should an autonomous vehicle avoid a jaywalker who suddenly steps off the curb, even if it means swinging abruptly into the next lane? If a car that has stopped at an intersection for schoolchildren to cross senses a lorry approaching too fast from behind, should it move out of the way to protect the car's passengers, or take a hit and save the children? "Many or all of those decisions will have to be programmed into the car," says Jason Millar of the University of Ottawa, Canada.

"When a philosopher says it's an interesting problem, engineers tend to just shrug"

Millar trained as an engineer before switching to philosophy, and knows this is no run-of-the mill engineering problem. "When a philosopher comes along and says, 'There's this interesting new problem you have to deal with', the car companies and engineers, very understandably, look strangely at that philosopher and kind of shrug their shoulders," he says.

Answering such "what do we do if…" questions is a two-step process. First, the vehicle needs to be able to accurately detect a hazard; second, it must decide on its response. The first step mainly depends on the efficient collection and processing of data on the whereabouts and speed of surrounding vehicles, pedestrians or other objects. "Cars need sensors that can give them a picture of the world around them," says Alex London, a philosopher at Carnegie Mellon University in Pittsburgh, Pennsylvania. These might include video cameras to read traffic lights and road signs, or systems that emit laser or radar pulses and analyse what bounces back.

Google's self-driving cars have eight sensors, Uber's driverless taxis 24, and Tesla's new cars will each have 21, all combining their data into a stream, rather as we integrate what our various senses are telling us. "In robotics, it's called sensor fusion," says Raúl Rojas of the Free University of Berlin, who heads ›



BRUNO MANGYOKU

INTO FIFTH

A fully autonomous car that carries out moral reasoning (see main story) would rate as level 5 on a scale developed by the Society of Automotive Engineers. Here is how the scale breaks down

LEVEL 0
No autonomous features, may have automatic gear shift. *Most cars currently on the road*

LEVEL 1
Some autonomous features, e.g. automatic braking, cruise control. *Many newer car models*

LEVEL 2
Automated steering, braking and acceleration, but requires human oversight. *Tesla Model S, Mercedes-Benz 2017 E Class, Volvo S90*

LEVEL 3
Car can monitor its environment and drive autonomously, but may request human intervention at any time. *Audi A8 (2018), Nissan ProPILOT 2.0 (2020), Kia DRIVE WISE (2020)*

LEVEL 4
Car can drive independently but may request human intervention in unusual conditions, e.g. extreme weather. *Volvo (2017), Tesla (2018), Ford (2021), BMW iNext (2021)*

LEVEL 5
Car can drive independently in all conditions.

"Part of the problem with a rules-based approach is that often there are no rules"

AutoNOMOS labs, an autonomous vehicles research effort funded by the German government.

Sometimes the hazards are clear, says Nick Reed, leader of the GATEway project that will trial driverless shuttles along pavements in Greenwich, London, early this year. Part of the route they are testing involves a riverside path. "We definitely don't want the vehicle swerving left into the Thames," says Reed.

Moral drivers

Not everything is that obvious. Consider the only death so far linked to driverless technology, last May. It happened because Tesla's Autopilot system failed to detect that the whiteness ahead wasn't part of a bright spring sky, but the side of a trailer. A human might have made that mistake too, but sometimes driverless vehicles make a hash of things we master intuitively. "One of the things AutoNOMOS cars have struggled with is someone walking behind a parked bus," says Rojas. A human mind would expect them to reappear, and supply a pretty accurate estimate of when and where – but for a driverless car, that's an extrapolation too far.

Even if a sensor system allows an autonomous car to assess its environment perfectly, the second step to driving in a morally informed way – taking the information gathered, assessing relative risks and acting accordingly – remains an obstacle course. "At a basic level, it's about setting up rules and priorities. For example, avoid all contact with human beings, then animals, then property," says Lin. "But what happens if the car is faced with running over your foot or swerving into an Apple store and causing millions of dollars in damage?"

Part of the problem with such a rules-based approach is that often there are no rules – at least, no single set that a sensor system based purely on obvious physical cues could hope to implement. For one thing, they can't compute societal cues we all rely on when driving (see "Read my mind", right). For another, the information a video camera or radar echo can supply is limited. "Detecting a bus is one thing, detecting that it is full of schoolchildren is more difficult," says London.

Technologically, it's probably doable. A human intervention might program in details of the number and age of the passengers to be broadcast to surrounding vehicles, or sensors inside the bus might autonomously track its weight, including whether a person is sitting in a particular seat, says Lin. But who decides a hierarchy of what lives are worth, and how do we eliminate discrimination and bias in how the cars are programmed?

There's one way to avoid such thorny moral questions, says Lin: simply ignore them. After all, a human driver is likely to know nothing about those in the vehicles around them. "We could avoid some ethical dilemmas by being deliberately blind to certain facts," says Lin. This "veil of ignorance" approach amounts to developing responses to simple versions of likely situations, either by preprogramming them or letting the car learn on the job.

The first approach suffers from the problem that it is pretty much impossible to anticipate all possible scenarios – for example, an encounter with a woman in an electric wheelchair chasing a duck into the road with a broom, as recorded by a Google car in 2014. The second approach seems more promising. A car might learn as it goes along, for example, that jaywalkers are more likely to be found on city streets than country roads, but that swerving to avoid one on a quiet country road brings less likelihood of hitting something else. Or it might learn that it's OK to break the speed limit occasionally to make way for an ambulance.

But basic rules still need to be programmed, and whole new ethical issues also arise, says Millar: a programmer will not be able to predict what exactly a car will do in a given situation. We don't want autonomous vehicles to act unpredictably. Just as it's important for cars to predict the actions of human road users, so it matters for people to be able to anticipate a car's behaviour. Hence the question of what an autonomous car will do when it encounters that trolley-problem-like dilemma.

But fixating on such an extreme case probably doesn't help, says Rojas. "Who has ever experienced that situation? It's one possible situation in a million days. We first need to solve 99.9 per cent of the more pressing problems" – things like how to avoid pedestrians, stay within a lane, operate safely in bad weather, or push software updates to cars while safeguarding them from hackers. Millar agrees, but says that's not what the thought experiment is about. "It's just used to illustrate the point that engineers don't have the moral authority to make all the decisions in their cars," he says.

At the moment, companies such as Tesla and Google – which recently announced a withdrawal from building its own cars in favour of supplying software to other manufacturers – work on algorithms behind closed doors, but there are growing calls for

GOOGLE

Google's driverless cars have encountered groups of people playing leapfrog (top) and a wheelchair user chasing a duck with a broom

READ MY MIND

The traffic light at the junction is red, but a police officer is gesturing for you to advance. Or at least that's what you think at first, before wondering whether it's just a drunkard waving his arms about.

Driving safely requires us to constantly judge other people's actions – a very human capability known as theory of mind. Imagine you're at an intersection and it's not clear who should go first, says David Danks, who teaches psychology and philosophy at Carnegie Mellon University in Pittsburgh, Pennsylvania. "You creep out a bit. Then someone waves and you go all the way through." You understand that, having signalled, the other driver will wait until you have gone past before moving off.

Programming this ability into cars has proved challenging. "A 4-year-old has more theory of mind than a driverless car," says Danks. Reliably recognising what mental states are encoded in facial expressions or bodily movements is way beyond even cutting-edge tech.

We need to change that before autonomous cars hit the road big-time, says Christian Gerdes of Stanford University in California. "If the car is looking at the scenario very differently than a human being, it may take an unexpected action," he says. Gerdes thinks there may be a lesson in the way people with Asperger's syndrome or some forms of autism observe social behaviours adopted by individuals without autism, so as to reproduce them in the appropriate situation. Implementing this strategy in an autonomous vehicle, as with much else in the field, would rely on one thing: more data.

transparency and common standards. "We need to move towards some consensus as to what solutions are acceptable," says Christian Gerdes of Stanford University in California. He headed a US Department of Transportation team that, last September, produced the first Federal Automated Vehicles Policy. It sets out decision-making ethics as one of 15 points the developers of autonomous vehicles should address, and calls on them to be transparent about their work on algorithms that "resolve conflict situations". It also urges companies to consult to come up with solutions that are "broadly acceptable". "We're not really trying to program ethics, but to program ethically," says Gerdes. Similar calls are being made in the UK. Autonomous vehicles "cannot be expected to make moral decisions around which society provides no agreed guidance", as Tim Armitage of the industry consortium UK Autodrive put it in a white paper compiled last month by law firm Gowling WLG.

