

New Scientist

WEEKLY April 1-7, 2017

SPECIAL ISSUE

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Will our knowledge survive us?

How can I tell facts from lies?

Do animals know things?

How much can one person know?

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How much can we ever know?

Can I know myself?

Is everything knowledge?

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PHOTOGRAPHED FOR NEW SCIENTIST BY ATULOKESH PANIGRAHI

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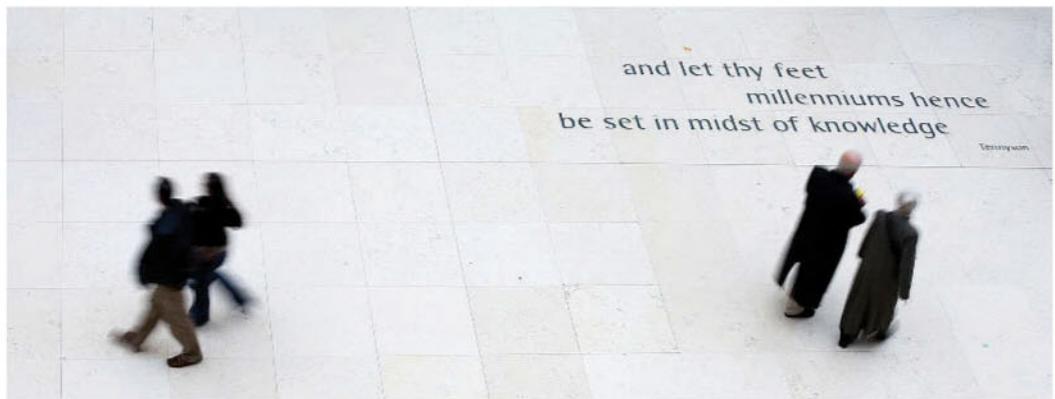
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Who really knows?

Philosophers of knowledge, your time has come

A COMMON refrain heard around *New Scientist's* offices in recent weeks has been "episte... what?!" Even among educated and well-informed people, epistemology – the study of knowledge – is neither a familiar word nor a well-known field of enquiry. But it has never been more important.

Much has been written about the post-truth world in which facts have ceased to exist, or at least to matter. All kinds of forces have been blamed, but one that goes unremarked is that sorting truth from falsehoods is actually very difficult. In an increasingly complex world, it is largely an exercise in taking somebody else's word for it (see page 30).

One obvious example is climate

change. The majority of climate scientists say that the world is warming and that human activity is to blame. How do they know? Should we agree with them?

One person might say that we should: the scientific method is a reliable guide to reality, and climate scientists are trustworthy. But another might argue that science sometimes gets things wrong, pointing to occasions in the past when scientists have fallen prey to groupthink or have been caught hiding data. The line of argument that seems most plausible to someone depends more on their cultural and political affiliation than on knowledge. Rigorous epistemological analysis tends not to come into it.

And herein lies a problem. In the current crisis over truth, epistemology is nowhere to be seen. Instead, we rely on intuition and common sense – what might be called "folk epistemology". The argument thus resembles a debate about medical ethics to which nobody remembered to invite a bioethicist.

Philosophers may be reluctant to enter the public square, afraid of being derided by the post-truthers as yet more "fake news" or tarred with that pejorative term "expert". But epistemology has become one of the most relevant and urgent philosophical problems facing humanity. Philosophers really need to come out – or be coaxed out – of the shadows. ■

Garbage out, garbage in

PLUS ça change. Last year, the UK government dropped a plan to ban a highly secure form of encryption used by messaging services such as WhatsApp. Now this either unworkable or mathematically impossible idea has risen like a zombie.

The home secretary, Amber Rudd, used a TV appearance to relaunch the discredited policy on end-to-end encryption, saying

that there should be "no place for terrorists to hide". Her comments follow the revelation that Khalid Masood used WhatsApp a few minutes before his attack in Westminster.

Rudd's comments are ill-informed at best. End-to-end encryption underpins not just messaging apps but also online shopping, banking and even government websites. Banning

it would cause chaos. In any case, you cannot legislate the mathematics of encryption out of existence. People would still be able to find ways to securely encrypt their messages.

A ban on end-to-end encryption was a terrible, unworkable idea when the previous home secretary proposed it. Theresa May, who has since become prime minister, frequently proved herself to be impervious to evidence. Sadly, Rudd has picked up where she left off. ■



Made in China, but at what cost?

Drug patent battle

A GROUP of charities, led by Médecins Sans Frontières, is fighting to have a drug's patent revoked by the European Patent Office. Sofosbuvir can cure hepatitis C in just three months,

"There are 80 million people in the world with hepatitis C, but only 5.4 million have access to the drug"

but costs up to €55,000 for a course of treatment.

The drug's patent is held by pharmaceuticals firm Gilead of Foster City, California, giving the company a monopoly over the drug in Europe.

"There are 80 million people in the world with hepatitis C, but only 5.4 million have access to sofosbuvir," says Yuan Qiong Hu, legal adviser for MSF's patent challenge. "Revocation of the patent would be a key step towards making generics available."

Generic versions of sofosbuvir are already made in Egypt and India, and bring down the cost of a course of the drug to €185, but

these aren't available in Europe.

Gilead argues that despite the high cost of the patented drug, it saves money in the long run. "Our medicines save the healthcare system money, while curing patients of a deadly disease," says Sarah Swift, director of public affairs at the firm.

MSF will argue that the patent is invalid because it does not contain an "inventive step". Gilead has already had sofosbuvir patents revoked in China, Egypt and Ukraine, and decisions are pending in Russia, India, Thailand, Argentina and Brazil.

Real cost of consumption

CHINESE-made goods bought in western Europe and the US have, in effect, killed more than 100,000 people in China in one year alone – as a result of the air pollution associated with their manufacture.

Microscopic pollutant particles in the air cause millions of deaths worldwide each year. People in countries like China are shouldering the biggest burden – and over a fifth of that burden comes from goods they export. "When we see pictures of terrible smog in Beijing, we have a tendency to point fingers and say they should clean up their stuff," says Steven Davis at the University of California, Irvine. "But that's a little unfair because when you and I go to Walmart and buy a lawn chair, it's a few cents cheaper, and as a result

people are dying in China."

Davis and his colleagues assessed 3.45 million premature deaths worldwide that were associated with particles less than 2.5 micrometres in diameter. Particulate matter that small is mostly produced by burning coal, and exposure can lead to early death from heart disease, stroke and lung cancer.

The researchers showed that 22 per cent of premature deaths related to air pollution in 2007 were associated with goods and services produced in one country and consumed in another. This means that consumption in western Europe and the US was linked to more than 108,000 premature deaths in China in that year (*Nature*, DOI: 10.1038/nature21712).

WhatsApp rebuked

THE debate over encryption has been reignited in the UK after the home secretary, Amber Rudd, said that end-to-end encryption in apps such as WhatsApp was "completely unacceptable".

Rudd spoke following the revelation that British extremist Khalid Masood used WhatsApp a few minutes before launching his attack on Westminster last week. But security experts say any attempt to clamp down on encryption is unworkable. "My impression was that primarily she

doesn't know what she is talking about," says Paul Bernal at the University of East Anglia, UK.

An encryption ban would affect other applications like online banking, while introducing a "back door" for security services would make all users less secure. "Encryption is not just for terrorists, it's for everyone," says Jillian York at the Electronic Frontier Foundation.

In any case, the Investigatory Powers Act lets security services hack a suspect's device to read messages without needing to crack encryption, says Bernal.

Rocket relaunch

SPACEX will relaunch a used booster stage of a Falcon 9 rocket for the first time this week.

Last April, a Falcon 9 rocket booster launched a Dragon cargo capsule towards the International Space Station before landing on a drone ship in the Atlantic Ocean – the first such landing on a boat. Now, the same booster will help carry a communications satellite into orbit.

The launch was scheduled



60 SECONDS

for late last year, but had to be delayed due to the explosion of a Falcon 9 on the launch pad in September.

After a successful test firing on 27 March, the rocket has been cleared for take off on 30 March. SpaceX is reportedly providing this launch for satellite firm SES at a discount from the usual \$62 million price, and CEO Elon Musk has expressed hopes that reusable rockets could cut the cost of sending things to space.

After the launch, the booster will return to Earth, aiming for another landing on the drone ship and another possible reuse.

Trump climate blow

IT POSES a serious challenge to international action to limit warming. As *New Scientist* went to press, Donald Trump was expected to sign an executive order aiming to reverse many of the climate policies introduced by Barack Obama.

Even if all those policies were implemented in full, the US was already set to miss its target for cutting greenhouse emissions under the Paris agreement. If Trump's order succeeds just in part, then – barring an economic slump – the US will probably fall short by a much bigger margin.

Under the Paris deal, countries committed to their own, voluntary emissions targets and also to make more ambitious cuts over time. If the US is flagrantly violating the spirit and letter of the agreement, other countries are less likely to try to keep to it.

It's not yet clear if the US will withdraw from the Paris pact, as Trump has previously said it should. Some think it would be better if the US did pull out, as it could not then block new measures taken under the deal. But the withdrawal of the country responsible for a third of all greenhouse gas emissions since the industrial age would seriously harm the agreement's credibility.

Fix US cyber risks

ELECTRICITY grids and other critical infrastructure in the US have 25 years' worth of fundamental security flaws that need addressing.

That's the main finding of a report by Joel Brenner and his colleagues at the MIT Internet Policy Research Initiative, with input from industry experts.

"Controls on an oil pipeline can use the same hardware as your teenager's computer," says Brenner, who was once inspector general at the US National Security Agency.

Suppliers make the most profit by selling generic hardware and software for multiple purposes, but both come with exploitable security holes.

"We know how to fix the vulnerabilities, but there's no market incentive for companies to do so," says Brenner.

With around 85 per cent of US critical infrastructure being privately owned, the report says the Trump administration could reward companies that improve security – by offering tax breaks. The report also proposes a mandatory minimum security standard for components used.

Join hunt for Planet 9

The search for Planet 9 is going public. In January 2016, a pair of astronomers suggested a hidden planet about 10 times the mass of Earth might exist on the fringes of our solar system. Now you can take part in the hunt, scanning images from the SkyMapper telescope, thanks to the Australian National University and citizen science group, the Zooniverse.

Biggest dino print ever

The world's biggest dinosaur footprints have been found in north-west Australia. They are 1.7 metres across and belong to a sauropod. The site they were found at was a river delta 130 million years ago, with dinosaurs crossing wet sandy areas.

Musk's neural lace

Elon Musk is launching a brain-computer interface company. According to a *Wall Street Journal* report, Neuralink aims to make "neural lace" technology that will put tiny electrodes in the brain, allowing direct communication with machines. A firm called Kernel invested \$100 million last October to develop something similar.

Paralysis breakthrough

A man paralysed from the shoulders down can feed himself thanks to a neuroprosthesis that uses brain signals to stimulate electrodes implanted in one arm and hand. This is the first time such a technique has restored reaching and grasping movements to a person with a chronic spinal cord injury (*The Lancet*, DOI: 10.1016/S0140-6736(17)30601-3).

Tasmanian tiger seen?

Plausible eyewitness accounts of large, dog-like animals in north Queensland have spurred a scientific hunt for thylacines, thought to have died out in 1936. Scientists from James Cook University are setting up camera traps and planning a survey to start this month or next.

Shallow reefs teeter on the brink

UNEXPECTED coral bleaching in the South China Sea shows that shallow reefs can heat up much more than the surrounding ocean. That makes them more vulnerable than we thought, suggesting that efforts to limit global warming to 2°C under the Paris Agreement may not be enough to save tropical reefs.

In June 2015, an El Niño weather pattern led to the South China Sea warming by 2°C – something not expected to cause significant coral damage. However, at Dongsha atoll in the northern part of the sea, the water temperature soared by 6°C above average, killing 40 per cent of the coral.

This spike occurred because the atoll's shallow water amplified the

El Niño effect, work led by Thomas DeCarlo at the University of Western Australia shows (*Scientific Reports*, doi.org/b4wq). What's more, unusually weak winds slowed the spread of heat into the surrounding water, trapping it within the atoll.

"Ocean temperatures are already warming due to climate change," says DeCarlo. "But what we've shown is that on top of that, local weather anomalies or processes like reduced wind can drive reef temperatures even higher."

"The only hope now is to minimise carbon dioxide emissions as much as possible and try to protect reefs as best as we can on a local scale," says Bill Leggat at James Cook University in Townsville, Australia.



In much hotter water than thought

Pregnancy after the menopause

Two women conceived with their own eggs after experimental therapy

Jessica Hamzelou

TWO women thought to be infertile have become pregnant using a technique that seems to rejuvenate ovaries.

It is the first time such a treatment has enabled women with menopause symptoms to get pregnant using their own eggs. "I had given up hope on trying to get pregnant," says one of the women, WS, who is now six months pregnant. "To me, it's a miracle."

The approach uses a person's own blood, isolating platelet-rich plasma, which has a large number of the cell fragments usually involved in clotting. Konstantinos Sfakianoudis and his colleagues at the Genesis Athens Clinic in Greece are using this plasma in an attempt to repair women's reproductive systems, injecting it directly into the ovaries and uterus. So far, the team has given

menopausal," she says. "After the sixth IVF, the doctor said we should stop there, and consider egg donation."

WS received treatment at the Genesis Athens Clinic, then had standard IVF treatment in Germany, which prompted her to release three eggs. The highest quality egg was fertilised, and an embryo was implanted in her uterus. "Everything is going well," she says. "It's a girl".

The other woman, a 39-year-old from the Netherlands, had not had a period for four years, and had been showing other signs of menopause. She had treatment at the clinic in December 2016. A month later, she began menstruating

again, says Sfakianoudis.

She then underwent "natural" IVF, which avoids the use of hormones, and became pregnant.

High hopes

However, she miscarried last week, a few months into her pregnancy. Women between the ages of 35 and 39 have around a one in five chance of miscarriage during the first 12 weeks. "Even with the miscarriage it's extremely encouraging," says Sfakianoudis. He hopes she will try again.

Doctors say the results seem promising, but rigorous trials are needed before drawing conclusions. "Anything that might help ovaries regain function

would be fabulous," says John Randolph at the University of Michigan in Ann Arbor. "A lot of people have high hopes of doing something like this."