Not perfect, just better

Only Apple has publicly commented on the US guidelines so far (and so acknowledged its own driverless car programme for the first time), urging that "data sharing should not come at the cost of privacy." But, Gerdes stresses, "The intent isn't for companies to reveal proprietary information. It's to have enough openness about how cars are programmed to manoeuvre around and respect vulnerable road users."

That's a start, but no solution will be perfect, warns Nick Bostrom, a philosopher at the University of Oxford and director of its Future of Humanity Institute. "We should accept that some people will be killed by these cars." That's where we also need to put things in context, he says. In 2013, car crashes killed nearly 1.3 million people around the world, injuring up to 50 million more. Nine in every 10 accidents result from human factors: a moment's distraction caused by reading a text message or yelling for the kids to behave, or falling asleep because of monotonous motorways. "Our challenge isn't to build the perfect system," says London. "It's to build a system that is better than the one we have now."

In Brian Wood's case, the 21-year-old driver of the oncoming Chevy had been distracted by taking off her sweater. Had her car been fully autonomous, it seems likely Wood would be alive today. In ensuring morals rule on the autonomous road, we may find ourselves meeting driverless vehicles halfway. ■

Sandy Ong is a science writer based in New York City

Reflections of my year on Mars

How will the first settlers to the Red Planet get on? **Sheyna Gifford** should know, after surviving a year-long NASA simulation

How did you and five crewmates end up living on a volcano in Hawaii?
NASA wanted to know what happens, psychologically and socially, when you send six people off to live isolated on another planet – how we work together, how we respond to stress, how well we communicate with Earth. It was their longest-running Mars simulation, called the Hawaii Space Exploration Analog and Simulation (HI-SEAS) mission. For 366 days up to August 2016, six of us lived in a geodesic metal dome.

Who was with you in the dome?
Our group consisted of the commander, science officer, engineer, biologist, architect and me, the medical officer. We wore digital badges that monitored our interactions. For the most part we were lab rats, but we also did our own science, looking at the mountain's geology, testing our hydroponic food-growing techniques and studying our own microbiomes.

How was the mission like living on Mars?
Our communications with the outside world were all delayed by 20 minutes, just as they could be between Mars and Earth, depending on their relative positions in space. We couldn't use phones or Skype. Every time we went outside the habitat, we wore spacesuits. We didn't see another soul for a year.

Did people fall out with each other?
We had some personality differences, but when times were tough we stayed together because we were all professionals. Working on our assigned duties and focusing on the mission kept the group unified. That was a big lesson.

What challenges stick in your mind?
The hardest part was the second quarter, when we were low on power and food. Due to administrative problems, we didn't get a promised resupply – we were down to two kinds of dried vegetables, spinach and kale, and nobody wanted to eat them. And it was extremely cold. Morale was low, but on a mission like this, there will always be a trough.

There was a permanent fallout of our second-quarter blues: we developed a culture of staying in our rooms alone whenever it was cold. That habit never changed.

Did things turn for the better?
We got a resupply at Christmastime that included a third battery, so even when the days were short the lab could run for a day and a half on one day's charging with our array of solar panels. Everything was suddenly great – we turned the heater on and started cooking. On Hannuka I cooked and taught everyone how to play a traditional Jewish game.

"I took my tomato and smelled it like a maniac for 10 minutes"

How did you celebrate festivals on "Mars"?
That's an interesting question – what meaning would Christmas have on Mars anyway? It's not connected to Martian seasons or to anyone who ever lived or died on Mars. Instead of Christmas, we celebrated a sort of non-denominational holiday.

But our first Martian holiday was in honour of our first tomato harvest. Our astrobiologist spent months raising those tomatoes. They grew out of bottles, hydroponically, because we had very little soil, just like on Mars. We each got one. We set out plates, sprinkled over dried parsley, lit candles and showed up nicely dressed for our one tomato. We called this holiday the Jour de la Grand Tomate – Day of the Great Tomato. That was the first fresh tomato we'd had in at least four months.

I took my tomato and smelled it like a maniac for 10 minutes – it smelled like a whole hothouse of tomatoes. When I finally tasted it, it burned my lips. There wasn't anything wrong with it, there was something wrong with my lips. We didn't have any acidic food; we had been eating powdered tomatoes. I had to eat the tomato carefully.

Did you miss family and friends?
Hugely. Getting email from them was essential to my well-being. I watched as crewmates who did not have that support suffered. Just having that email arrive is critical – it's proof that you still exist and still matter.

PROFILE
Sheyna Gifford served as chief medical officer on NASA's Hawaii Space Exploration Analog and Simulation mission. She is now scientist-in-residence at the Saint Louis Science Center, Missouri

CARMEL JOHNSTON

Based on your experiences, what sort of outlook would the first Mars colonists develop?
If you took someone born and raised on Mars and dropped them in Times Square, they would freak out at the amount of electricity being used for no good reason. Probably all the electricity we produced in a day would be burned in seconds. Earthly trash cans are full of things we Martians would never throw away. We either reuse it or melt it down and 3D-print it into something else. We don't value stuff on Mars except in terms of its utility. Money is useless, and the only thing that matters is how smart, sane and capable you are.

What was it like being the chief medical officer?
The job of a doctor gets redefined. You go back to being like the old town doctor who goes around talking to people about their health, trying to keep them from getting sick. Once they get sick, what you can do is limited.

A space doctor begins each day with a prayer that they won't have to do their job that day. We were lucky – only one person got seriously hurt during the mission, and it was me. I was exploring the local terrain when a lava tube collapsed on me and I hurt my knee.

You also experimented with virtual reality. What was that all about?
NASA want to know if VR can help with some of the loneliness or boredom when you're living in a distant dome. They created an immersive experience on Earth using a 360-degree camera and recorded audio, and then we could step into it using equipment in the dome. The VR took me to Boston. I put the goggles on, and I was suddenly standing back on a familiar street. People were looking at me – they had been recorded approaching the VR camera, gesturing at it. It was like I had been physically beamed back to Earth. That would be a great way to use VR on Mars.

The day I participated in that experiment, my grandmother passed away – expectedly. The communication delay couldn't be turned off because it wasn't a crisis situation under the rules of our mission. So I had to say goodbye to her over delayed video, which is something you never want to do.

Some might argue it's better to send people with less to lose into space. Would you agree?
The question is more basic: do you send social or asocial people? I say send people with the largest number of earthly attachments, for several reasons. One, if crew relationships go to hell, they'll turn back to their support network. Two, they will fight like crazy to get back; they will hold the ship together. Three, which might be the most important reason: people on Earth want to come too, but they can't. So you want super-social citizens of the world who constantly send messages back. We should send people who have lived in multiple countries, have practised multiple religions and are as flexible as possible. You're not up there for you, after all. You're up there for Earth. ■

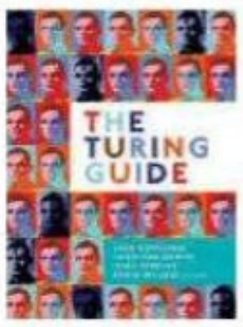
Interview by Conor Gearin

All around Turing

An enormous and probably definitive guide to the life, times and genius of Alan Turing captures for the first time his extraordinary diversity, says **Andrew Robinson**

NATIONAL PHYSICAL LABORATORY (C) CROWN COPYRIGHT/SCIENCE PHOTO LIBRARY

The Turing Guide by Jack Copeland, Jonathan Bowen, Mark Sprevak and Robin Wilson, Oxford University Press



DURING the 20th century, any book calling itself *The Turing Guide* would have been inconceivable. But in 2017 we have a massive and extraordinarily wide-ranging volume about the life, work and influence of mathematician Alan Turing. This is despite his achievements being shrouded in official and personal secrecy at the time of his death in 1954, aged 41, and for decades afterwards. The new guide is the work of four editor-writers: Turing historian Jack Copeland, computer scientist Jonathan Bowen, philosopher Mark Sprevak and mathematician Robin Wilson.

In the 1960s, Turing was known only to a few mathematicians, computer scientists and philosophers – and to one science-fiction writer, Arthur C. Clarke. In his 1962 book *Profiles of the Future*, Clarke showed himself well informed about the Turing test for machine "thinking", noting that: "An electronic brain that passed this test would, surely… be regarded as an intelligent entity" – like the computer HAL that Clarke would soon imagine in *2001: A Space Odyssey*.

Turing encapsulated his own test in a humorous human-computer "conversation", quoted in *The Turing Guide*. Human: "In the first line of your sonnet which reads 'Shall I compare thee to a summer's day', would not 'a spring day' do as well or better?" Computer: "It wouldn't scan." Human: "How about 'a winter's day'? That would scan all right." Computer: "Yes, but nobody wants to be compared to a winter's day."