The team isn't sure how the treatment might be working. The plasma may awaken stem cells in the ovary, encouraging them to make eggs, but there is debate over whether such stem cells exist. Or the plasma itself may contain stem cells, says Randolph. "We need to figure out how this works and how safe it is," he says.

Simply sticking a needle into an ovary might have an effect, says Claus Yding Andersen at Copenhagen University Hospital in Denmark. Damaging an ovary can change the shape of its blood vessels, which may cause isolated egg follicles to be provided with a blood supply for the first time, enabling them to release eggs.

Sfakianoudis is planning a clinical trial in Greece and the US, comparing the plasma with a placebo injection. Until then, it is impossible to say how well the treatment is working, if at all, says Kutluk Oktay at New York Medical College. Even once menopause starts, some egg follicles remain, so there is a small chance that women can still get pregnant without any intervention, he says.

If it works, the treatment would be particularly welcome to the 1 per cent of women who experience menopause before the age of 40. Menopause usually occurs around the age of 50, and so far, Sfakianoudis's team has not treated anyone over 52. He says it is not his place to judge how old is too old to start a family.

But pregnancy is riskier in older age, says Andersen. "I do think it's questionable whether we should allow women in their 60s and 70s to get pregnant," he says. ■

"Anything that may help ovaries function again would be great. Many have high hopes of doing this"

this experimental therapy to more than 180 women, many of whom sought treatment because they have a disorder that damages the lining of the uterus.

But the team has also given the treatment to 27 menopausal and peri-menopausal women between the ages of 34 and 51. Some had treatment because they wanted to stop symptoms of the menopause, but most did it because they wanted to get pregnant. Eleven of these women have since had IVF, and two women have managed to get pregnant.

WS, a 40-year-old from Germany, had been trying to get pregnant for more than six years. "The doctor said I was peri-



BSPSA / ALAMY

Fresh fertility

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Mice shared our homes even before farming

THE close relationship between house mice and humans began in the earliest settlements about 15,000 years ago – before the advent of farming that made our crops such a draw for the rodents.

"The question that interests us is: do house mice become associated with humans due to farming or before farming?" says Lior Weissbrod at the University of Haifa, Israel. To find out, his team collected 272 mouse teeth from 14 archaeological sites in Israel dating from 200,000 to 10,000 years ago. From these, they identified two species: the house mouse and its short-tailed relative, the Macedonian mouse.

The house mouse first appears in the homes they looked at about 15,000 years ago, displacing the short-tailed mouse. At that time, people called the Natufians started to settle in fixed locations, living in stone houses with hearths and burying their dead. "This suggests the Natufian people were quite deliberately putting down roots, placing their ancestors in a particular location," says Terry O'Connor at the University of York, UK. But they continued to hunt and didn't farm.

Some 3000 years later, when the Natufians returned to a seasonally mobile lifestyle, the wild mice made a comeback. Finally, from about 11,500 years ago, when people in the region began farming and became sedentary, the wild mice were displaced again (*PNAS*, doi.org/b4wn).

This shows a strong link between people's mobility and the mice species living with them, says Weissbrod. "When people are sedentary, they're giving a competitive edge to the house mouse," he says. "Once they're moving back to a mobile way of life, the competitive edge shifts again to the wild one." A more flexible diet, stress tolerance and greater agility thanks to longer tails may have given the house mice dominance over wild mice in settlements. Sam Wong ■



Boom bang the heat's gone

Double death explains universe's coldest spot

THE coldest place in the universe marks the grave of two stars. So says a team that trained the ALMA telescope on the spot, known as the Boomerang Nebula.

Point a telescope almost anywhere in the cosmos and you'll see that it is at 2.7 kelvin – cold enough to freeze hydrogen on Earth. But one spot is even colder – the Boomerang Nebula, 5000 light years away in the constellation Centaurus. Here the temperature is 0.1 kelvin, or just above absolute zero. A mystery for years, astronomers can now see that this cosmic winter was caused by a stellar duo's violent death.

When small stars perish, they expand and create glowing shells of ionised gas, called planetary nebulae. But when astronomers observed the Boomerang Nebula in 1995, they saw something quite odd. It's the only known object in

the universe to absorb light from the cosmic microwave background (CMB) – the afterglow of the big bang that keeps the universe 2.7 degrees above absolute zero. That means the nebula must be even colder.

Expanding gases will cool, but no one knew how Boomerang's central star could eject enough gas

"We can chart the whole evolution of the Boomerang Nebula, which I think is unprecedented"

to cool it to the temperature we see now in so short a time.

"Obviously, something special had happened at this source," says Wouter Vlemmings at Chalmers University of Technology in Sweden.

So Vlemmings and Raghvendra Sahai at NASA's Jet Propulsion Laboratory turned ALMA, the

Atacama Large Millimeter/submillimeter Array, towards the chilly nebula.

Now we have the first detailed map of the Boomerang. On large scales, at least 3.3 times as much mass as the sun contains is being swept away from the central star at 170 kilometres per second within a spherical shell of gas. Could a single star produce such an outburst? Sahai didn't think so.

ALMA's high resolution let the team probe the frigid heart of the system as well. It turns out that within the shell of gas two smaller bubbles are expanding outward from the central star.

The team suggests that the single star was actually two, with one much larger than the other. When the massive star died and started to swell, it swallowed the smaller one. The companion continued to orbit the primary star's core within the shell of gas. Eventually, it spiralled into the core roughly 1000 years ago in a violent merger that disgorged the two smaller lobes of gas (arxiv.org/abs/1703.06929).

"We can chart the whole evolution of this object from the beginning to the end, which I think is unprecedented," Sahai says.

That evolution explains why the Boomerang is atypical. "In most of these situations, the outflowing gas comes out in a trickle," says Mark Morris at the University of California, Los Angeles. But thanks to the binary interaction, Boomerang's gas came out in a gush instead.

Ultimately, the Boomerang Nebula will warm up too. It's just that astronomers are watching it when it's still quite cold.

"It could be a reasonably common event, but because of the short timescale and the number of sources, it might just be that in the immediate neighbourhood of the sun we only expect to see one or two of these," Vlemmings says. "We were probably somewhat lucky to find this source at the right time." Shannon Hall ■

Bias test to keep algorithms ethical

Matt Reynolds

COMPUTERS are getting ethical. A new approach for testing whether algorithms contain hidden biases aims to prevent automated systems from perpetuating human discrimination.

Machine learning is increasingly being used to make sensitive decisions, says Matt Kusner at the Alan Turing Institute in London. In some US states, judges make sentencing decisions and set bail conditions using algorithms that calculate the likelihood that someone will reoffend. Other algorithms assess whether a person should be offered a loan or a job interview.

But it is often unclear how these systems come to their conclusions, which makes it impossible to tell if they are fair ones. An algorithm might conclude that people from a certain demographic are less likely to pay back a loan, for example, if it is trained on a data set in which loans were unfairly distributed in the first place. “In machine learning, we have this problem of racism in and racism out,” says Chris Russell, also at the Alan Turing Institute.

Kusner and Russell are part of a team that has developed a framework to identify and eliminate algorithmic bias. A fair algorithm, the team says, is one that makes the same decision about an individual regardless of demographic background. Because someone’s background

can influence other aspects of their lives, such as their neighbourhood or academic achievement, it’s not enough to ignore obvious race or gender cues; you have to consider how variables interact.

So the team maps out variables in a data set and tests how they might skew decision-making processes. If there is evidence of bias, the researchers find a way to remove or compensate for it.

The team applied this to 2014 stop-and-frisk data from the New York City Police Department, modelling variables

that influenced police officers’ decisions to stop someone.

First, the team considered all variables, including the skin colour and appearance of stopped people. Then, they considered only data points related to actual criminality, such as whether the person was found to be carrying a weapon and whether they were arrested.

The team found that police generally saw black and Hispanic men as more criminal than they did white men, stopping them more often – so a machine-learning analysis of these events might deduce that criminality is correlated with skin colour.

But evidence of actual criminality was similar across the different groups. A model trained like this could help decide where to place police patrols without discriminating by ethnic origin (arxiv.org/abs/1703.06856).

“I think these guys get it right,” says Simon DeDeo at Carnegie Mellon University in Pittsburgh, Pennsylvania. Rather than trusting algorithms to make ethical choices, he says, we need to work out what is fair. “The big problem is getting the computer to be able to explain itself to us.”

The team now wants to try the approach in other areas. It could be useful for firms that are legally obliged to keep their processes free from discrimination, such as mortgage providers. ■



FRANCIS ROBERTS/ALAMY STOCK PHOTO

Algorithms discriminate, too

Supermassive black hole was kicked out

BOING! Gravitational waves may have bounced a supermassive black hole from the centre of its home galaxy. Unless we are just looking at it from the wrong angle, that is.

In a galaxy 8 billion light years away, a supermassive black hole a billion times the mass of the sun is far from home. It's more than 35,000 light years from the galaxy's centre, where

such black holes usually live, and hurtling further out at 2000 kilometres per second.

Marco Chiaberge at the Space Telescope Science Institute in Maryland and his colleagues spotted this rogue black hole, the biggest ever detected, using the Hubble Space Telescope. They think it may be ricocheting from a powerful blast of ripples in space-time called gravitational waves.

As two black holes orbit one another, they should emanate gravitational waves. If the holes have different masses or rates of rotation,

the waves radiate more strongly in one direction than in all the others. If the black holes smash together and merge, the resulting hole recoils in the opposite direction.

We knew smaller black holes could merge and rebound in this way, but this is the first time it has been seen with supermassive ones (*Astronomy & Astrophysics*, doi.org/b4sk).

“This is an extreme kick – right

“This is an extreme kick – right on the edge of what we’d expect – so it would be a very unusual system”

on the edge of what we’d expect – so it would be a very unusual system,” says Daniel Holz at the University of Chicago.

Such a system might demonstrate that supermassive black holes merge, a phenomenon for which we only have circumstantial evidence.

It is also possible that the black hole wasn’t kicked out. The motion we see could be because it sits in another galaxy behind the one to which it seems to belong. “It could be incredibly extreme physics or it could be pedestrian astronomy,” says Holz. “Time will tell.” Leah Crane ■

Mini organs in a dish mimic menstrual cycle

IT'S ovulation in the lab. A simulated female reproductive system behaves almost like the real thing over 28 days.

"Menstruation in a dish is one of my goals," says Julie Kim of Northwestern University in Chicago. Kim works with organoids - small 3D clumps of tissue that behave more naturally than traditional, flat cell cultures. Linking different organoids together enables researchers to study complex organ systems in miniature, an approach that could lead to new insights and less animal testing.

Now Kim's team has hooked up tissue from the ovaries, uterus, cervix and fallopian tubes, as well as the liver, which makes compounds that help to transport hormones.

The tissues responded to hormones made by the mini ovary: oestrogen in the first two weeks, then progesterone for the next two weeks. In the first half of the cycle, eggs grew and burst out of the ovary - mimicking ovulation. Tiny hairs in the fallopian tube began to beat faster, as if to waft the egg along, while cells in the uterus proliferated (*Nature Communications*, DOI: 10.1038/ncomms14584).

But the uterine cells didn't die and break away during the progesterone phase, which normally triggers menstruation - probably because the uterine organoid had no blood vessels. Kim is now introducing these, but she hasn't yet managed to get them to break down, which should prompt the uterine cells to die off.

If Kim's team manages to complete the miniature menstrual cycle, it may lead to treatments for painful periods, fibroids and infertility.

"Having this functional axis between the ovaries and the other organs is what makes this so interesting," says Anthony Atala at the Wake Forest Institute for Regenerative Medicine in Winston-Salem, North Carolina. "In our body it's not just the isolated organ that's doing the work; you have these interactions with other organs." Clare Wilson ■



TUOMAS MARTTILA/PLAINPICTURE

Drug could be the first to reverse type 2 diabetes

NO INSULIN injections, no avoiding sugar. A daily drug can reverse diabetes in mice, opening up the possibility of an easier way for diabetics to keep their blood sugar level within safe limits.

In 2016, the number of people living with diabetes in the UK surpassed 4 million - an increase of 65 per cent over the course of a decade. Some 3.5 million have been diagnosed, but 550,000 are thought to have undiagnosed type 2 diabetes, which is linked to being overweight, and can develop later in life.

Many people develop type 2 diabetes as they age, because their body's response to insulin - a hormone that controls how much sugar circulates in our blood - gets weaker. Some people can manage their symptoms by sticking to a restrictive diet, or using drugs to remove sugar from their system, but many of these have side effects, such as weight gain.

Such drugs manage the disease, but can't reverse it. "We don't have anything that can overcome insulin resistance," says Emily Burns of charity Diabetes UK.

As a result, many people end up having to inject insulin. But a drug

that restores the body's sensitivity to insulin could change that.

Stephanie Stanford at the University of California, San Diego, and her team have developed an oral drug that can restore the ability of diabetic mice to control their blood sugar levels (*Nature Chemical Biology*, doi.org/b4wk).

"This could lead to a new therapeutic strategy for treating type 2 diabetes," says Stanford,

"Finding a way to make cells respond to insulin again is an important and exciting strategy"

whose team believes the drug could mean that fewer people become dependent on insulin injections.

"If this new drug works as described, it could be used to reverse insulin resistance, but we need to know first if it does that safely in people," says Burns.

The drug works by inhibiting an enzyme called low molecular weight protein tyrosine phosphatase (LMPTP), which seems to contribute to cells losing their sensitivity to insulin.

By hindering LMPTP, the drug reawakens insulin receptors on the surface of cells - especially in the liver - which normally absorb excess sugar from the blood when they detect insulin.

"Our inhibitor increased activation of the insulin receptor in the liver, and reversed diabetes without any apparent negative side effects," says Stanford.

Targeting enzymes like LMPTP has long been a goal for diabetes researchers, says Daniel Drucker of the Lunenfeld-Tanenbaum Research Institute in Toronto, Canada. So far, most of these efforts have focused on another tyrosine phosphatase enzyme, but it has proven difficult to block this without also causing side effects, says Drucker.

"Our compound is very specific for the target, but the next step is to rigorously establish if it's safe for use in clinical trials," says Stanford.