But Clarke on Turing the man was (given the time of writing) much less well informed. He was a "brilliant mathematician" who "first indicated how thinking machines might be built" and then "shot himself a few years after publishing his results".

Only between the 1970s and 2000 did a truer picture of Turing start to emerge, with the gradual declassification of the UK's wartime codebreaking effort at Bletchley Park, and the publication in 1983 of *Alan Turing: The enigma*. This was an eye-opening biography by Andrew Hodges, a mathematician and gay rights activist, who provides a brief foreword to *The Turing Guide*.

A man of parts

This new version of Turing came in three parts. First, there is the theoretical founder of modern computing, with his 1936 paper "On computable numbers". Then, there is the brain of recent plays and movies, which mostly focus on his key role in codebreaking, beginning with cracking the Enigma code in 1941 using the bombe, a machine he co-invented. Last, we have the man convicted of homosexual practices in 1952 and forced to take female hormones, and who fatally ingested cyanide at home probably by biting into a poisoned apple: a possible, but certainly not provable, suicide.

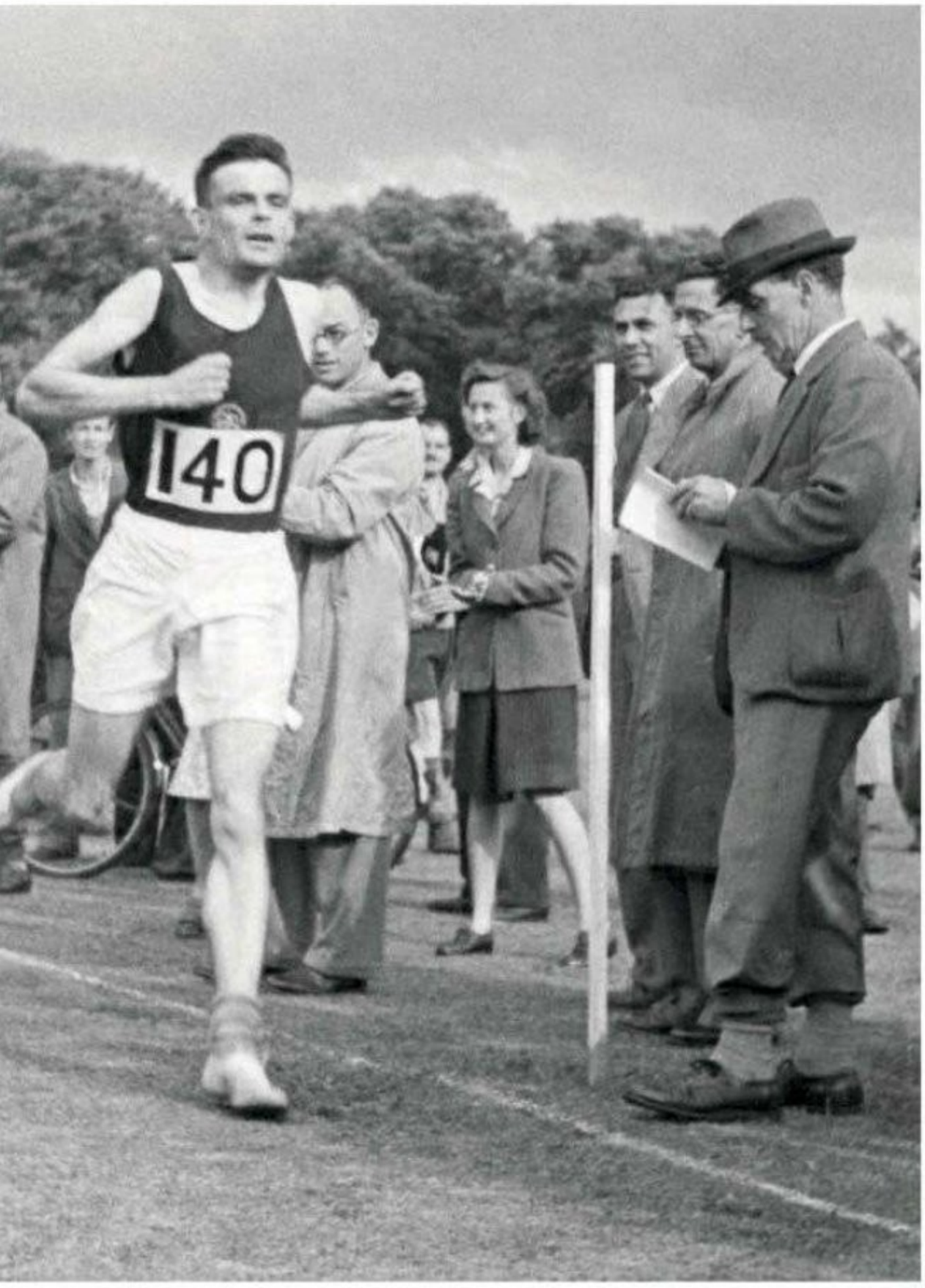
In 2009, Turing received a posthumous apology from the prime minister for this shabby treatment; in 2012, an extensive centenary celebration; and in 2013, an official pardon from the Queen.

Today, he is widely known as an intellectual warrior and has become something of a cult figure. Steve Jobs wanted his company's bitten-apple logo to be associated with Turing's love of apples. And in 2015, staff at the UK's monitoring centre GCHQ queued out of their Cheltenham building to get an exclusive GCHQ copy of a new biography, *Prof: Alan Turing decoded*, by his nephew John Dermot Turing, who contributes a chapter in the guide.

Turing still lacks the final accolade of a statue in central London to complement that of his ultimate boss, Winston Churchill, who called the codebreakers "geese that laid the golden eggs – but never cackled". As the editors write pointedly in their preface: "It is no overstatement… without Turing, the war would probably have lasted longer, and might even have been won by the Nazis."

A handful of the guide's 33 contributors worked at Bletchley and knew Turing personally. Their reminiscences can be fascinating, funny, even moving. Captain Jerry Roberts, for example, was a graduate student of French and German who worked on Tunny, Adolf Hitler's code for communicating with his top commanders that Turing broke using a technique nicknamed "Turingery". Roberts writes: "I have a strong mental image of him walking along the corridor in one of Bletchley Park's Huts. With his gaze turned downwards, he was a shy and diffident man, flicking the wall with his fingers as he walked… he was not a warrior king. But at that juncture, he was the most influential man in Europe bar none, and we owe our freedom to him."

Mathematician Peter Hilton worked on Tunny as an 18-year-old undergraduate. He recalls the priceless story of how Turing unexpectedly volunteered for the local Home Guard so he could become a first-class shot with a rifle. However, when filling in the standard application, Turing took



SSPL/SCIENCE MUSEUM/GETTY

Turing became an accomplished runner (left); after the war, he worked on the early computers

the logical precaution of writing "No" against the question: "Do you understand that, by enrolling in His Majesty's Local Defence Volunteers, you render yourself liable for military discipline?"

When he failed to show up for parades and was court-martialled, the colonel asked him: "Do you realise this is a very serious offence?" Turing calmly referred to his application. The colonel read it, then said, apoplectically: "You were improperly enrolled. Get out of my sight!"

On the German side, such military rigidity often supplied valuable clues to the British codebreakers. For instance, the tendency of Tunny operators to repeat a message that had gone wrong in transmission, without changing the wheel settings on their encryption machine, offered the codebreakers two not-quite-identical messages for comparative analysis. They termed these "depths", as Copeland explains in his chapter, "Tunny: Hitler's biggest fish".

Of the book's 42 chapters, Copeland contributes eight that he wrote alone and eight written with others. Bletchley veterans aside, most contributors are, like the editors, academics working in mathematics, computer science, cognitive science, artificial intelligence, philosophy – and biology. Including the latter specialism was just as well because Turing's final work, his 1952 theory of morphogenesis, concerned the chemical basis for the evolution of patterns in nature, such as animal stripes, and the concept of artificial life.

There are, meanwhile, plenty of surprises. For example, a literature professor describes Turing's interest in the paranormal, which led him to claim in 1950 that "the statistical evidence, at least for telepathy, is overwhelming"; and there is Turing the composer, responsible for some of the earliest computer music, recorded by the BBC in Turing's Manchester labs.

"Turing was the most influential man in Europe bar none, and we owe our freedom to him"

Meaning of genius

Has anything significant been omitted from this authoritative collection? More reflection about Turing's impact on gay rights might have been welcome. So would a separate chapter on the nature of his "genius", given that the term is applied to Turing by so many of the contributors. Indeed, Copeland and Bowen finish their engaging and informative introductory chapter by describing Turing as a "shy, gay, witty, grumpy, courageous, unassuming and wildly successful genius". Very true – but which of these adjectives also apply to other geniuses in mathematics, physics and invention, and which are unique to Turing?

Considering my admiration for most of the guide, it may seem odd to recommend Turing newcomers to start with Hodges's book. But it makes sense: his biography has little mathematics, and largely non-technical accounts of codebreaking. *The Turing Guide,* on the other hand, varies enormously, from the wholly biographical to the highly technical – with the latter particularly apparent when describing Turing's contribution to mathematics and codebreaking. Graduate to it.

Once you do, you will find the whole Turing (or as much as we can ever know). Inevitably for a collection and with someone of such diverse achievements, and unconventional personality and personal life, there will be many voices and angles on the same aspects of Turing, and repetition.

But it is, I think, pretty much the last word on the subject. And it will ensure that while we may never decode the whole of Turing's mind, his name will never again be forgotten. ■

Andrew Robinson is author of *Genius: A very short introduction*

The year is 2017...

Books will no longer call language an instinct, we will grapple with gravity, blow kisses at infinity, build a tame fox – and stop lazily tolerating sexism. Please...

Gravity's Kiss: The detection of gravitational waves *by Harry Collins, MIT Press*
On 14 September 2015, scientists detected ripples in space-time, confirming a major prediction of Albert Einstein's 1915 general theory of relativity. There's no shortage of books celebrating the find, but Collins, a sociologist of science at Cardiff University, UK, has followed the hunt for gravitational waves for over 40 years. This book should crown his efforts to understand how humans use science to grapple with the edges of the knowable world.

One Thousand and One Fossils: Discoveries in the desert at Al Gharbia, United Arab Emirates *by Faysal Bibi, Andrew Hill and Mark Beech, Yale University Press*
Berlin-based palaeontologist Faysal Bibi and his co-authors reveal a world of lush greenery some 7 million years ago, when Arabia's Empty Quarter was full of all manner of mammals, now lost. It promises to be a scholarly volume, but is packed with colour photographs and meticulous reconstructions. Perfect for armchair time travellers.

How to Tame a Fox (and Build a Dog): Visionary scientists and a Siberian tale of jump-started evolution *by Lee Alan Dugatkin and Lyudmila Trut, University of Chicago Press*
In the late 1950s, Russian geneticist Dmitry Belyaev set out to trace how domestication alters wild animals. In a country that had outlawed genetics for a decade, his cover was that he was breeding foxes for the fur trade. His investigation was an extraordinary success: within just two or three generations, Belyaev's fox cubs were beginning to behave more like dogs, wagging their tails and eagerly licking


GETTY

the researchers. US evolutionary biologist Lee Alan Dugatkin and Russian geneticist Lyudmila Trut explore the experiment's implications.

The Imagineers of War: The untold story of DARPA, the Pentagon agency that changed the world *by Sharon Weinberger, Knopf*
Many of us have a vague idea about the internet having its roots in defence spending, but no hard specifics about the agency involved. This is it: the covert Defense Advanced Research Projects Agency (DARPA), which has shaped technology and war in secret for nearly 60 years, providing solutions to Pentagon challenges. The astonishing story, told by a journalist, reeks of the cold war. The internet aside, DARPA's "successes" (Agent Orange, self-driving cars) depend on perspective. Its failures are easier to agree on: who on earth proposed powering a missile-seeking particle beam by draining the Great Lakes?

Your Brain is a Time Machine: The neuroscience and physics of time *by Dean Buonomano, W. W. Norton*
Our experience of time is not the same as time itself; the former is largely our creation. French philosopher Henri Bergson once publicly debated this point with Einstein – and lost. If only he'd had recourse to this book, written by one of the first neuroscientists to ask how the human brain encodes time. Take that, Albert!

"Within just two or three generations, Belyaev's fox cubs were beginning to behave more like dogs"

Testosterone Rex: Myths of sex, science, and society *by Cordelia Fine, W. W. Norton*
With all deep and bloody controversies (racial differences, IQ, male vs female smarts, etc), it is vital to keep up with the nuances of the latest research. Good writers such as Cordelia Fine remind us of that, and she finds engaging ways to serve it up – while we wait for the consensus to shift.

Beyond Infinity: An expedition to the outer limits of the mathematical universe *by Eugenia Cheng, Hachette*
As ideas go, they don't get bigger and more beguiling than infinity, with everyone from Zeno (paradoxes) to Georg Cantor (infinite sets of different sizes) weighing in. Mathematician Eugenia Cheng, author of *How to Bake* π, takes us on a journey, checking in first at Hilbert's Hotel, that most unrestful of thought experiments. It wil be interesting to see what Cheng makes of that other little symbol: ∞.

How Language Began: The story of humanity's greatest invention *by Daniel L. Everett, Liveright*
The recent rush for the new frontier in the study of language (Vyvyan Evans's evolutionary account, and Tom Wolfe's bravura takedown of linguistics giant Noam Chomsky) gathers pace this year with a book by Daniel Everett, the man Wolfe called an "instant folk hero". Everett, no believer in language instincts, argues that *Homo erectus* invented language and symbols, and that culture and language together are the pillars of human cognition. ■

From the deepest forests of Madagascar to the centre of dark matter research, *New Scientist* is now organising science-centred trips across the globe. Curated by our editors, these exclusive tours are packed with unique insights, natural wonders and opportunities to learn more about science first-hand. We've teamed up with respected, responsible travel partners and engaged local experts and field specialists to join each expedition. Join us on the journey of a lifetime

Journeys of discovery

NEW SCIENTIST DISCOVERY

UNITED STATES

A history of space flight

CHIP SOMODEVILLA/GETTY

Join us on a two-week, action-packed tour in the US with *New Scientist* astronomy and space experts. Covering six states, seven space centres and three museums, you'll enjoy VIP experiences and gain genuine insight into the science and people behind modern space exploration.

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 (after chatting to an astronaut at lunch). Venture into the Spaceport Operations Center at Virgin Spaceport America and interact with crew members. Enjoy talks from astronomer and astronaut-in-training Nigel Henbest (May) or *New Scientist*'s physical sciences editor Lisa Grossman (September).

- From £4030
- Departures: 8 May 2017 and 25 September 2017, 14 days
- Booking info: call +44 (0)203 3089 917 or visit **newscientist.com/travel/spaceflight**

SPAIN

Ancient caves and human origins

AGE FOTOSTOCK/ALAMY

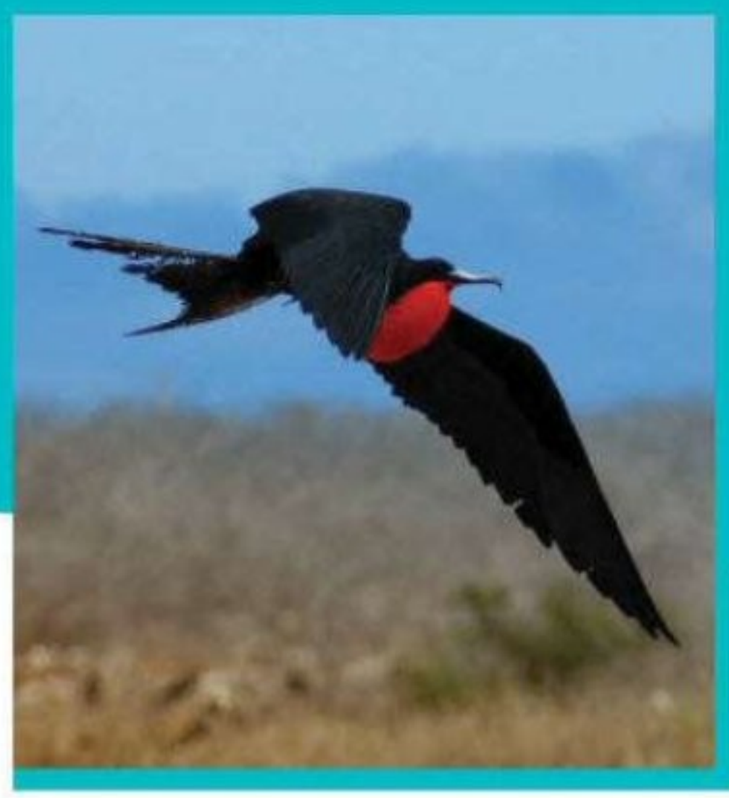
Step over 10,000 years back in time to discover how our ancestors played, lived and worked on an illuminating tour in Spain. On a one-off trip curated by our editors, we'll visit Bilbao for wine-tasting and local food before embarking on a seven-day tour of the caves of El Castillo, Las Monedas, La Peña Cave, El Pindal and Tito Bustillo.