"Finding a way to make cells respond to insulin again is an important and exciting strategy," says Burns. "So far, the drug has only been tested in mice, and while some research in human genetics suggests this approach could work in people too, we need more research before we know how relevant this could be for people with type 2 diabetes."

Andy Coghlan ■

FIELD NOTES Namie, Japan

Fukushima ghost town reopens

Fred Pearce

NAMIE is a ghost town, its backstreets deserted, its shops shuttered. Weeds push through the cracks between paving stones, and black bags of radioactive soil waiting for disposal are piled up everywhere.

The town was hurriedly evacuated six years ago after an earthquake and tsunami triggered a meltdown at the Fukushima Daiichi nuclear power station a few kilometres

For a few days back in 2011, Namie was dangerously radioactive. But the short-lived isotopes were soon gone. "People could have been returning after a month, when the iodine had disappeared," says Shunichi Yamashita, a thyroid cancer specialist at Fukushima Medical University, who advised the Japanese government in the aftermath of the accident.

His advice was ignored. So only now, six years on, is Namie about to reopen for business. The question is, how many will want to return.

After the government evacuated more than 100,000 people living within 20 kilometres of the stricken power plant, it said they should be allowed to return to their homes when radiation dose levels fell below 20 millisieverts a year. That is a fifth of the level at which

Ghost town no more?

For the first time since the Fukushima nuclear disaster in 2011 the nearby town of Namie will open its doors to residents



"It's very difficult to convince the public that it is safe to return, they don't accept the scientists' view"

away. Is it ready for the return of its population?

The Japanese government thinks so. From 1 April, restrictions on access will cease, the first train will pull into the railway station, buses will run again, and its 21,000 or so former residents will be able to resume their lives there.

When I visited last August, Namie was strangely ordered. Workers were repairing roads and buildings left empty since the evacuation. Truck drivers bringing construction materials into the town obeyed the fully functioning traffic lights.

I peered through the window of a hairdressing salon that could just have been shut for lunch, with hair cuttings on the floor and magazines in a rack by the door. Abandoned bicycles stood upright in shelters. One still had an umbrella in its basket.

In the old city hall, officials were planning the citizens' return. Not before time.



Given the all-clear

doctors say long-term health effects are possible.

On my journey to Namie, my Geiger counter recorded levels of 80 millisieverts a year in some villages in the nearby mountains. But the town itself has long since dropped below, as radioactivity decayed and workers removed contaminated soil and vegetation. Here I recorded typical doses of around 2 millisieverts – similar to the natural background level.

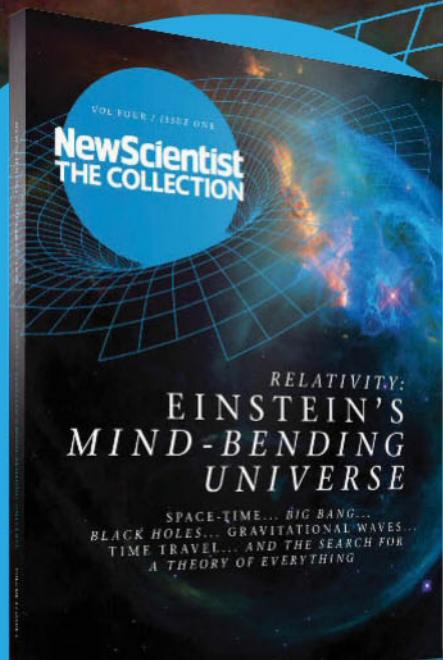
Even so, evacuees are proving reluctant to return. In the nearby town of Naraha, only a fifth of people returned when the government gave the green light in September 2015, and surveys suggest Namie will be no different. One reason is that the accident and its chaotic aftermath broke public trust in official reassurances about anything nuclear. "It's very difficult to convince the public that it is safe to return. They don't accept the scientists' view, because they see us as nuclear allies," says Ken Nollett, director of radiation health at the Fukushima Medical University.

Fears of radiation are deep-seated. Ito Tatsuya, a former

teacher whose wife had run a pharmacy close to the railway station in Namie, told me that however much money is spent trying to decontaminate and rehabilitate his town, "it's a strange feeling, but I never want to go there again".

It probably doesn't help that there have been reports recently of sky-high radiation levels inside the molten core of one of the reactors – levels that would kill humans in seconds. Another reason for the reluctance is that the long delay in reopening the town means that many evacuees have built new lives elsewhere. They have new jobs, homes and schools for their children.

As the all-clear is sounded in Namie, there is a growing concern that it may be destined to remain a ghost town in an empty landscape for decades to come. The main residents may be the resurgent wildlife. Wild boar root around in gardens and break into homes. In the eerie silence as I prepared to depart Namie, an urgent message came over the public address system in the street: a bear had been spotted on the outskirts of town. ■

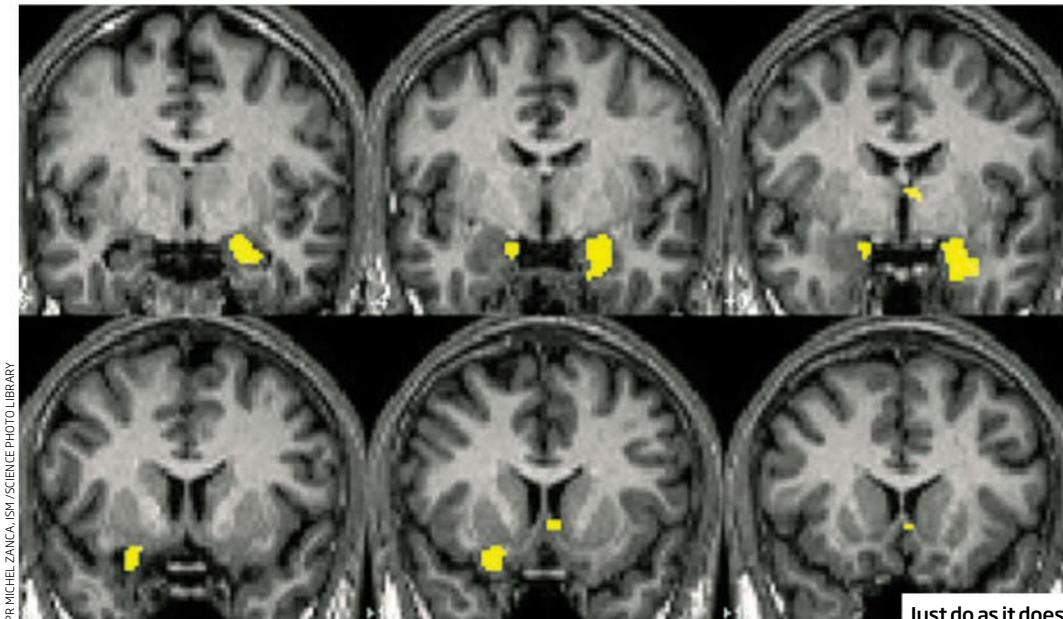


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Brain scans aid machines to see more like us

ARTIFICIAL intelligence is taking image recognition tips from a real expert: the human brain.

Using fMRI brain activity scans as a training tool has boosted the ability of machine learning algorithms to recognise objects. The technique could improve face recognition systems or help autonomous vehicles better understand their surroundings.

Machine learning is still a long way behind humans when it comes to tasks like object recognition, says David Cox at Harvard University. So his group trained algorithms to process images more like we do.

They analysed how regions of the brain's visual cortex responded to images containing four different types of object: humans, animals, buildings and food. The data came from a volunteer who viewed more than 1200 images while an fMRI machine measured their brain response.

The different objects had their own corresponding pattern of brain activity, and the strength of

the signals indicated how difficult each image was to classify.

The team used this information to train its machine learning algorithms. If an algorithm made a mistake on an "easy" image, it was more heavily penalised than if it made an error on a "difficult" image. This feedback essentially told the system what information it should base its classifications on to minimise

"If an AI makes mistakes that a human would make, humans will continue to trust that system"

errors. As a result, it performed better on images easily recognised by the brain, effectively making decisions in a more human-like way (arxiv.org/abs/1703.05463).

Training a basic image classifier with the fMRI data improved its accuracy by 10 to 30 per cent across the different categories, says team member Walter Scheirer at the University of Notre Dame, Indiana. The method could allow relatively basic machine

learning models to approach the accuracy of state-of-the-art neural networks, he says.

Algorithms that make decisions in a similar way to us could also be easier to understand and trust, says Cox. Computer systems sometimes make mistakes that humans wouldn't – like Tesla's Autopilot system failing to notice a white trailer against a bright sky. Systems trained on brain data would make mistakes in a more human way. "And if you make mistakes that a human would make, humans will continue to trust that system," says Cox.

"These are preliminary results, but they're impressive and they suggest that this is a new line of work that could be really fruitful," says Thomas Naselaris at the Medical University of South Carolina in Charleston.

Next, the researchers will look at how cells in rat brains react to different images. The hope is that understanding how the brain works at this level could lead to systems that more closely mimic human decision-making. "The really exciting stuff is going to come from looking at the fine-grain detail of how individual cells are connected and how they're firing," says Cox. **Matt Reynolds** ■

Superheavy elements may live in odd stars

AT THE edge of the periodic table is the fabled "island of stability", a zone where superheavy elements are thought to enjoy long lives. A team of astrophysicists suggests the place to seek these elusive atoms is in certain unusual stars.

Most elements heavier than lead – atomic number 82, meaning it has 82 protons in its nucleus – are unstable and radioactive. But physicists have long speculated that there might be long-lived elements with 114 or more protons in their nuclei.

We can try to create such elements by smashing atoms together to form larger nuclei. But our best particle accelerators have so far only built short-lived atoms that decay in a fraction of a microsecond.

Stars are natural nuclear reactors, and most heavy elements are forged in supernovae. Now, Vladimir Dzuba at the University of New South Wales, Australia, and his colleagues think the oddball Przybylski's star could be harbouring superheavy elements.

A variable star some 370 light years away, it has unusually little iron or nickel. It is also the only star believed to contain short-lived elements called actinides, with atomic numbers ranging from 89 to 103.

Dzuba argues that the actinides, whose signatures seem to be present in the star's spectrum, are a sign that the island of stability elements exist there. Their slow decay is what gives rise to the observed elements, he says: since actinides decay quickly relative to a star's lifetime, they ought to be gone unless there is some mechanism to replenish them (arxiv.org/abs/1703.04250v1).

But Stephane Goriely at the Free University of Brussels (ULB), Belgium, doesn't think the evidence for actinides is that strong to begin with.

"Przybylski's stellar atmosphere is highly magnetic, stratified and chemically peculiar," he says. "The presence of such nuclei remains to be confirmed." Jesse Emspak ■

Best evidence that hypnotism is real

Clare Wilson

YOU are feeling sleepy... or are you? In a stage hypnosis performance, ordinary people seem to become puppets, made to talk in silly accents, act like babies or do other embarrassing things. But have they genuinely lost command of their bodies, or are they just pretending?

Now we have some of the best evidence yet that people who are hypnotised do feel like they are acting involuntarily. When estimating split-second timings, hypnotised people behaved as though their actions were outside their control, in ways that would have been difficult to fake.

Sceptics think that rather than being in some state of altered consciousness, hypnotised people do as they are told because it would be socially awkward not to. People who are highly susceptible to hypnosis – about one in 10 of us – could just be especially suggestible and eager to please, say the cynics.

To investigate this mystery, Peter Lush at the Sackler Centre for Consciousness Science in Brighton, UK, and his team have

used a known trick of the mind. When we do something that causes something else, we perceive these two events as occurring closer in time than if they are unrelated. For example, if we believe that pushing a button makes a sound, it seems like the sound occurs sooner after pushing the button than if we think they are independent – known as “intentional binding”.

Lush’s team asked 18 people who were highly susceptible to hypnotism to sit in front of a very accurate clock and do a task repeatedly where they pressed a button, triggering a beep after 250 milliseconds.

If their finger was pulled down involuntarily – by a string – they perceived the period before the beep as 176 milliseconds on average. If the string wasn’t pulled and they chose when to press the button, they estimated it as 91 milliseconds, showing intentional binding. But if they were commanded to press the button while hypnotised, they perceived it as 156 milliseconds – closer to the involuntary state (*Psychological Science*, doi.org/b4sh).

SCOTT MACBRIDE/GETTY



Push that button

“This feeling of involuntariness is a key element of the hypnotic experience,” says David Spiegel of Stanford University, California.

This result is more convincing than simply asking hypnotised people whether they feel in control of their actions because they could be lying, says Devin Terhune at Goldsmiths University of London. In this latest study, the volunteers were unlikely to have known what their answers should have been in the three different situations. “It’s much better than self-reports,” says Terhune.

Brain scans of hypnotised

people have previously shown that, when they are told to feel pain, similar regions of the brain become active as when people really are in pain. But brain imaging studies can be hard to interpret, says Lush. “This is the most objective evidence yet that people who are hypnotised feel that their actions are not under their own control.”

Lush says studying intentional binding could also help us to investigate mental conditions that affect our sense of power over our own bodies, such as schizophrenia. ■

Pay crash looms for online gig workers

IT’S basic supply and demand. A huge number of people in South-East Asia and sub-Saharan Africa looking for online “gig economy” work could cause a race to the bottom on pay and conditions, according to a report from the Oxford Internet Institute, UK.

Millions of people in countries like Kenya, Nigeria, South Africa, Vietnam and Malaysia sign up to websites that

pay them to do tasks such as data entry, transcription and graphic design. The jobs can last minutes or months, and are generally outsourced from companies in richer countries. “The sheer variety of people doing this work is surprising. Almost any sort of work is being done digitally,” says Mark Graham, one of the report’s authors.

Over three years, Graham and his colleagues conducted 152 interviews and surveyed 456 workers. Seventy per cent of those surveyed said gig work was one of their main sources of income, but nearly half said they felt easily replaceable. One gig-work

platform had 1.75 million registrants, but only 200,000 had completed an hour’s work or earned at least US\$1.

The team says demand for such work will get higher, because a billion more people are expected to get online by 2020, the majority of whom will come from low- and middle-income countries. “There will be a huge surge in demand for online jobs, and unless strategies and policies are

put in place, it will be a race to the bottom,” says Graham.

These gig workers don’t have any employee protections. The report argues that the handful of countries generating the digital work, mostly in North America and western Europe, should enforce minimum standards.