See the oldest known cave painting in the world in El Castillo and experience the wonders of the caves in small groups by torchlight. Accompanied by *New Scientist* features editor Catherine Brahic and local archaeology experts, you'll enjoy specialist talks along the way. Round off your trip by creating your very own cave art.

- From £1685
- Departure: 5 September 2017, 7 days
- Booking info: call +44 (0)203 3089 917 or visit **newscientist.com/travel/caveart**

ECUADOR

Darwin's Galapagos



Jump on board our *New Scientist*-chartered boat for a magical voyage through the Galapagos Islands. Accompanied by Jonathan Green, a naturalist, photographer and diver based in Ecuador, you'll experience this living laboratory with an expert guide. As founder of the Galapagos Whale Shark Project, Jonathan has devoted years to collecting data and to understanding and ultimately protecting these elusive creatures, which have roamed our oceans for millions of years.

A paradise for natural history, animal and geology lovers, we have curated a distinctive trip which includes an exclusive visit to the Charles Darwin Research Centre, where you will have the opportunity to meet field researchers. Spot blue-footed boobies, explore Buccaneer Cove and step ashore to see Sullivan Bay's incredible volcanic formations. Inspired by Darwin's visit in 1835, we have created a journey packed with learning about the diverse, and often surprising, ecosystem that exists only on the Galapagos Islands.

- From £5775 (includes a direct donation to the Charles Darwin Research Centre)
- Departure: 31 March 2018, 10 days
- Booking info: Call +(44) 0128 560 0129 or visit **newscientist.com/travel/Galapagos**

"A magnificent trip, I'd do it again in an instant"

Viv, Indonesia 2016

SteppesTravel

INDIA

Track snow leopards

STEVE WINTER/NATIONAL GEOGRAPHIC CREATIVE

Endangered, beautiful and elusive, snow leopards are rarely seen in the wild. In an effort to promote their well-being and to offer the chance to glimpse these solitary creatures, we've teamed up with wildlife specialists Steppes Travel and the Snow Leopard Conservancy to offer our readers a one-off itinerary, exclusive to *New Scientist*.

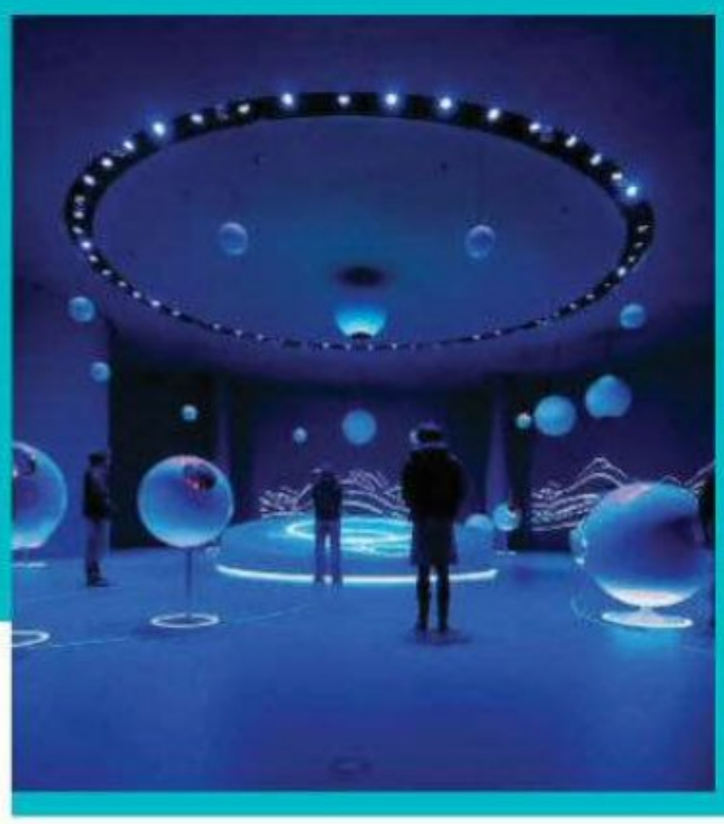
You'll take part in camera-trapping, which is vital for charting these precious creatures, and hear from an expert geologist who has studied the Himalayan area for decades. Explore this wild, mountainous corner of India to spot not only snow leopards but blue sheep, ibex and Ladakhi urial by 4WD and on foot, before returning to the warmth of a local homestay. There will also be a chance to learn about everyday life in rural Ladakh and spend time acclimatising in the beautiful city of Leh. In a small group of like-minded, adventurous people, this special trip is set to be a once-in-a-lifetime expedition.

- From £5295 (includes a direct donation to the Snow Leopard Conservancy)
- Departure: 26 February 2018, 13 days
- Booking info: Call +(44) 0128 560 0129 or visit **newscientist.com/travel/snowleopards**

SteppesTravel

GENEVA

Inside dark matter at CERN



It's the largest particle physics laboratory in the world and discovering the mysteries of the universe is its daily business. With thousands of scientists from every corner of the globe working here on the great questions of contemporary physics, it's the place to visit if you're curious about dark matter, the origins of the universe or the LHC, with its 27-kilometre circumference.

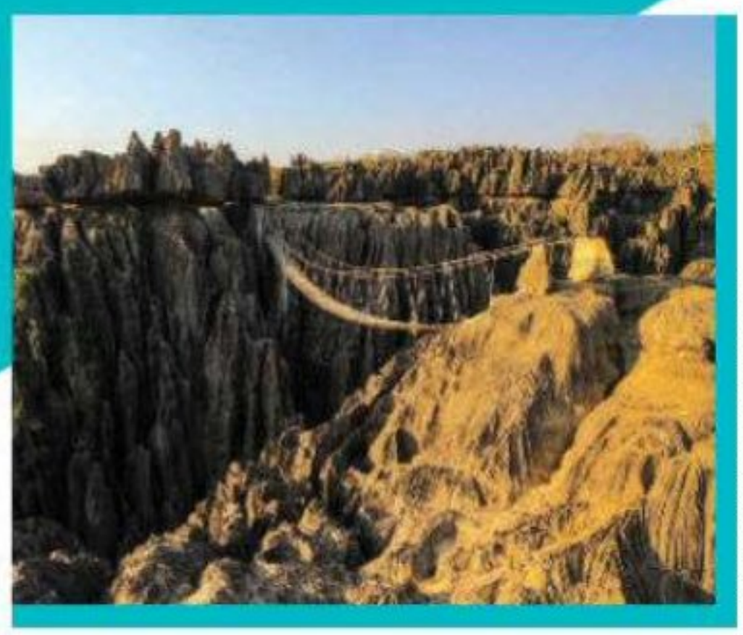
Enjoy a lecture from a *New Scientist* physicist before your visit and experience a simulation of a particle accelerator. We'll also discover the history of Geneva, visiting the Museum of the History of Science, learn about traditional watchmaking at one of the oldest workshops in the city and take Europe's highest cable car up the glacier near Chamonix to see the spectacular panoramic view of the valley below.

- From £1598
- Departure: 8 June 2017, 6 days
- Booking info: Call 020 7593 2283 or visit **newscientist.com/travel/cern**

Kirker

MADAGASCAR

Lemurs, baobabs & the Tsingy park



DENNIS VAN DE WATER/SHUTTERSTOCK

Join us for a very special two-week wildlife tour to experience Madagascar's unique ecosystem. Spend two days with the team at the Durrell Wildlife Conservation Trust, where you'll hear from Richard Lewis about the Kirindy dry forest project, accompany community rangers on a daytime patrol and ,when night begins to fall, join an evening walk to spot the forest's nocturnal occupants (including giant jumping rats). Meet the Lac Bedo community and visit tangled mangroves that provide a vital habitat for a diverse range of plant and animal life. Learn how the endangered, cat-like fossa is being protected after starting the tour in Andasibe where you'll listen out for the ear-splitting indri lemur.

Journey across the island by privately chartered plane to the mind-boggling Tsingy de Bemaraha national park, where you'll study the geology of the rugged limestone fortress and take a walk through the iconic Avenue of Baobabs in the Menabe region. In a group of only 10 people, this is set to be a magical experience.

- From £4995 per person
- Departure: 23 September 2017, 13 days
- Booking info: Call +(44) 0128 560 0129 or visit **newscientist.com/travel/madagascar**

SteppesTravel

ITALY

The science of the Renaissance

L. TOSHIO KISHIYAMA/GETTY

Scientific wonders await. Join us on our next journey

Encounter the great scientific minds and discoveries of the age on an eight-day cultural adventure across Florence, Pisa and Bologna. Led by art and architecture expert Andrew Spira, you'll wander through echoing churches, study extraordinary museum collections and visit hidden Renaissance buildings.
On this distinctive trip, you'll also enjoy a special lecture from *New Scientist*'s editor-at-large, Jeremy Webb. From the Ptolemaic planetarium in the dome of the Old Sacristy, San Lorenzo, to Bologna's Anatomical Theatre, you will be guided through the astronomical, architectural, medical and mathematic discoveries of the period. The trip includes three evening lectures from our experts and four-star hotels throughout.

- From £1795
- Departures: 9 March and 2 November 2017, 8 days
- Booking info: Call +44 (0)20 7251 0045 or visit newscientist.com/travel/renaissance

TRAVEL EDITIONS

These are just a few of the tours that we are running in 2017 and beyond. You could also join us as we:

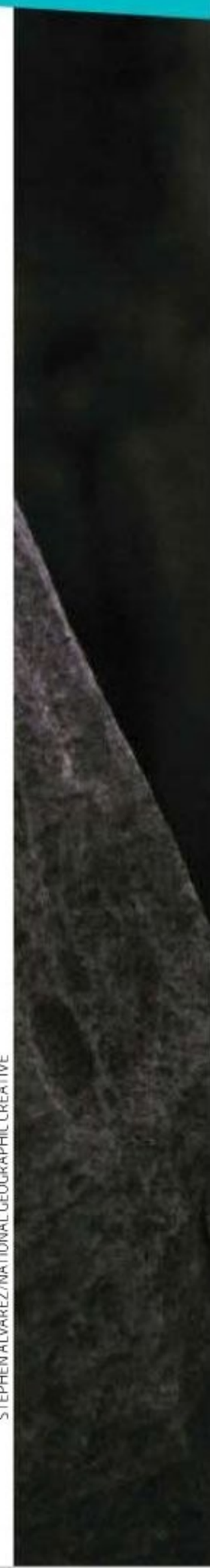
- Visit Japan in winter: visit futuristic Tokyo to hear from innovation experts and chat to a local expert at Yonomine Onsen, where you can take a dip in the astonishing hot springs.
- On an adventure in the land of ice and fire: our previous tours to Iceland have sold out. By day you'll explore lava caves and geothermal power plants, by night you'll look out for the aurora borealis. Due to popular demand we will soon be announcing additional tours for 2017 and 2018.

To find out more about where we're heading next and to give us more suggestions, visit **www.newscientist.com/travel/discovery**

You can also subscribe to our Discovery newsletter to receive the latest information about new trips, as we release them.

Follow us:
Facebook: facebook.com/newscientistdiscovery
Twitter: @NS_Discovery

"A superlatively wonderful experience"
Peter, Alan Turing 2016



STEPHEN ALVAREZ/NATIONAL GEOGRAPHIC CREATIVE

NewScientist Jobs

Incorporating ScienceJobs.com
To apply online visit **newscientistjobs.com**

East Coast Office, 50 Hampshire Street, Cambridge, MA 02142
Email NSSales@NewScientist.com **Phone** 781 734 8771
Calls may be monitored or recorded for staff training purposes

New or recent doctoral recipients with research interests associated with the following are encouraged to submit scholarship applications prior to January 5, 2017.

Departments - Awards related to the following areas are anticipated: Applied Ocean Physics & Engineering; Biology; Geology & Geophysics; Marine Chemistry & Geochemistry; Physical Oceanography; and in cooperation with the USGS laboratory located on the WHOI campus.

Institutes – Each Institute fosters interdisciplinary research addressing critical issues, and we will award a scholarship to support related research: Ocean and Climate Change Institute; Coastal Ocean Institute; Ocean Exploration Institute; Ocean Life Institute

The National Ocean Sciences Accelerator Mass Spectrometry Facility (NOSAMS) will award a fellowship in the development and implementation of new techniques in marine science radiocarbon studies.

A joint USGS/WHOI award will be given to a postdoc whose research is in an area of common interest between USGS and WHOI Scientific Staff. The individual will interact with both USGS and WHOI based advisors on their research.

Awards are competitive, with primary emphasis placed on research promise. Scholarships are 18-months with an annual stipend of $58,500, a research budget and eligibility for health and dental insurance. Recipients are encouraged to pursue their own research interest in association with resident staff. Communication with potential WHOI advisors prior to submitting an application is encouraged.

Further information may be obtained at:
www.whoi.edu/postdoctoral

An Equal Opportunity/ Affirmative Action Employer

WOODS HOLE OCEANOGRAPHIC INSTITUTION 1930

USP
THE UNIVERSITY OF THE SOUTH PACIFIC

UNIVERSITY OF THE SOUTH PACIFIC

Faculty Of Science, Technology And Environment

Seeks applications for the following positions:

Lecturer/Senior Lecturer in Biology
School of Biological and Chemical Sciences – FBI008
Deadline: 13 January 2017

Deputy Director IAS
Institute of Applied Sciences (IAS) – FIA079
Deadline: 10 January 2016

Lecturer/ Senior Lecturer in Coral Reef Ecology
School of Marine Studies - FMS073
Deadline: 31 December 2016

Lecturer/ Senior Lecturer in Maritime Transport
School of Marine Studies - FMS087
Deadline: 31 December 2016

Apply online at: www.usprecruits.usp.ac.fj

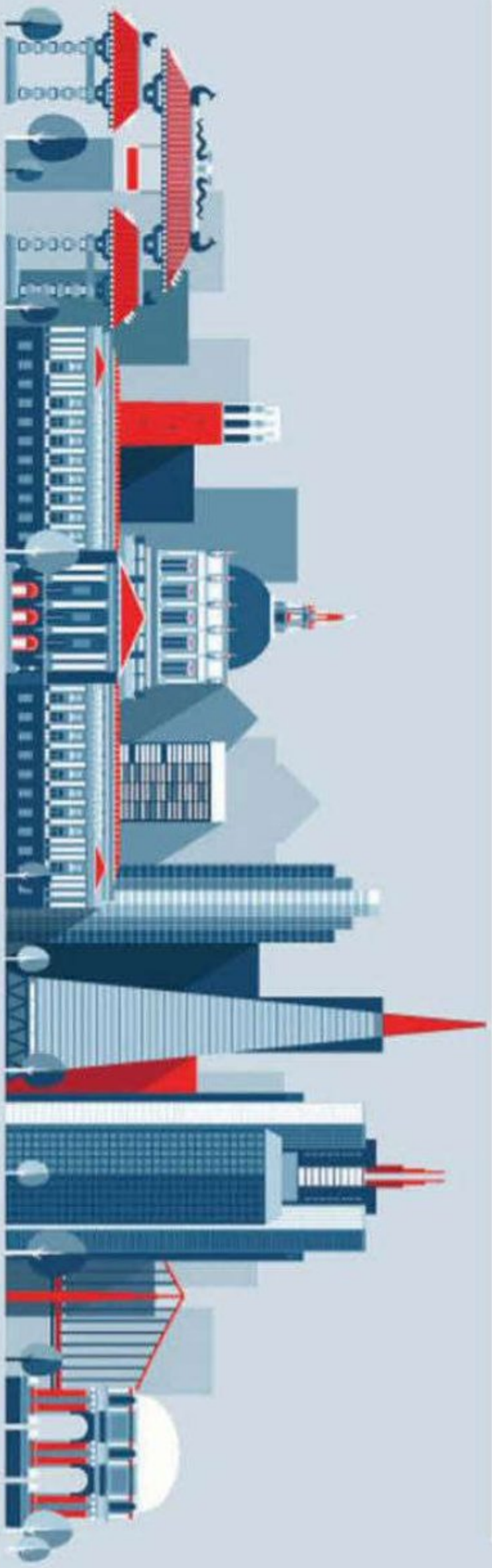
The University of the South Pacific is one of two regional universities in the world and is the leading tertiary education provider and research facility in the South Pacific. We are supported by 12 Pacific Island Countries; Cook Islands, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu and Vanuatu.

oSTEM®

OUT IN SCIENCE, TECHNOLOGY, ENGINEERING & MATHEMATICS, INCORPORATED

2017 Conference

CHICAGO



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

EDITOR'S PICK

Will no one think of the aliens under fire?

From Ben Haller, Ithaca, New York, US

We seem to be making progress toward building space probes that can travel near the speed of light and reach Proxima Centauri in just 20 years (15 October 2016, p 7). This is a nifty idea, but it might be worth pausing to consider what this would look like from Proxima Centauri's perspective.

We would be hurling near-light speed projectiles at their system. If one hit a planet by sheer bad luck, it would detonate with considerable force. If our theoretical probe has a mass of 5 kilograms, its kinetic energy at 60 million metres per second, "only" a fifth the speed of light, would be about 10^{16} Joules. That's twice as much energy as a 1-megaton atomic bomb – fairly large as atomic bombs go nowadays.