But this would be hard to enforce, says Andrea Broughton at the Institute for Employment Studies in Brighton, UK. “A lot of work goes under the radar, not registered by any regulators,” she says. “How do you even start to work out what to regulate?” Timothy Revell ■

“Unless policies are put in place to protect online workers, it will be a race to the bottom”

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IN BRIEF

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Stopping polio vaccines from evolving the ability to harm

WE'RE on the brink of wiping out polio, but the virus used in vaccines keeps evolving to become harmful again. Now we know how – and we may be able to stop it.

Polio has largely been brought under control by the oral polio vaccine, which contains a weakened form of the live polio virus. The virus replicates inside us and can be passed on to others, transmitting immunity to people who haven't been vaccinated.

But the weakened virus sometimes re-evolves the ability to cause disease. In the 10 years leading up to 2015, there were around 750 reported cases of paralysis

caused by vaccine-derived poliovirus (VDPV) worldwide.

A new vaccine in development may put a stop to this. Raul Andino and colleagues at the University of California, San Francisco, analysed the genes of the vaccine and 424 samples of VDPV from 30 different outbreaks. They found that in every case, the weakened vaccine virus had undergone the same three evolutionary steps to become virulent again, a process that requires only seven or eight mutations. Recreating these mutations in the lab made the vaccine virus replicate more efficiently, and kill more mice (*Cell*, doi.org/b4r3).

Using this knowledge, Andino's team has designed a vaccine that should be less likely to go through these steps. "What we're trying to do is put the virus in an evolutionary cage so it can't evolve further," says Andino.

Brain genes link pain and depression

PEOPLE who have chronic pain are more likely to experience mood disorders, and the two may be linked by changes in gene activity.

"At least 40 per cent of patients who suffer from severe forms of chronic pain also develop depression at some point," says Venetia Zachariou of the Icahn School of Medicine at Mount Sinai in New York.

Zachariou and her team studied

mice with damage to their peripheral nervous system, which show symptoms similar to people with chronic pain. Previously, pain behaviour in mice had only been studied for a week's stretch at most, but Zachariou's team monitored their mice for 10 weeks. "At the beginning, we saw only sensory deficits and pain-like symptoms. But several weeks later, the

animals developed anxiety and depression-like behaviours."

The team found changes in the activity of nearly 40 genes in three brain regions known to be associated with depression and anxiety (*Science Signaling*, doi.org/b4rz). Some of these genes are involved in inflammation, which in some cases is thought to be linked to depression in people.

The findings may one day lead to better drugs for people who have chronic pain.

Moon plumes come from cosmic crash

THE wound at Enceladus's south pole may have been caused by a massive collision.

Saturn's icy moon spews plumes of liquid and vast amounts of heat from its south pole, probably from an interior ocean. But the rest of the moon is cold and relatively homogeneous.

In an effort to solve the enigma, Angela Stickle and James Roberts at Johns Hopkins University in Maryland simulated a giant impact in the past. A collision large enough to cause huge cracks in the ice would have left the south pole warm and weakened, explaining the plumes, they told the Lunar and Planetary Science Conference in Texas on 21 March.

The blow didn't even have to happen exactly at the south pole. Because the dent would cause a dip in the local gravity, the moon's rotation would shift so the impact site would gradually migrate towards the pole.

Digital signals turn water to lemonade

WHEN life hands you lemons, make virtual lemonade.

A system of sensors and electrodes can digitally transmit the basic colour and sourness of a glass of lemonade to a tumbler of water, changing its look and taste.

Nimesha Ranasinghe at the National University of Singapore and his team used a colour sensor and a pH sensor to capture the appearance and acidity of a drink. This data was sent to a special tumbler full of water. An electrode stimulated the drinker's tongue to mimic the lemonade's sourness, while LED lights replicated its colour (doi.org/b4sj).

"People are always posting pictures of drinks on social media – what if you could upload the taste as well?" says Ranasinghe.

Crowd-calming steps, with maths

WE MAY now have a universal mathematical law describing how pedestrians behave. Such knowledge could help ease rush-hour congestion and prevent tragedies like fatal stampedes at festivals or sporting events.

Individuals within large groups are difficult to track, so crowds are often modelled as a fluid made of particles, one for each pedestrian. But people are more unpredictable than idealised particles.

To improve on that, Federico Toschi at Eindhoven University of Technology in the Netherlands and his colleagues set up cameras to record the movement of individuals along a corridor at the university. The cameras used a Microsoft Kinect 3D motion sensor with a built-in infrared illuminator to correct for varying lighting. The team designed software to track the heads of people as they walked.

Using footage of more than 72,000 pedestrian paths captured over the course of a year, the researchers modelled the average route people took (*Physical Review E*, doi.org/b4sb).

The model amounts to a law that can, for instance, predict how often someone is likely to make a sudden U-turn, which could clog up a busy hallway. The team is now working with museums to streamline the flow of visitors.



PLAINPICTURE/GOTOFOTO/CHINCH GRYNIEWICZ

Electrified sand could explain Titan's backward dunes

STATIC electricity could be the reason why the strange dunes on Saturn's largest moon face the wrong direction.

Titan is a hazy moon with a thick, orange nitrogen atmosphere. Its poles are home to placid methane lakes and its equatorial regions are covered with dunes up to 100 metres high.

But the dunes seem to be facing the wrong way. Prevailing winds on Titan blow towards the west, but the dunes point east.

To understand these shifting sands, Josef Dufek at the Georgia

Institute of Technology in Atlanta and his colleagues placed grains of organic materials like those on Titan's surface in a chamber that simulated conditions there. Then they spun them in a tumbler.

When the team opened up the chamber, static electricity from the grains jostling in the dry air had clumped them together (*Nature Geoscience*, doi.org/b4vq).

"It was like when you open a box on a winter morning and the [foam] packing peanuts stick everywhere," says Dufek.

Sand grains on Titan maintain that charge and stick together for much longer than particles on Earth could because of their low density and the dryness of the moon's atmosphere. That could explain why the dunes don't align with the wind. The breeze close to Titan's surface is relatively mild, generally below 5 kilometres per hour. The sand's "stickiness" would make it difficult for such weak winds to move them.

More powerful winds from storms or seasonal changes could blow them eastward.

Teach your phone not to interrupt

IS NOW a good time? Smartphones that learn when you're most willing to receive notifications could stop apps from interrupting at inconvenient moments.

An app developed by Janne Lindqvist and his team at Rutgers University in New Jersey asked volunteers to rate their mood and how busy they were, from "highly interruptible" to "highly uninterruptible", many times a day over four weeks. It also used the phone's sensors to collect data on each person's location and movement, and combined these with a personality test.

After 16 days, the app's machine learning algorithm could predict someone's availability rating with an accuracy of 75 per cent.

The team found that people were least happy to be interrupted while shopping and more open to notifications when in a good mood. And people with similar personalities were likely to have similar preferences. The team will present the work at a conference in Denver, Colorado, in May.

But the app won't lead to fewer notifications, says Lindqvist. It could instead be used to target notifications at times when people are more likely to respond.



GERD TROMM/GETTY

Big brains mean smarter mate choice

IT TAKES brains to choose a good partner. In one of the first studies to look at the cognitive demands of selecting a mate, female guppies with big brains preferred more colourful males - a trait linked with good health and foraging ability.

Alberto Corral López at Stockholm University in Sweden and colleagues tested females bred to have large or small brains, or brains similar in size to those of wild guppies. Previous studies have shown that big-brained guppies do well at cognitive tests, suggesting they are smarter.

Each female had the chance to

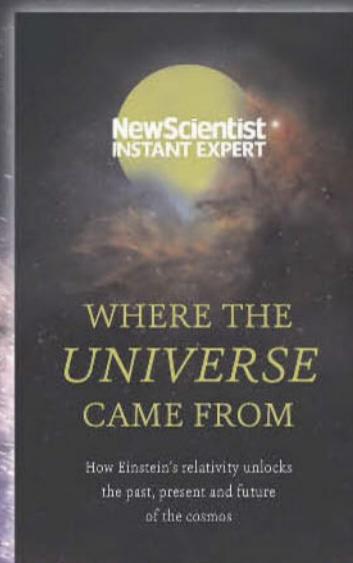
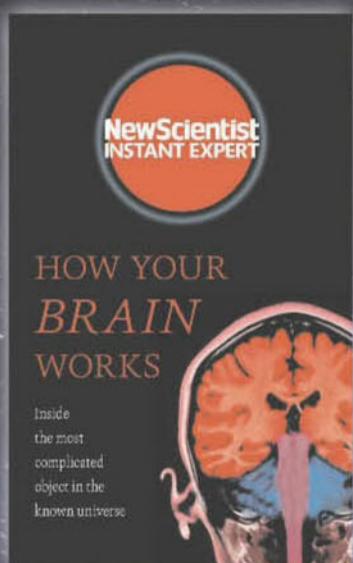
associate with two males, one more colourful than the other. Females are known to spend more time close to males they prefer to mate with.

The wild-type and large-brained females both strongly preferred more colourful males, while small-brained females showed no preference (*Science Advances*, doi.org/b4rx).

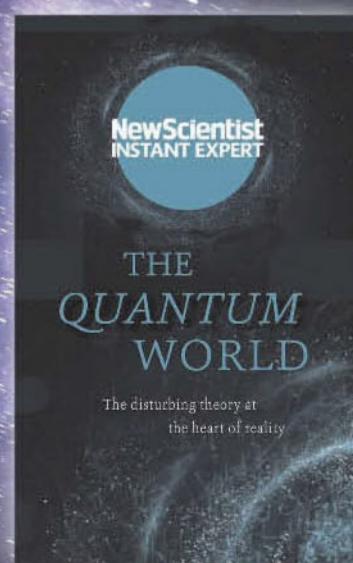
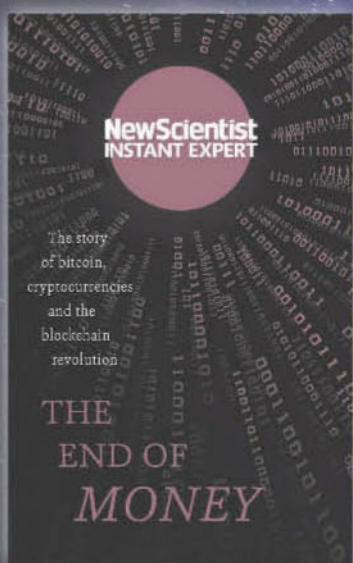
Tests showed this wasn't due to differences in colour perception, hinting at more complex cognitive processing, says Corral López. "It's not sensory input, but how they process the information they receive from the different males."

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Ticking time bomb

Lyme disease is set to explode in the US this year, and there's no vaccine. How worried should you be, asks **Chelsea Whyte**

BY THE time he had finished his walk through the woods in New York state, Rick Ostfeld was ready to declare a public health emergency. He could read the warning signs in the acorns that littered the forest floor – seeds of a chain of events that will culminate in an unprecedented outbreak of Lyme disease this year.

Since that day in 2015, Ostfeld has been publicising the coming outbreak. Thanks to a changing climate it could be one of the worst on record: the ticks that carry the disease have been found in places where it has never before been a problem – and where most people don't know how to respond. The danger zone isn't confined to the US: similar signs are flagging potential outbreaks in Europe. Polish researchers predict a major outbreak there in 2018.

In theory, Ostfeld's early warning system gives public health officials a two-year window to prepare. In many other cases, this would be enough time to roll out a vaccination programme. But there is no human vaccine for Lyme disease. Why not? And what can you do to protect yourself in the meantime?

Lyme disease is the most common infection following an insect bite in the US: the Centers for Disease Control estimates that 300,000 Americans contract Lyme disease each year, calling it "a major US public health problem". While it is easy enough to treat if caught early, we are still getting to grips with lifelong health problems that can stem from not catching it in time (see "Do I have Lyme disease?", right).

This is less of a problem when Lyme is confined to a few small areas of the US, but thanks in part to warmer winters, the disease is

MIKE PERES/CUSTOM MEDICAL STOCK PHOTO/SCIENCE PHOTO LIBRARY



Tick tock

spreading beyond its usual territory, extending across the US (see map, right) and into Europe and forested areas of Asia. In Europe in particular, confirmed cases have been steadily rising for 30 years – today, the World Health Organization estimates that 65,000 people get Lyme disease each year in the region. In the UK, 2000 to 3000 cases are diagnosed

Anyone living on the edge of the Lyme disease maps now will likely be at risk soon"

each year, up tenfold from 2001, estimates the UK's National Health Service.

So how could a floor of acorns two years ago tell Ostfeld, a disease ecologist at the Cary Institute of Ecosystem Studies in Millbrook, New York, that 2017 would see an outbreak of Lyme disease? It's all down to what happens next.

A bumper crop of the seeds – "like you were walking on ball bearings" – comes along every two to five years in Millbrook. Crucially, these nutrient-packed meals swell the mouse population:

"2016 was a real mouse plague of a year," he says. And mouse plagues bring tick plagues.

Soon after hatching, young ticks start "questing" – grasping onto grasses or leaves with their hind legs and waving their forelegs, ready to hitch a ride on whatever passes by, usually a mouse.

Gut reaction

Once on board, the feast begins. Just one mouse can carry hundreds of immature ticks in their post-larval nymph stage.

This is where the problems for us start. Mouse blood carries the Lyme-causing bacterium *Borrelia burgdorferi*, which passes to a tick's gut as it feeds. The tick itself is unharmed, but each time it latches onto a new host to feed, the bacteria can move from its gut to the blood – including that of any human passers-by.

"We predict the mice population based on the acorns and we predict infected nymph ticks with the mice numbers. Each step has a one year lag," Ostfeld says.

Ostfeld published his discovery of this chain of causation in 2006. Last year, researchers in Poland found the same trend there, with the same implications. "Last year we had a lot of oak acorns, so we might expect 2018 will pose a high risk of Lyme," says Jakub Szymkowiak at Adam Mickiewicz University in Poznan, Poland.

Those who live in traditional Lyme disease zones are well versed in tick awareness – wear long trousers in the woods, check yourself thoroughly afterwards, and more. But this advice will be less familiar in places that used to sit outside Lyme zones – like Poland. "That's sort of the perfect storm," says Ostfeld. "The public

is unaware, so they're not looking for it and they don't get treated."