Any intelligent life along the path travelled by one of these probes, from Proxima Centauri onwards across the universe may deem our actions criminally negligent at best, if not an act of war. Maybe we should be patient, wait a little longer for our technology to develop, and think of a better plan.

Who's afraid of artificial intelligence taking over?

From Greg Nuttgens, Porthcawl, Mid Glamorgan, UK

Toby Walsh suggests that the much-discussed world takeover by self-replicating artificial intelligences is unlikely (19 November 2016, p 30). I would go further and suggest that such a scenario is impossible.

For a machine to replicate itself, it must extract the materials needed to manufacture itself, establish a supply chain, and set up factories and assembly plants. Even if such a thing were possible, the machines would have to be set up by humans to carry out these functions, and why would we even consider setting them up to do so?

Also, machines need energy to work. If they get out of hand, surely all we need to do is switch them off?

From Joseph Oldaker, Nuneaton, Warwickshire, UK

Why does no one mention hardware in these articles on how AIs may supersede humans? What substrate made of what materials are these intelligences running on? Is the power source 100 per cent reliable? Do they have a temperature-controlled environment that would need to be fail-safe?

It would be instructive to see an analysis now of all the materials, processes and supply chains required to build and run a super computer from the ground up.

From Allan Paxton, Brisbane, Queensland, Australia

Stephen Hawking's fear that "the development of full artificial intelligence could spell the end of the human race" joins history's long list of doom-sayers vexed by revolutionary innovation.

"Sounds like an excuse for men to continue being overly whiny when they're sick"

Melissa Brown remains sceptical that viruses may have evolved to hit men harder than women (17 December 2016, p 7)

For some, things like the cross-bow, gunpowder, steam power, X-rays and atomic power heralded "the end of life as we know it". Super-AI will surely inject a sorely needed mega-dose of rationalism into human affairs, since it will be unbound by (often psychotic) human bias.

More reasons to fear the collapse of civilisation

From Robert Brayley-Hodgetts, Hove, East Sussex, UK
Your speculative articles on the next 60 years were excellent (19 November 2016, p 30). But Debora MacKenzie, considering the possibility of civilisation collapsing, missed a few simple bets. For example, in countries such as the UK, one of the greatest threats lies in how few days' supply of food we have if global disruption stops food trade.

How long before there are food riots in London?

Second, climate patterns, including rainfall, are shifting as the world continues to warm. Rivers that pass through many different countries will attract the worst of nationalist fervour as different societies use and pollute their increasingly precious water: any bets on the odds of water wars before 2050?

Finally, if current cyber events are any indication, then cyberwarfare will almost inevitably shut down the world wide web, with only small local or city-wide data-grids left running.

On the net benefits of free trade treaties

From Murray Dobbin, Powell River, British Columbia, Canada
Dan Ariely and Vlad Chituc state that there is "virtual unanimity" amongst economists regarding the benefits of free trade (19 November 2016, p 21). But what of the views on particular "free trade" treaties held by economists Joseph Stiglitz and Jeffrey Sachs, *Financial Times* analyst Martin Wolf, or former World Bank chief economist Lawrence Summers? All have been extremely critical of these deals: as Sachs says, they "are mostly investor protection agreements..." They allow corporations to sue governments for any legislation or regulation that affects their profits.

The Canadian government's own Global Affairs department concluded that the Trans Pacific Partnership agreement would, if ratified, permanently increase the country's GDP by just 0.127 per cent, not until 2040. Maybe I misunderstand the concept of "net benefit" but I do have a good grasp of "net loss."

Genetically modified organic food could work

From Edward Anderson, Glasgow, UK
It was fascinating to read of a possible link between gut bacteria and Parkinson's disease, and that it's plausible that pesticides may be a contributory factor (3 December 2016, p 8). In the same issue, Michael Le Page dismisses any health benefits of organic food, as if it is a known fact that pesticides have no impact on our health (p 21).

More work needs to be done to understand the full range of effects that the non-organic methods have. What is the impact of pesticides on surrounding wildlife? How much does it cost us to filter out those pesticides from our water supply? What is the human cost of increased antibacterial resistance caused ›

by intensive farming? Genetic modification is clearly worthy of exploration: but acceptance won't come from attacking organic food. GM can be an ally of organic food if it can be shown to reduce our dependence on pesticides and reduce the quantities of fertilisers and water required. Crops that are resistant to pesticides may increase yields but they are a direct affront to one of the main reasons people eat organic.

I may not turn into Superman by eating an organic apple, but then it's not all about me.

Phones would be safer if 'off' meant 'off'

From Toby Pereira,
Rayne, Essex, UK
That apps, even when "off", can spy on you through your phone's microphone without your knowledge, (5 November 2016 p 22) is disturbing. The simplest and most obvious protection would be for phone manufacturers to include physical on/off switches for microphones and cameras. That way users can ensure these input devices are only on when you explicitly want them to be. Similarly, a physical on/off switch for the whole phone would be much safer and more reliable.

Mystery and explanation of ancient glyphs

From Simon Tanlaw,
London, UK
Genevieve von Petzinger's work on cave art and the mysterious pictographs covered in your article is incredible (12 November 2016, p 36). It raises the question: how did our ancestors manage to standardise detailed pictographs around the globe 30,000 years ago, without any known method of long-distance communication apart from the canoe?

From Phil Stracchino,
Gilford, New Hampshire, US
You print a photo showing "bell shapes" at El Castillo in Spain. That shape, particularly in red and with the centre line present in some of the figures, is instantly recognisable to anyone who has done any significant amount of work with leather. Those are almost certainly slightly simplified animal hides.

These feet are made for walking, not electricity

From Sam Edge,
Ringwood, Hampshire, UK
The old chestnut of generating power from footfalls is back again (5 November 2016, p 23). Saying that "one footstep… yields between 10 and 30 volts" conveys little information. I want to know how much usable electrical energy one footstep generates.

A calculation of the mechanical energy dissipated by an average footstep tells me there is no possible way that this will ever be anything other than a curiosity. The environmental costs of construction and maintenance are going to far outweigh the energy produced.

When your face is a ticket and you have a movie…

From Adrian Bowyer,
Foxham, Wiltshire, UK
The facial recognition system used at the ticketed tourist town of Wuzhen "detects facial movements, so can't be fooled by someone holding up an image of another person's face," Timothy Revell writes (26 November 2016, p 25). That's such a 20th-century image.

What does it do when you show it a movie on a tablet?

Sorted for substances other than alcohol

From Lyn Williams,
Neath, West Glamorgan, UK
Jon White describes young people drinking less (3 December 2016, p 38). But he makes no mention of what they are doing instead, if anything. I suggest, because of the high price of alcohol, they are popping pills instead.

I suspect those promoting a reduction in alcohol use have only done half a job. I suggest more research to clarify.

The editor writes:

■ Some researchers have indeed suggested that "party drug" consumption may be correlated with alcohol price. But it's inevitably difficult to get accurate figures for the former.

TOM GAULD

Warning: this letter may cause hallucinations

From Graham Waddingham,
Colchester, Essex, UK
Helen Thomson reports that "tactile hallucinations are less common than their auditory or visual cousins" (5 November 2016, p 28). I beg to differ. I would suggest that I could induce one in many readers right now, just by asking them to ponder: are you feeling itchy?

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.

OLD SCIENTIST

What was *New Scientist* talking about in Januaries past?

SOLOMON KRUEGER/PLAINPICTURE

LONDON was swinging and even *New Scientist* occasionally delved into affairs as far out as an early Pink Floyd concert. In our 6 January 1966 issue, we reported on "an abstract motion picture projector called Box 3". It was created by artist John Healey and was being used in hospitals for its "psychological effects". Apparently the box could "stimulate or soothe, beguile or inspire" using a non-repetitive, symmetrical, curving coloured pattern. It was proving particularly popular in the maternity ward of University College Hospital, London, where it induced "a state of quiet contentment" in expectant mothers. Well, it was 1966, but presumably even Timothy Leary, enthusiastic promoter of LSD, hadn't expected maternity wards to be listening when he uttered his "Turn on, tune in, drop out" exhortation later that year.

There was another semi-hippy moment in our 8 January 1976 issue when we reviewed a book called *Hallucinations*. Although it mainly considered hallucinations prompted by psychiatric problems or neurophysiological issues, it also gave due regard to the perceptions of the drug-addled mind. Enthusiasts of psychedelia would particularly enjoy the illustration of "associative changes claimed for complex images induced by tetrahydrocannabinol".

In our 6 January 1990 issue, we bust open still more doors of perception. Some people who experienced "lucid dreams" were helping researchers discover more about sleeping brains. Lucid dreaming, we explained, is the state of being asleep but aware you are dreaming. Some dreamers were so adept that they could count to 10 within their dream while signalling to the (awake) researchers the start and end of the count. We also suggested that such dreams might link to the Box 3-style fruitloopery of the 1960s in the form of an out-of-this-world prog rock staple. Alleged UFO abductions, we speculated, might be the result of lucid dreaming. **Mick O'Hare** ■

To delve more into the *New Scientist* archives, go to **newscientist.com/article-type/old-scientist/**

WELCOME to a brand new year! After the litany of disasters that befell 2016, we're hoping to ride a soaring regression to the mean in 2017. No doubt many of you have decided on your New Year's resolutions, and so have we: absolutely no more nominative determinism. And we really mean it this time. None! Don't even think of sending more in. Now, on with the show.

LAST month, British MPs met to discuss the progress of the Department of Health's cancer strategy. Naturally David Tredinnick, Parliament's resident professor of potions, was keen to make his contribution – a word we use rather lightly.

Tredinnick stood to complain that far too much of the UK's squeezed health budget was being spent on treatments that have been proven to work.

Tredinnick also told MPs that Chinese herbal medicine could treat "cervical cancer, non-Hodgkin's lymphoma, HIV, colon cancer, head and neck cancer, breast cancer and prostate cancer".

Feedback suspects that these claims, were they to be expressed outside Parliament, would likely fall foul of the 1939 Cancer Act forbidding the promotion of ineffective treatments. "I believe that several of my constituents are alive today because they have used Chinese medicine," Tredinnick insisted.

WARMING to his theme, the Bosworth MP also heralded the benefits of reiki healing, aromatherapy, reflexology, oxygen therapy, homeopathy and raw food to people with cancer. On the medical power of miracle foods, Tredinnick reminded MPs of the old computing adage "Garbage in; garbage out," sending MP Nic Dakin into fits of laughter. No doubt Dakin was wondering, as we are, what exactly Tredinnick has been swallowing.

LONDON'S Design Museum is celebrating its move into new quarters in Kensington with an advertising campaign encouraging people to visit "the museum that never closes".

Peter Rummer is therefore confused to find these very same posters advising visitors that the building shuts at 6 pm.

IN-FLIGHT magazines are an endless source of delight, Feedback thinks, and Peter Kitchen has the latest gem.

During a trip to Australia, he found an ad for the Made In Earth jewellery company, which claims to create "exquisite silver jewellery set with the finest natural gemstones from all over the world and beyond".

"As an ex-miner of gemstones in Africa," says Peter, "this made me think I should have set my sights considerably higher."

PREVIOUSLY Feedback discussed the creative and comic ways in which titles can get truncated by machines (2 July 2016).

Patrick Fenlon thinks this often results in irresistibly obscure headlines. "I note your online edition has provided another example," he says, "with 'Court orders UK to take urgent action to reduce air…'"

READER Brian King previously complained of ephemeral foods finding their way on to the menu, such as "bunless meat-free burgers" (3 December 2016).

"I remember writing to Rowntree's in York 60 years ago when I was a mere lad," says Chris Smith, "and suggesting that they advertise Polo Mints as 'The mint with the non-fattening centre'."

Sadly Chris's early foray into copywriting was much ahead of its time, and "the mint with the hole" kept being just that.

A PUZZLE that may require some elementary thinking: Mike Lavan writes to ask if it's possible to find celebrities whose names can be spelled using only single letters featured on the periodic table.

"The late actor Bob Hoskins had such a name," says Mike, "though I am not aware that he ever felt inclined to pursue a career in chemistry. Are there any examples of chemists who have elements-only names?"

JANUARY is a time to take stock, if not metaphorically then literally, as many of us prepare to file tax returns.

Pity the headache faced by Jayne Shardlow's accountant, after she received an invoice for a number too large for us to print in full, but which we've rounded up as $\$8.77\times10^{197}$.

Jayne says, "I'm concerned that we don't have sufficient funds." Feedback isn't sure the planet does, either.

FINALLY, Loren Byrne writes to highlight Canada's search for a national bird (bit.ly/ns-birdbrain). She notes that "one of those advocating for the grey jay is none other than an ornithologist named Dr David Bird."

Which of course means our New Year's resolution has also taken flight. Oh well, there's always 2018.

PAUL MCDEVITT

"Of the 25 most-cited physics papers of 2016, 11 are about a particle that didn't exist," Davide Castelvecchi on the hype about the Large Hadron Collider's illusive 750 GeV signal

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.

It's a steel

Why is stainless steel, er, stainless?

■ The simple answer is that it contains at least 10.5 per cent chromium by mass, the sole requirement laid down by the British/European standard for stainless steel.

The more detailed metallurgical answer is that stainless steel is not one specific grade of steel, but a whole family of iron alloys with one thing in common: they all contain at least 10.5 per cent chromium by mass. It is this additional element that enhances their resistance to corrosion. Increasing the chromium content above 10.5 per cent improves this resistance, with the most common grades of stainless steel containing 17 or 18 per cent.

So, how does the protective mechanism work? The chromium and iron atoms that make up the alloy have very similar diameters (about 0.25 nanometres) so they readily intermingle on a common, cubic lattice. In practical terms, this means that the chromium atoms – which comprise at least one in every 10 atoms in stainless steel – are uniformly dispersed throughout the solid metal.

"The film on stainless steel is extremely adherent and inert, and is self-repairing in oxygen"

When these iron/chromium alloys are exposed to oxygen, including ambient air, the highly reactive chromium atoms immediately form a thin, chromium-rich oxide layer on the metal surface that is commonly known as a passive film. Additional chromium atoms migrate from the main body of the steel to the surface to build up this oxide layer, resulting in a protective film that is around 13 to 15 nanometres thick. The passive film is extremely adherent and inert, and, most importantly, is self-repairing in any environment containing oxygen.

Colin Honess
Former UK representative on the European standards committee for stainless steels
Sheffield, South Yorkshire, UK

■ Stainless steel was discovered by accident a little over 100 years ago, just before the first world war. The British army had a problem: its new explosive – cordite – rapidly wore out gun barrels. The search was on for a high temperature, wear-resistant steel – and where better to hunt than in Sheffield, the "city of steel" in the north of England, where Harry Brearley was in charge of the laboratories selected for this work. He followed a promising line, alloying iron with chromium.

The standard way to examine the structure of a new alloy is to polish a sample and then etch the surface with acid so that the crystal structure can be seen under a microscope. Brearley tried to etch his new alloy with nitric acid but found he still had a polished surface. Somewhat annoyed, he tried another acid, but that was no better. After trying several other acids, frustration turned to elation as he realised he had discovered a corrosion-resistant steel.

Being Sheffield born and bred, Brearley knew he was in the right place to exploit this discovery. Sheffield made cutlery. Silver was expensive and too soft for making a knife with a sharp edge, and ordinary steel rusted or stained. The new steel was just what the cutlers wanted. They called it stainless steel.

Robert Senior
Retired from British Steel
Oakham, Rutland, UK

■ The name is a bit of a misnomer because stainless steel can be stained.

The apparent stainless effect comes from adding chromium, with a composition of 18 per cent being common for most household usage, but one of up to 26 per cent being best f or harsher environments. Depending on the desired properties, other metals may be added, such as nickel, which reduces brittleness at low temperatures. Nickel also makes the steel non-magnetic without the need for heat treatment.

When the chromium oxide layer that forms on the surface is broken or scratched, further chromium reacts with oxygen and the layer is repaired. However, staining can occur if the protective layer is broken by aggressive reagents or in a non-oxidising environment.

Heating can also cause discoloration as it leads to uneven oxidation. The varying oxide thickness results in rainbow-like colouring because of interference within reflected light – an effect also seen in titanium.

Joe Geesin
Stourport-on-Severn
Worcestershire, UK

This week's questions

STIRRING UP TROUBLE

My son was vigorously stirring a very hot cup of drinking chocolate as he thought that would cool it down. I said stirring the liquid was adding energy to it. Who is right? If him, what's the best speed to stir at to cool the hot chocolate? And if me, is it possible to heat it up by stirring very fast?

Hamish Steiner
Cooma, New South Wales
Australia

IT AIN'T SNEEZY

I am an amateur singer and during the high season for allergies in Canada I completed three performances of Beethoven's Ninth Symphony. Many singers were unwell but there was not one cough or sneeze on stage. Why is it that once a singer steps on stage, symptoms are seemingly suppressed?

Howard Freeland
North Saanich, British Columbia
Canada

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.

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