It's not obvious when you have been bitten or infected: ticks are the size of a poppy seed, and not everyone gets the classic "bullseye" rash that is supposed to tip you off. The flu-like symptoms that follow are also easy to misdiagnose. And because antibodies to Lyme disease take a few weeks to develop, early tests can miss it. "That's when you get late-stage, untreated, supremely problematic Lyme disease," Ostfeld says.

The best approach would be to vaccinate people at risk – but there is currently no vaccine. We used to have one, but thanks to anti-vaccination activists, that is no longer the case.

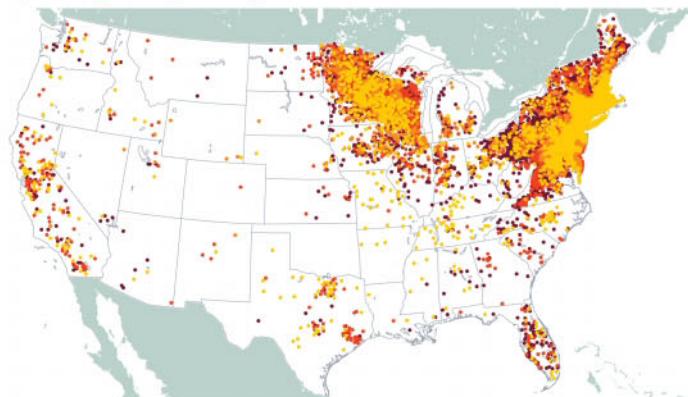
In the late 1990s, a race was on to make the first Lyme disease vaccine. By December 1998, the US Food and Drug Administration approved the release of Lymerix, developed by SmithKline Beecham, now GSK. But the company voluntarily withdrew the drug after only four years.

This followed a series of lawsuits – including one where recipients claimed Lymerix caused chronic arthritis. Influenced by now-discredited research purporting to show a link between the MMR vaccine and autism, activists raised the question of

Lyme on the march

Cases of Lyme disease have spread across the US as warmer winters encourage the ticks that carry it to move into new areas

● 2001 ● 2005 ● 2010 ● 2015



DO I HAVE LYME DISEASE?

The symptoms of Lyme disease, which you can get from a tick bite, aren't always obvious. At the site of the bite, a red splotch will often start to grow into what looks like a bullseye target.

Not everyone gets this unmistakable sign, however. Over the next few weeks, flu-like symptoms, including aches and fever, can follow. Left untreated, Lyme disease can lead to a host of problems, chronic joint inflammation, facial palsy, issues with short-term memory, heart rhythm irregularities, and inflammation of the brain and spinal cord.

WHAT TO DO

IF YOU'VE BEEN AROUND TICKS

The best way to prevent Lyme disease is to do a thorough tick check. Nymph ticks are so tiny they can be hard to spot, so find a partner, strip down, and

whether the Lyme disease vaccine could cause arthritis.

Media coverage and the anti-Lyme-vaccination groups gave a voice to those who believed their pain was due to the vaccine, and public support for the vaccine declined. "The chronic arthritis was not associated with Lyme," says Stanley Plotkin, an adviser to pharmaceutical company Sanofi Pasteur. "When you're dealing with adults, all kinds of things happen to them. They get arthritis,

go over places that are hard to reach. Make sure you check your partner's armpits, scalp and groin for ticks.

IF YOU FIND A TICK

If you know it has been on you for under 36 hours, use tweezers to twist and pull it out correctly, and you will probably be fine. That's because the Lyme-causing bacteria that live in a tick's gut are slow, and it takes 36 to 48 hours for them to make it into your bloodstream. Always see a doctor if you are unsure.

IF YOU'VE MISSED THE WINDOW

It's best to see a doctor for a Lyme disease test – but not right away. Your antibodies to Lyme disease take weeks to form, so an early test can give a false reassurance. Wait four to six weeks before requesting a blood test.

they get strokes, heart attacks. So unless you have a control group, you're in la-la land."

But there was a control group – the rest of the US population. And when the FDA reviewed the vaccine's adverse event reports in a retrospective study, they found only 905 reports for 1.4 million doses. Still, the damage was done, and the vaccine was benched.

After that, "no one touched it", says Thomas Lingelbach, CEO at Valneva, a biotech company based in France. Until now: Valneva has a vaccine in early human trials. It will improve on Lymerix, acting against all five strains of the disease instead of just the one most common in the US, and it will be suitable for children.

Lingelbach knows the battles his firm will face. "It will be hard to convince anti-vax lobbyists," he says. That fight is still some way off: any public roll-out is at least six years away.

What makes this wait especially galling for some is that there is a vaccine for your pet. "It's ironic that you can vaccinate your animal and you can't vaccinate yourself," Plotkin says.

In the animal vaccine, instead

IF YOU TEST POSITIVE

If you do test positive for Lyme disease, a course of antibiotics will usually stop the infection in its tracks fairly quickly.

IF SYMPTOMS LINGER

A small percentage of people who are treated will continue to have symptoms like fatigue or sore joints and muscles. This condition is called post-treatment Lyme disease syndrome, sometimes referred to as chronic Lyme disease. It isn't exactly clear what causes these symptoms, it could be a delayed immune response or even another illness altogether. Until this controversial area of medicine is clarified, it's best to avoid getting Lyme disease in the first place, at least while a vaccine is still in development.

of exposing Fido to a weakened version of the antigen to trigger antibodies, it works within the tick, neutralising *B. burgdorferi* by altering the expression of a protein on the bacterium before it enters the bloodstream. This is

"It's ironic that you can vaccinate your animal, but you can't vaccinate yourself"

how a human version would work. "The underlying scientific principle is not very far away from what it is in the veterinary environment," says Lingelbach.

Some people have suggested taking the animal vaccine, but Plotkin doesn't recommend this as it hasn't been tested in people so there is insufficient safety data. "You just don't have classical efficacy data in humans," he says. It is also illegal in the US and UK for vets to practise medicine on humans.

While we wait for a human vaccine, you might start keeping track of your local acorn populations – but brush up on your anti-tick measures before you hit the woods. ■



THE SECRET SCIENCE
IN YOUR HOME

At the cutting edge

Understanding the secrets of shaving requires a small army of scientists – plus a steady stream of bewhiskered men willing to try out the latest technology

CHANCES are when you pick up your razor in the morning you don't think too much about how it does its job. Most of us slap on the foam, turn on the hot tap and get stuck in while our minds wander. We tend to shave with our thoughts far from our face.

At Gillette's Innovation Centre near London, they are very aware of this. "We spend every day thinking about the science of shaving so you don't have to worry about it," says

Dr Kristina Vanoosthuyze, Gillette's senior manager of scientific communications. It doesn't take a visitor long to grasp just how complex that science is, and how many disciplines it involves. The red-brick building resembles a mini-university, where biologists, skin experts, engineers, product designers, materials scientists and physicists work to deliver the closest and most comfortable shave that technology will permit.

The mission is more challenging than you might think. A typical facial hair is as strong as copper wire. Facial skin, by contrast, is

soft, gel-like and undulating. It is also rich in nerve endings. Cutting a hair close to the skin without irritating it requires, first and foremost, a super-sharp blade. The edge of Gillette's latest blade is sharper than a typical surgeon's scalpel, with a radius at the tip of just 25 nanometers. This is about the limit of what's possible with existing materials: if the blade edge were any thinner it would collapse under the forces generated during shaving.

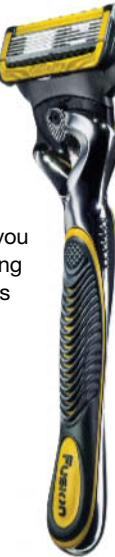
You feel this force as the resistance created as the blade cuts stubble. Quantifying and reducing the different forces and stresses on the skin and hair is perhaps the biggest challenge of all for Gillette's engineers. "Everything we do is about managing this," says Vanoosthuyze. The more work that's needed to pull the blade through the stubble, the greater that feeling of tugging and the more uncomfortable and irritating a shave feels.

Don't feel the force

One of the big contributing factors to shaving irritation is the applied load on the blades as you press a razor to your face. Over the years, Gillette has come up with a number of solutions to this, including the use of multiple blades to distribute this load and hence reduce the load on each individual blade. The company's latest razor, the ProShield, uses five blades

"We'll stop making razor blades when we can't keep making them better."

King C. Gillette



Engineers use 3D printing to rapidly convert new concepts and ideas into prototypes

positioned 1.05 millimeters apart. Each is a fraction closer to the skin than its leading neighbor, meaning a hair can get cropped five times in a single stroke. The arrangement makes for a smoother shave. But it requires precise engineering: to allow the blades to accommodate the irregular contours of the face, each has to be welded to supports which are positioned on little springs.

Advances like this are made possible by the use of high-speed imaging cameras, which allow Gillette's scientists to watch under high magnification what happens to a blade when it



meets facial hairs and skin. This equipment has helped them calculate critical details such as the optimal distance between multiple blades, and the optimal angle of the blades to the skin. It has led to some breakthrough innovations, according to Dr Kevin Cowley, Research Fellow, who helped to develop some of the unique imaging techniques used here.

Time for your close-up

For instance, by fixing a camera to the business end of a razor, they found that the optimal distance between the blades of the first Fusion model (released in 2005) was not constantly maintained during the shave. Their solution? A stabiliser which supports each of the five blades at the centre of the cartridge to help maintain an optimal span, a feature introduced in 2010 with the updated Fusion ProGlide.

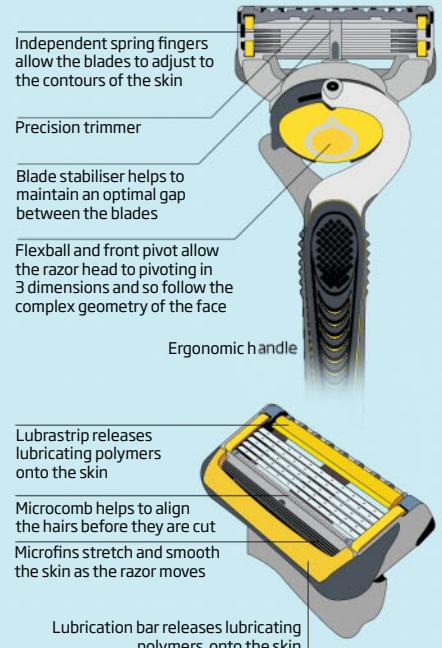
Another area where consumer insights have proved invaluable is the challenge of reducing the friction between the blades and the skin, another major contributor to shaving irritation. Since 1985, Gillette's razors have featured a lubricating strip infused with polyethylene glycols situated just behind the blades. In 2016, with the ProShield, the company added an additional strip in front of the blades, a response to the realization that most men "over stroke", running their razor over areas of the face that they've already shaved and that lack foam or gel.

While it can take up to five years to turn new insights and ideas into testable prototypes, Gillette has made the process as efficient as possible by ensuring that every stage of development takes place under one roof. Sketches and cardboard models of components and parts are reconfigured as computer-manipulated virtual representations and eventually assume physical form via a rapid prototyping 3D printer. "Whatever designers can draw, we can build it, often in a matter of hours," says Dom Piff, senior engineer in the rapid prototyping facility. Once the 3D designs have been agreed, engineers in the manufacturing workshop – whose lathes, mills, molds and precision cutting machines take up most of the center's ground floor – make high-grade versions that can be put through their paces in the consumer testing rooms.

In a glass cabinet on the center's ground floor, a collection of some of the first safety razors commemorates the origins of Gillette at the start of the 20th century, along with a photograph of the man who started it all: King C. Gillette. Today's researchers are still guided by his business mantra: "We'll stop making razor blades when we can't keep making them better." Gillette's latest razor may be the best that scientific understanding allows for now. But tomorrow is another shave. ■

More at: www.us.pg.com

Anatomy of a razor



THE Gillette Innovation Centre outside London houses an impressive range of technology and expertise, but none of it would be much use unless the company had a good idea of what men wanted from a shave. That's why, each morning five days a week, Gillette invites up to 80 bearded members of the public to its consumer testing rooms where technicians watch them through two-way mirrors as they try the latest products and prototypes. According to Angela Richardson, who leads this facility, they've found that no two men shave the same way, with huge variation in the time they take (from 30 seconds to 17 minutes), the number of strokes (30 to 700) and the load they put on the razor (0.5 Newtons to 4 Newtons).

Watching men shave has resulted in many improvements in razor design. For example, the observation that they frequently contort their mouths – the so-called "shave face" – to capture elusive hairs under the jawline and chin led to the development in 2015 of the Gillette Flexball (above) with a 3D pivot that follows the contours of the face. The result is a closer shave, particularly in harder to reach areas of the face.

Time to talk

There's no reason why a deal to maintain UK-EU science cooperation can't be struck in the Brexit negotiations, says **Chris Leigh**

WITH the triggering of Article 50, talks on the UK's exit from the European Union can finally begin.

While much is uncertain, it is clear Prime Minister Theresa May wants to control UK immigration from EU nations by leaving the single market, so ending a commitment to freedom of movement. This raises questions over how collaboration between British and EU scientists on EU-funded research will continue and how new border controls will affect the flow of overseas scientists to the UK.

Having campaigned for Brexit, I am optimistic that a deal can be struck to continue joint research and that a new immigration system can keep talent arriving. Ensuring UK science thrives after Brexit is a government priority.

May's comments give clues to a future research relationship: "There may be... European



programmes in which we might want to participate. If so... it is reasonable that we should make an appropriate contribution [to EU funds]." And: "We will also welcome agreement to continue to collaborate with our European partners on... science, research and technology initiatives."

It appears May is open to an "association agreement" to retain links with the €80 billion EU research fund, Horizon 2020. This would mean carrying on paying into the fund, but would allow UK scientists to apply for grants and work on EU research. In all, 16 non-EU countries are associates. Some have not signed up to freedom of movement.

There are, of course, non-EU projects, such as those run by CERN and the European Space Agency, where involvement will go on regardless. But I accept that many see benefit in continued

Android alert

Security flaws in today's robots are a wake-up call for the industry, says **Paul Marks**

WE HEAR a lot about robots getting smarter thanks to AI, but less about steady gains in strength and durability.

Their growing physical prowess raises risks to people near them should something go wrong, which means it is ever more vital that these devices remain entirely under our control.

This was brought home to me at the Human Robot Interaction conference in Germany. There, I got to grapple with a peculiar, hyper-flexible type of robot arm that looked, and moved, like an elephant's trunk. I pushed against it and it pushed back with some oomph – it was not the kind of strength you'd want to mess with.

Still, robots only do what we tell them to, right? Perhaps not.

It turns out they suffer from the same kind of affliction that hit personal computers in the 1980s and the internet in the 1990s: software vulnerabilities that could allow attackers to hijack them. So say teams of forensic software engineers at two US firms researching digital threats.

They discovered that well-known robots, including the Pepper and Nao humanoids

"Robotics tends to be steeped in a research ethic at the expense of real world concerns"

from Japanese firm SoftBank and the Baxter and Sawyer light industrial droids from Rethink Robotics in Boston, had dozens of vulnerabilities.

Flaws included insecure communications, authentication problems and weak cryptography. Many were common to multiple robots because it appears a lot of shared software makes it through to production models.

What might these kinds of vulnerabilities mean? That some robots could be hacked and controlled by unseen attackers for their own ends. They could decide where the robot goes and what it does, including what it

involvement in the 3 per cent of UK R&D that relies on the EU.

Given apparent UK interest in an association agreement, there seems no logical reason why our scientific relationship with the EU should change. Yes, the other EU states must agree to it, but would they exclude a nation with five of the world's top 20 universities or that has produced more Nobel laureates in science and medicine than any other EU member?

As the UK takes back control of immigration, it will need to mitigate the impact on science and develop a strategy to maintain the inward flow of researchers and academics. Thankfully, there is evidence to suggest this does not require open EU borders. A 2012 study showed that states with strict controls, such as Australia, the US and Canada, recruit a greater percentage of foreign researchers than the UK, France and Germany.

It may require innovative solutions, such as a simplified fast-track visa for researchers or the removal of genuine overseas students from immigration statistics, but the UK can continue to recruit the brightest and best minds from across the globe. ■

Astronomer Chris Leigh is part of the pro-Brexit Scientists for Britain group

films, records or transmits. All the robot-makers identified were said to be fixing these problems, which is good news, but the worry lingers that there might be more of them.

Security tip-offs do the robotics industry a favour. It tends to be steeped in a research ethic at the expense of real-world concerns.

For robotics to fulfil its huge potential, public trust will be essential. That means the industry must grapple with these kinds of issues now before the robots get to grapple with us. ■

Paul Marks is a science and technology writer based in London

INSIGHT Internet



MORSAIMAGES/GETTY

Social norms are distorted online

Free speech needs saving from itself

Sally Adee

"THE remedy is more speech, not enforced silence," wrote US Supreme Court Justice Louis Brandeis in 1927 defending freedom of speech. Ninety years on, his position is often taken as read: in the marketplace of ideas, the truth will out.

So it's no surprise that many were aghast when Germany's justice minister introduced a draft law on 14 March that would lead to social media firms, including Facebook and Twitter, being fined up to €50 million if they failed to remove hate speech within 24 hours of a complaint.

"If we were trying to do this with any other media, you'd be talking about taking books off people's shelves and going into libraries and ripping up magazines," Vint Cerf, one of the internet's founders, told a forum on internet and liberty. "We seem to be doing this just because in this medium we can."

For people like Cerf and many US firms who view online speech through the lens of the First Amendment, Germany's approach may look like suppression of the right of free

expression. But it may be a necessary first step in re-establishing a shared moral reality. In the age of bots, misinformation and anonymity, free speech itself may be used to enact a kind of censorship.

In 2011, Russian citizens took to Twitter to criticise contested election results. The hashtag #триумфальная (Triumfalnaya - a Moscow square that hosted a protest) became very popular, but it was soon neutralised by at least 2000 bot accounts swamping Twitter with nonsensical tweets, shutting down constructive debate.

Such actions can mean the spread of public opinion is misrepresented or

"In 2011, tweets by Russian protesters were swamped by nonsensical messages from thousands of bots"

moral consensuses are thrown out. This has been noticed by some Jewish communities, who have seen bot-borne upticks in public anti-Semitism. By artificially amplifying particular views, bots are effectively censoring speech without suppressing it.

One recent study suggested that

how credible people find a statement on Twitter depends most on how many times it is retweeted. If that is a rule of the marketplace, the best ideas won't rise to the top.

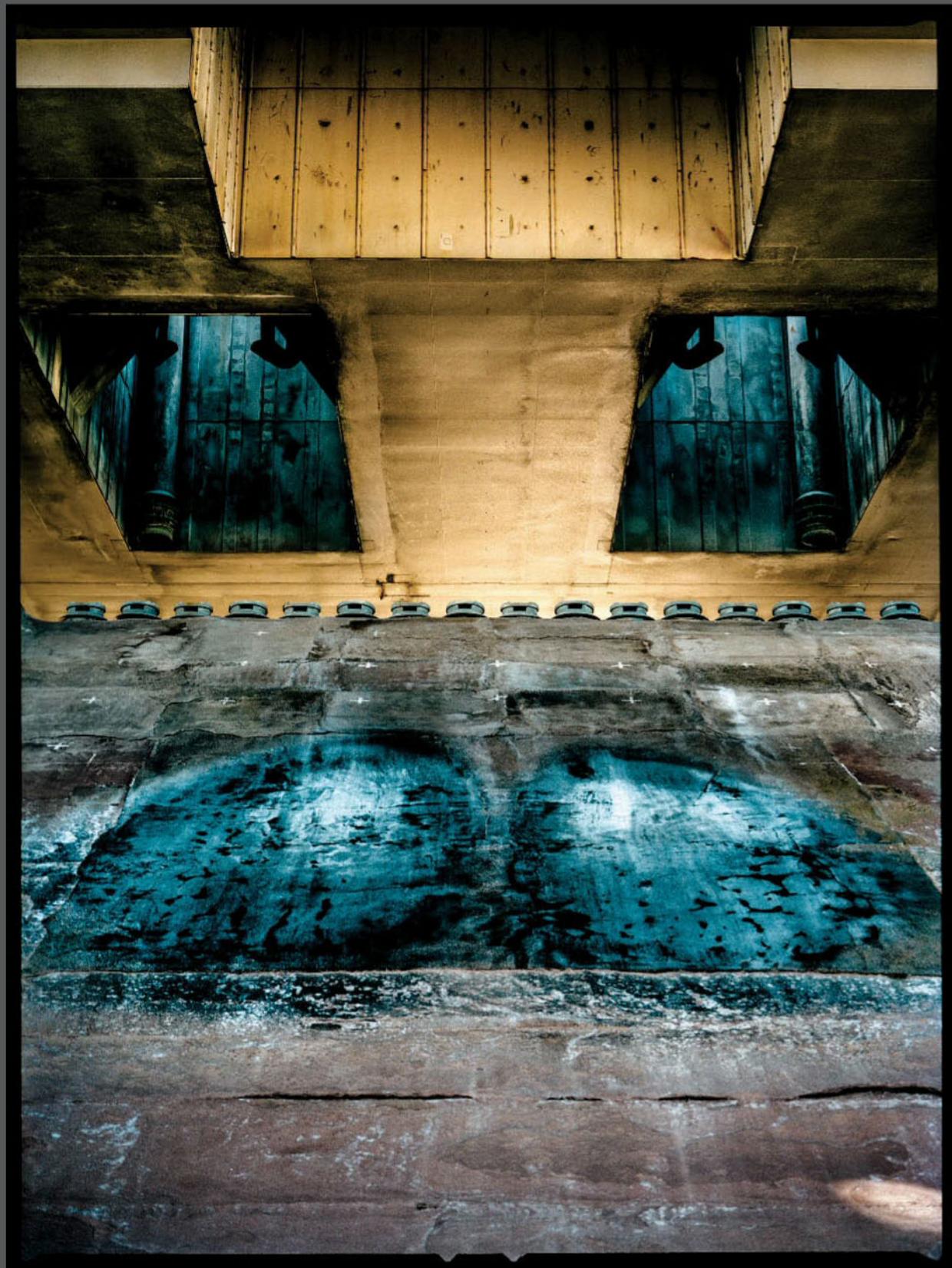
Last year's US presidential election showed just how outdated Brandeis's belief in the power of a large volume of free speech now is. The most accurate information didn't gain the most prominence. Instead, the mainstream media gave space to many made-up ideas and stories.

Together, all this undermines "moral suasion" – the force that nudges people not to do or say things that are too far outside the accepted norm. Once a society deems certain attitudes reprehensible – misogyny, for example – it becomes difficult for individuals to advocate them in public.

But with the moral consensus distorted online, there has been a resurgence of views many of us thought had been defeated – "scientific" racism, for example. So should Facebook and Twitter decide what constitutes hate speech and delete it as soon as possible?

There are many good reasons to be wary of outsourcing the policing of moral beliefs to firms, even if they are only implementing national laws, as would be the case with the German plan. But it is better to focus on the problems of relying on multinationals with corporate interests to police our moral consensus than to hide behind the old defence of free speech. ■

APERTURE





Rocket graffiti

UNDER launch pad 39A at NASA's Kennedy Space Center in Florida lies a trench. As rocket engines fire up for lift-off, it fills with streams of hot exhaust, safely diverting them at the expense of being scorched and scarred.

It was in 1967 that launch pad 39A became the premier spot from which to send humans into space, whether to the moon atop a colossal Saturn V rocket, or into low Earth orbit aboard the space shuttle.

When he looked at the layers of residue and engineers' markings built up over nearly 50 years, Michael Soluri perceived a modern cave painting. "The engineers just saw ablated material - it was part of their job," he says. "I saw something else. To me, it was all part of a magnificent mural made by man."

The blue ovals (pictured far left) are residue from the main engines of the space shuttle launch vehicle, which used liquid hydrogen and liquid oxygen (below).

The Saturn V rocket, on the other hand, used kerosene, which burned black. The most powerful rocket ever made, it left marks right up to the end of the fire trench, melting and peeling parts of its walls (pictured left).

All those scars are now gone. In 2014, SpaceX signed a 20-year lease for launch pad 39A and replaced the trench's walls and floor. Its new rockets will make their own marks. Leah Crane



Photographer

Michael Soluri

michaelsoluri.com

The innovation experts

If you are a young innovator hoping to change the world, Leave a Nest offers grants, funding opportunities and links to a seasoned network of experts and entrepreneurs

It started with a paper cup. That was the only prop Atsushi Shimizu used to pitch his idea for an unusual, cylinder-based wind turbine that, unlike other wind turbines, can not only withstand hurricanes but run on them. Two years later, Shimizu's company, Challenergy, has installed the first 3-metre-tall prototype on the Japanese island of Okinawa, which experiences hurricanes every year.

The speedy progress from paper cup to working wind turbine couldn't have happened without Leave a Nest – a Japanese company that supports innovators with ideas that could change the future. "We believe in the advancement of science and technology for global happiness," says Shohei Michael Maekawa, president of Leave a Nest UK.

Now, Leave a Nest is offering the same opportunity to innovators in the UK. Young scientists and engineers with big ideas are invited to pitch, develop and grow those ideas with the company, which offers funding, networking and support.

Leave a Nest was founded in 2002 as the brainchild of 15 Japanese graduate students. At the time, the group wanted to connect children with adult scientists – people who might inspire them to prepare for a career in science. The team launched a "Science Bridge Communicator" scheme to train young researchers to deliver science workshops to schoolchildren and so equip the next generation with the skills and understanding to make sense of science. Since launching, they have reached over 90,000 children this way. The company also publishes a series of publications for teachers, middle and high-school students, graduate students and adult researchers in Japan and the rest of the world.

Fourteen years later, with a staff of 60, Leave a Nest has built another successful side to its business – nurturing fledgling innovations at

any stage of their development towards commercial success. The company focuses on "real tech" – technology that requires physical development such as biotech, agritech and robotics rather than software-related technology such as e-commerce or game development. It then works with "super factories" in Japan to create physical products.

Would-be entrepreneurs need only the earliest shoots of an idea, says Maekawa. If it's a potentially world-changing one, Leave a Nest will help them create business models, brush up their presentations and connect them with big companies and super factories that can offer additional advice and funding.

To this end, Leave a Nest has partnered with over 300 Japanese companies, along with universities and government bodies. The result is a vast network of knowledge for new start-ups to tap into. This is how Challenergy and many other companies found their feet. With help from Leave a Nest, they were able to attract investment from large Japanese firms, as well as the Japanese government.

Leave a Nest's philosophy is based on a

Challenergy, a start-up backed by Leave a Nest, is harvesting energy from hurricanes



PERSOL TECHNOLOGY STAFF CO LTD



unique entrepreneurial cycle. First, it identifies important Questions and addresses them with Passion, as a Mission and with Innovation: the company calls this its "QPMI cycle". It is also able to draw on a wide range of expertise it has built up over many years to create a "knowledge-based platform" that is a key element of Leave a Nest's success.

Take Shimizu, for example, whose driving question was how to find an alternative energy source for Japan. Conventional wind turbines cannot cope with hurricanes, partly because they are unable to adapt to rapid changes in wind direction. Shimizu's design is based on cylinders rather than blades, and can respond to unpredictable wind patterns. "Shimizu didn't have any team members, or a prototype, when he pitched his design," says Maekawa. "It was his passion that won the judges over."

Leave a Nest helped Shimizu develop a mission – one that involved recruiting other like-minded people with various skill sets to work with him to develop his idea. As funding came in, the team worked on innovative ways to develop their concept with super factories, first as a 1-metre prototype, and then as a 3-metre device – the latest version that has just been installed on location in Okinawa. The turbine has already begun to generate energy for the island.

Shimizu was the winner of Leave a Nest's first TECH PLANter competition, which Maekawa describes as a "seed accelerator programme". As well as funding and networking, winners are trained in how to present their ideas and attract support and new team members. "The aim is to create a real tech ecosystem," says Maekawa.

Other previous winners include a team from India that designed a device to diagnose typhoid disease using tiny magnetic beads, and a group from Thailand exploring the use of gold nanoparticles in wound healing.



DAVID STOCK

Leave a Nest is now hoping to reproduce this success in the UK. Maekawa is concerned about the impact that Brexit might have on UK-based scientists, who could lose significant sources of funding from Europe. British scientists have a history of pioneering achievements, he says, including understanding the double-helix structure of DNA and creating Dolly the cloned sheep.

It was Maekawa's admiration for such achievements that led him to study in the UK. Now Leave a Nest UK's mission is to create a structure that allows more world-changing science and technology to come out of Britain. "This is a huge matter for me," he says.

This will be a busy year for Leave a Nest UK, with three goals. First, Leave a Nest is launching a grant scheme for UK-based scientists, engineers and entrepreneurs called the LNest Grant. The £3500 award is for people aged under 40 with a promising

"Let's change the world together! There are many ways to work with us"

idea, and successful applicants can spend their money any way they wish. "Usually, funders require that grant be spent on specific things like travel," says Maekawa. "We didn't want to restrict it – in theory you could spend it on ice cream, and that would be fine."

The team is also planning a hyper-interdisciplinary conference – an event for UK universities, entrepreneurs, companies and government to get together and share their ideas. Leave a Nest has been running such events in Tokyo for years. The UK event is scheduled for September.

Third, the company is running a TECH PLANter competition in the UK in October.

TAKE THE NEXT STEP

To find out more about Leave a Nest:

Check out the website
<https://en.lne.st/>

Like Leave a Nest on Facebook
facebook.com/LNEST.Global/

Like the Leave a Nest TECH PLANter World Facebook page
facebook.com/techplanterW/

Become a member of TECH PLANTER
<https://goo.gl/forms/IYfs81R385Exhtox2>

Ask Leave a Nest UK president
Shohei Michael Maekawa
a question at
gpd@lnest.jp

Those with ideas for world-changing technologies will have the opportunity to pitch to a panel of judges. The winners will receive all the same training, networking and funding opportunities, as well as the technical help to build prototypes for their designs.

There will also be a cash prize of around £1600 for the winning team. "We accept teams at any stage of development," says Maekawa. "We believe that greater diversity is better for our real-tech ecosystem." Judges will be looking for teams that can demonstrate a novel, practical idea that might just change the world, says Maekawa.

Oli Pinch, training manager at UCL Innovation and Enterprise, who attended the talk, says: "It's a really interesting idea. It's quite unique in a way, because it's an accelerator that's not looking to get intellectual property."

Those who don't enter for the prizes are still welcome to join the Leave a Nest community. "We are always open to people who have ideas and want to become members of our network," says Maekawa. The team is opening a "virtual" UK office next to University College London, in the city's heart.

In the meantime, anyone who is interested can sign up for the events and competitions at Leave a Nest's website or Facebook page (see above). Maekawa has high hopes. "Let's change the world together! There are many ways to work with us," he says. ■

More at: <https://en.lne.st/>

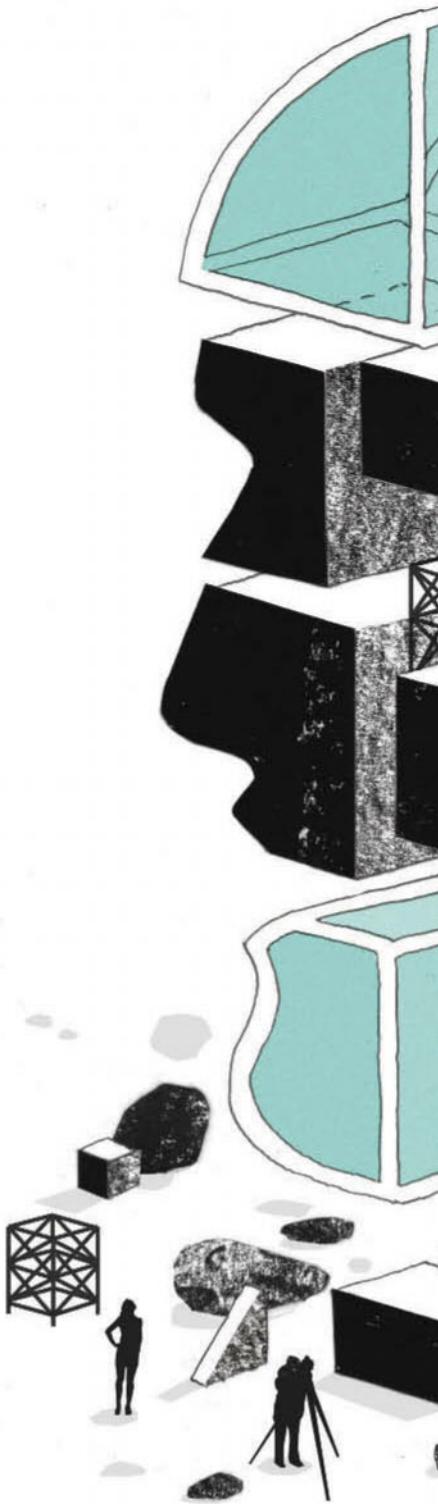
WHAT IS KNOWLEDGE?

- 1 WHAT IS KNOWLEDGE?**
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The pursuit of knowledge underlies human progress. In many ways we know more than ever before – yet distinguishing fact from opinion and truth from belief sometimes seems ever harder to do.

Over the next 12 pages we go back to basics, asking what knowledge is, its worth to us as individuals and as a species, and other central questions of epistemology – the science of knowledge itself

JAMIE MILLS





1 WHAT IS KNOWLEDGE?

'VE won the lottery. I haven't checked my numbers yet, but I just know. You know what it's like, when you just know you know.

Knowledge is a slippery concept: what we know, how we know we know it, what we know others know, what others know of what we know, how what we or they know differs from what we just believe. You would probably argue that, until I see the winning numbers, I can't know I have won the lottery - I can only believe it. Yet how do you know that?

Most of us make our way through life without peering too closely under the bonnet of epistemology - the theory of knowledge. "We manage it intuitively, we don't have to reflect and calculate," says Jennifer Nagel, a philosopher at the University of Toronto, Canada, and author of *Knowledge: A very short introduction*.

But it rewards closer inspection. For a start, the degree to which we know stuff and know what others know is quite possibly what separates humans from everything else on the planet, from rocks to chimpanzees (see "Do animals know things?", page 37). It is certainly the lubricant of all human interactions. "We can cooperate, communicate and compete better if we know what others know and

don't know," says Nagel. "Tracking states of knowledge can help you in the course of the argument, brace yourself against fallacies."

Yet defining the basic currency of knowledge is surprisingly difficult. To know something you must first believe it, but that's not enough: to make factual knowledge, that belief must also be true. "That is the one thing we're all happy to accept," says Nagel.

"True belief" is insufficient, though. A belief can be true just by chance, or we can arrive at a right answer via a wrong route. So epistemologists have traditionally added another condition for a true belief to count as knowledge: it must also be justified in some way. In the lottery example, the perceptual evidence of the numbers on my lottery ticket plus the testimonial evidence of, say, a broadcaster reading out the winning numbers creates the inferential knowledge that I have won - or not (see "Where knowledge comes from", below right).

STOP THE CLOCKS

For a long time, the conception of knowledge as a justified true belief ruled the roost. But then US philosopher Edmund Gettier put forward a couple of devastating counterexamples in a short paper published in 1963.

An example of a "Gettier problem" is someone glancing at a clock that says 12, at midday. The catch is that the usually reliable clock is broken, and is showing the right time only by chance. Our clock watcher believes it is midday, that belief happens to be true, and the stopped clock provides justification. But in fact no one knows it is midday - they just believe they know it.

Various attempts have been made since to tighten up the standards of justification to get round this sort of problem and provide a definition of knowledge everyone can agree on. But no one has quite yet nailed this one down. "It's kind of an awkward question," says Nagel.

"Knowing something is a far richer, more complex state than merely believing it"



In the end, though, an answer might not be the point. All these epistemological investigations point us to one fact that we are wont to forget: that knowing something is a far richer, more complex state than merely believing it. The ability to distinguish between fact and opinion, and to constantly question what we call knowledge, is vital to human progress, and something we cannot afford to let slip (see "How can I know the truth?", page 36).

"Knowing something is a mental state that locks you on to the truth," says Nagel. What that lock is, though - well, we don't really know. Richard Webb

2 WHY DO WE SEEK KNOWLEDGE?

In 1969, Robert Wilson, the first director of Fermilab near Chicago, was asked by a US Congressional committee whether the new particle accelerator he was seeking funds for would aid the fight against the Soviet Union. "This new knowledge has all to do with honour and country," he said. "But it has nothing to do directly with defending our country except to help make it worth defending."

Wilson's full testimony is a robust and elegant defence of the pursuit of knowledge for knowledge's sake. But it raises its own questions. In what sense is knowledge "worth it"? And what motivates our urge to acquire it?

Knowledge is more than just information. Even the nematode worm *Caenorhabditis elegans*, owner of one of the smallest brains we know, forages to maximise information about its environment, and so its chances of staying alive and reproducing.

But as far as we know *C. elegans*, or indeed any species other than our own, doesn't ponder the universe's origins; they certainly don't publish papers on it or build particle accelerators to find out (see "Do animals know things?", page 37). Knowing as we understand it involves abstracting information and interpreting it for use at different times and in other contexts. "When you have knowledge, you can do lots of things," says epistemologist Duncan Pritchard at the University of Edinburgh, UK. "You can deal with entirely new situations in creative ways."

Reading this article – weighing up its beliefs, truths, justifications and perhaps misapprehensions – won't get you a square meal or make you more attractive to a potential sexual partner (or perhaps only indirectly). And yet brain-imaging studies show that when we answer trivia questions or look at blurry images designed to pique curiosity, areas associated with our response to food and sex light up. That

suggests we treat knowledge as a similar primary reward.

The precise details of how we first came to love knowledge may always elude us. But it is easy to see how it would have spurred our success as individuals and as a species, furnishing us with the tools – often literally, if you think of cutting blades or fire – to survive and prosper.

In that case, we are in some way addicted to knowledge because it has served us so well in the past – as it still does today, in everyday life as well as at the frontiers of technological progress. As Abraham Flexner, founder of the Institute for Advanced Study (IAS) in Princeton, New Jersey, pointed out in a 1939 essay "The usefulness of useless knowledge", radio communication and all that came with it wasn't ultimately the invention of Guglielmo Marconi. It was down to James Clerk Maxwell and Heinrich Hertz, scientists who worked out the basics of electromagnetic waves with no practical objective in mind.

There are plenty of similar examples, says Robbert Dijkgraaf, current director of the IAS, who has written a companion essay to a reissue of Flexner's original this year. "The theory of general relativity is used every day in our GPS systems, but it was not the reason Einstein solved it," he says.

That doesn't mean science gets a blank cheque – and certainly not in a world where children are going hungry, as Wilson made plain in his testimony. There is such a thing as useless scientific research – it is just hard to say what it is, says Massimo Pigliucci, a philosopher of science at the City University of New York. "That is why scientists need to make a case to their peers and to the public for why what they do is interesting or important."

As to why they do it, it's no different for scientists than for anyone else. Seeking knowledge is what separates us from the worms. **Daniel Cossins**

WHERE KNOWLEDGE COMES FROM

One way to classify knowledge is by how we acquire it

PERCEPTUAL

The direct evidence of our senses

TESTIMONIAL

Facts we acquire from other people and media

INNER SENSE

Awareness of our own feelings and states, such as pain and hunger

INFERRENTIAL

Knowledge we stitch together ourselves from raw inputs

JAMIE MILLS



3 IS SCIENTIFIC KNOWLEDGE SPECIAL?

NULLIUS in verba: "take nobody's word for it". The motto of the Royal Society, the UK's national academy of science, encapsulates the spirit of scientific enquiry. Do an experiment, record its outcome faithfully and objectively, and make that record available for doubters.

This way of working means that, if knowledge is defined as the route to the truth (see "What is knowledge?", page 32), science is an expressway to enlightenment. Thanks to what science tells us about human physiology, the universe's history, nature's forces and Earth's geology, flora and fauna, we know Earth isn't flat, the universe is nearly 14 billion years old, and that there are no dragons or unicorns. We live longer and in more comfort, and can send space probes to the edge of the solar system. Pretty darn special, huh?

But let's take a more sceptical look,

A motto for science,
a motto for life

starting with that "we". Some people do believe Earth is flat. Others say the universe is 6000 years old. Some doubt the theory of evolution by natural selection, or the reality of human-made climate change. We is not everyone.

UNICORNS IN LOCH NESS

It is tempting to say that's their problem, not science's. But science is also limited in what it can say. It can't prove a negative: there might be dragons and unicorns, a monster in Loch Ness, a God. It can't even be definitive about all the positives. "Our evidence may at times leave us able to make only probabilistic judgements – we may sometimes be restricted to saying that a certain outcome or theory is likely to be true," says Jennifer Nagel at the University of Toronto, Canada.

This weakness becomes greater as we extend the scientific method into more complex realms with more variables and so more uncertainty, such as social

science or climate change. Science progresses legitimately through speculation and hypothesising, but until these speculations are tested by experiment, for a stickler any "knowledge" that emerges from them must strictly be labelled as provisional.

It is a weakness (or strength, depending on your point of view) exploited with gusto by climate-change sceptics, among others. But it points to a blunt truth: if scientific knowledge feels special to you, you are in its in-group. As we grow up, we absorb beliefs from our cultural environment. For some that means accepting scientific knowledge; for others it means "revealed" knowledge, from the Bible, say.

And here's the thing. For all the bluster about "the evidence", if you are a scientific believer you too are taking almost all of it on trust. "In principle everybody should be able to replicate scientific results given time, money and training," says Brigitte Nerlich at the University of Nottingham, UK. "But not everyone has a Large Hadron Collider or a climate-modelling computer." You are taking someone's word for it. Like other forms of knowledge, most of science comes down to trusting the source.

Not special, then? Perhaps – except that science also provides mechanisms to justify trust in the knowledge it generates. "Authority in science is earned – at least, when a scientific community is functioning well – by success at predicting, and more generally at analysing, empirical phenomena," says philosopher Edward Hall of Harvard University. Science's conclusions are accepted when they fit with our experience of the physical world, and are discarded when they cease to. That makes trust in science a justified true belief – and knowledge that true science generates a cut above the rest. Just don't take my word for it.

Michael Brooks



ALAMY STOCK PHOTO

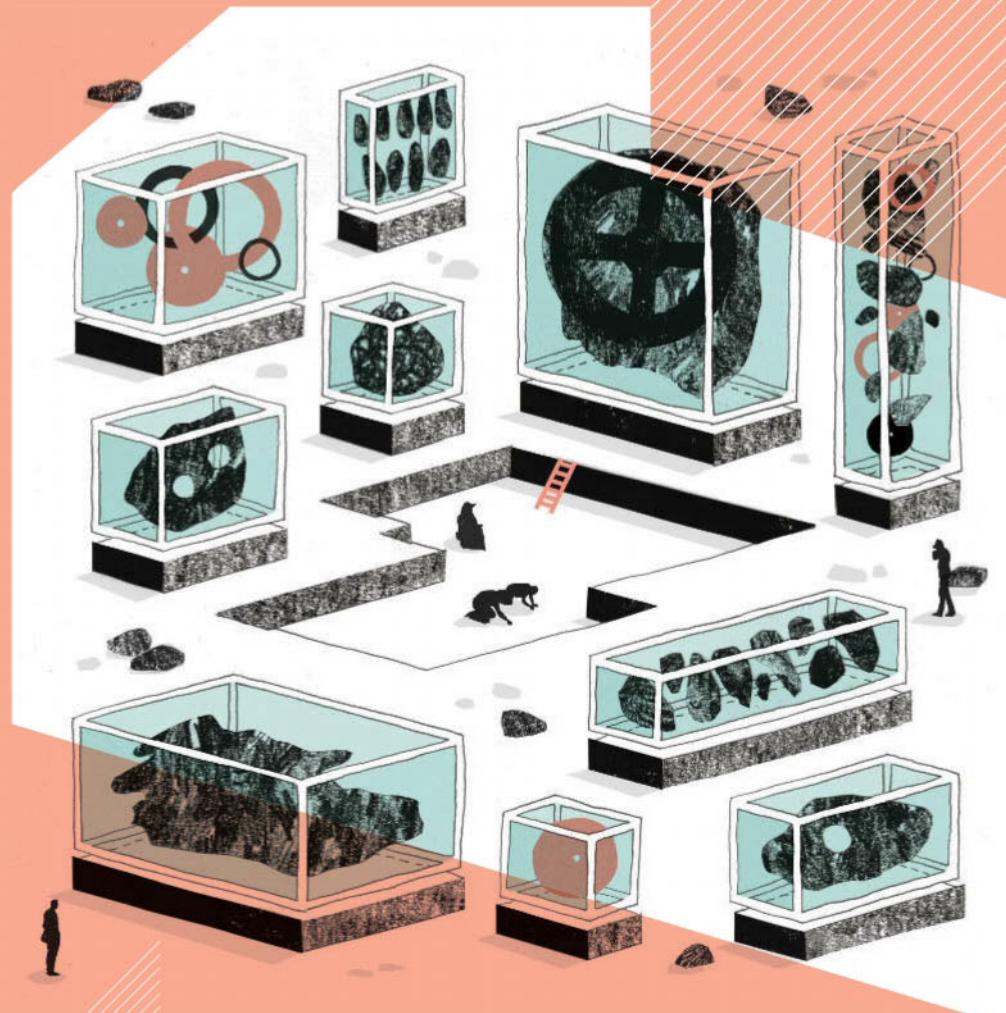
BY THE year 3700, Earth is far too hot for any human to call it home. On this planet at least, *Homo sapiens* nothing more than a memory - if there is anything left to remember the "wise man". But what of our wisdom - will any of it outlive us?

The conventional answer is no. Knowledge requires a knower, and there will be no sufficiently knowing minds around. But if information survives, perhaps in books or hard drives, maybe the knowledge isn't quite dead but dormant, ready to be resurrected by other minds that evolve or come to visit Earth in the distant future.

At first sight, that seems plausible: after all, we have done similar things with past knowledge. Take the reconstruction of the Antikythera mechanism, an ancient computer salvaged from a shipwreck off the southern coast of Greece, or the deciphering of Egyptian hieroglyphics thanks to the Rosetta stone. Meticulous work can bring previously lost wisdom back to life.

Crucially, however, there is a certain cultural continuity with those ancient times that allows us to draw inferences and make leaps in the dark: we know we are dealing with the legacy of other humans. Without that link, the survival of artefacts and raw data doesn't guarantee the survival of knowledge - and certainly not complex, multilayered knowledge.

Take our cosmology. Detailing how it explains the workings of a star, or demands the existence of something like dark energy, isn't easy with raw data alone. A cultural



JAMIE MILLS

WILL OUR KNOWLEDGE SURVIVE US?

relativist might even say it is impossible: every culture constructs its own knowledge and there is no objective starting point.

Michael Blome-Tillmann, a philosopher at McGill University in Montreal, Canada, thinks that's going too far. "There are very basic facts that we all know; if you drop a ball, it's going to fall on the ground. I don't see how there's any cultural relativity there."

Even if that is true, a lack of linguistic continuity with any future intelligence would be a stumbling block. Knowledge is intimately bound up with language, says James Collin at the University of Edinburgh, UK. Take a statement such as "there are

infinitely many prime numbers". Whether it is true or not, its language implicitly assumes that numbers exist. That might not seem controversial, but philosophically it isn't a given.

Or take the word "scarlet", or the subtle lexicon of names Canada's indigenous First Nations communities give to caribou. What they actually mean depends on a package of assumptions and inferences that aren't necessarily shared across cultures. When a language dies out, we can lose systems of reasoning that they contain. "If that's lost, then it can't be recovered," says Collin.

All this means that other minds might not be able to fully resurrect human knowledge once we are gone. Better to concentrate on not dying out in the first place. Joshua Howgego

"If books or hard drives survive, perhaps the knowledge is not dead"

5 HOW CAN I KNOW THE TRUTH?

POST-TRUTH was 2016's word of the year, according to Oxford Dictionaries. Not least in the furious debates surrounding the UK Brexit vote and Donald Trump's election as US president, claims and counter claims of fake news, dodgy experts and media mendacity have been flying around.

For a hardcore of relativist philosophers, that's all a storm in a teacup - there's no such thing as objective truth that exists outside our minds. Nonsense, harrumphs Peter van Inwagen of the University of Notre Dame in Indiana. If a doctor says I have cancer of the gut, he says, "whether that is true depends on what is going on in my gut, and not on what is going on in my doctor's mind".

Accept that, and the challenge - in the post-truth era as much as in the pre-post-truth era - is to ensure that our inside knowledge is aligned as far as possible with outside truth.

That's hard, not least because in a complex society we rely on the knowledge of others, even when we don't realise it. Ask someone if they know how an everyday object such as a ballpoint pen works and they'll generally say yes, until you ask them to explain it. It turns out that our confidence in our own knowledge is often based on the certainty that somebody else knows.

That is often good enough; ballpoint pens exist and work. "As individuals we know hardly anything," says Steven Sloman of Brown University in Providence, Rhode Island, co-author of *The Knowledge Illusion: Why we never think alone*. "But most of us do very well and as a society we create incredible things. We sent a person to the moon. How is that all possible? Because of the knowledge of other people."

So how much should we trust people who actually do know stuff? "It's not that we

want people to uncritically accept whatever experts say," says Timothy Williamson of the University of Oxford. A certain level of scepticism is healthy.

But it makes things difficult if we begin to mistrust expertise as a default. In philosophy, a true sceptic questions everything, so they have nothing left to build knowledge on. That's where we don't want to go as a society - while not losing sight of the fact that expertise differs in value and reliability (see "Felicitous falsehoods", below right). We should accept that, if we need a tooth pulled, going to see someone with a degree in dentistry just guarantees a dentist, not necessarily a good dentist, says Catherine Elgin of Harvard University.

How do we tread that fine line between healthy scepticism and destructive cynicism? First, think critically and assess the credentials, track record and potential bias of the sources we rely on. "If somebody is telling me this, what motives could that person have for wanting me to believe that, other than that it's true?" says van Inwagen. "Those are the practical questions."

Pose the same questions of yourself, too. "Ask 'How do you know?', 'How do they know?', all the time," says Elgin. Train yourself to ask whether your reaction to new knowledge is rooted in something trustworthy or something else, like wishful thinking. "Think about something like global warming," says Elgin. "To do something about that might require a certain amount of rather inconvenient stuff, so you'd really rather not believe it and start to make the sacrifices you would have to make."

And finally, avoid the seductive belief that you are privy to knowledge purposely being denied to others, or a warrior for truth when all others are peddling lies. Human beings are, in general, terrible at keeping secrets. "If you were sceptical you wouldn't be convinced by conspiracy theories," says van Inwagen. But these experts would say that, wouldn't they? Tiffany O'Callaghan



FELICITOUS FALSEHOODS

To get at the truth, sometimes we need to lie - for instance in building up scientific models that simplify an often complex world. The ideal gas law, for example, tells us how the volume, pressure and temperature of a gas are related, but assumes the individual molecules of the gas behave as perfect spheres that bounce off each other elastically.

Of course they don't. "But if you took into account the actual shapes of the actual gas molecules in a volume of gas, just the geometry, the problem of saying what is going on with this gas, would be incalculable," says Catherine Elgin, a philosopher at Harvard University.

So these felicitous falsehoods help us dig at deeper truths - as long as we don't forget where they are and let them become the weight-bearing part of the structures we build.

Economists, for example, have traditionally created models of stable markets by assuming that buyers and sellers have perfect information and make rational choices - only to be constantly surprised when the irrationality of human decision-making creates a messier reality.

So simplify for science's sake - but sensibly. "The real problem isn't with doing it, it's not being aware of what you're doing," says Elgin.

If you are a sceptic, you won't be convinced by conspiracy theories"

6 DO ANIMALS KNOW THINGS?

WORKERS at the David Sheldrick Wildlife Trust in Nairobi, Kenya, claim that elephants know they will be looked after at its rescue centre, even if the animals have never been there. Elephants that have had no contact with the centre, but know others who have, often turn up with injuries that need attention. That suggests not only abstract knowledge, but relatively sophisticated communication of that knowledge. Either that, or wishful thinking on our part.

The extent to which non-human animals "know" things is difficult to assess. The attribute known as "theory of mind" – the ability to know what others are aware of – has been demonstrated, although not always conclusively, in elephants, chimps, parrots, dolphins and ravens, for example.

Dolphins are even aware of lacking knowledge. Train a dolphin to answer a question such as "was that a high or low-frequency tone you just heard?" and they give sensible answers, even giving a "don't know" when the right response isn't clear. Some primates spontaneously seek further information when posed a question that they can't answer, suggesting they know both that they don't know and that they can change that.

Things look more mixed when we consider abstract knowledge: the ability we have to understand abstract properties such as weight or force, and squirrel away knowledge gained in one situation to be applied in some future, different context.

Great apes instinctively know that, of two identical cups on a seesaw, the lower one is more likely to contain food. "They have a spontaneous preference, from the first time, for the lower cup," says Christoph Voelter, who researches animal cognition at the

University of St Andrews, UK. "They seem to have certain physical knowledge about the world."

New Caledonian crows, on the other hand, don't have this know-how and make "mistakes" when assessing which stones will exert the most force on a lever to release food. "Crows aren't using knowledge of force when initially solving the problem," says Alex Taylor of the University of Auckland, New Zealand – rather, they seem to use trial and error.

GREAT OCTOPUS ESCAPE

There is evidence of animals showing regret at missed rewards, and knowledge of others' deceitful behaviour. But we can only infer an animal's state of mind from our observations, and inference rarely

tells the whole story. Take the daring escape of Inky the octopus when his tank was left open at the National Aquarium of New Zealand last year. We might conclude from the way he did an eight-legged runner that he knew he didn't want to be there. Or from how he seems to have made his way out of the building via a 50-metre drainpipe that he knew (or sensed, at least) it led to the sea. But in the end we can't know whether the escape was planned or just opportunistic.

Santino the chimpanzee is definitely a planner. He knew he would want to throw objects at visitors to Furuvik Zoo in Sweden when they came, so broke the concrete in his enclosure into discs suitable for hurling, and made a pile of them. Chimps in the wild have been observed to plan breakfast, sorting out in advance what they'll eat, where they'll get it and when they'll have it.

But there's still something crucial missing. A human toddler given a new object will investigate it thoroughly, checking through all its properties. "Humans perform these natural, systematic experiments to discover how the world works," says Voelter. "We don't have any evidence so far that other primates are the same."

This innate curiosity and our unsurpassed linguistic ability allow us to accumulate a huge, almost undoubtedly unique repository of abstract knowledge about the systems and objects around us. You couldn't teach a chimp quantum mechanics.

But we shouldn't diss animal abilities. After all, crows know who you are and can hold a grudge against you for years, found John Marzluff of the University of Washington in Seattle. At least they don't know where you live, says Marzluff. "In my experience they must see the person, out of the house, to respond to the person," he says.

Michael Brooks



FURUVIK ZOO

Are you thinking what I'm thinking?

7 HOW MUCH CAN WE EVER KNOW?

ULTIMATELY, the jumbo shrimp tells us why we are doomed to never fully understand reality.

But let's back up a bit first. We know we live in a universe where there are hard physical limits to what we can know. Light's finite speed restricts our ability to see in time and space, quantum uncertainty our understanding of subatomic particles.

So what? Our largest telescopes look back to a few hundred million years after the big bang, while our sharpest microscopes can spy on individual photons escaping from atoms. The universe is as it is, and we work quite well within its limits. True, we can't explain what happens at the big bang, or inside a black hole – but that's just a matter of devising better theories of nature and ways to test them.

So to know more we need to compute better. Easier said than done. Were we able to simulate the fine-grained movements of all the universe's matter, we might predict its evolution and fate. But with current computing power, that would take more time than the universe has to offer.

Computational power is a practical limitation we can blame for everything from unreliable weather forecasts to shoddy logistics: once you try to optimise an itinerary linking more than a few thousand destinations, it becomes impossible to compute. "There are so many parts to it it's simply improbable that we can work it out," says Noson Yanofsky, an information scientist at the City University of New York.

But ultimately, that's just a fig leaf for a mega-sized limitation. However powerful we make them, computers ultimately rely on human input to program them – and human thought is a glorious, uproarious, complex mess. Statements like "this statement is false", hating someone yet loving them and yes, that small-yet-large jumbo shrimp,

both compute and do not compute. "Language is an expression of the mind, and my mind and language is full of contradictions," says Yanofsky.

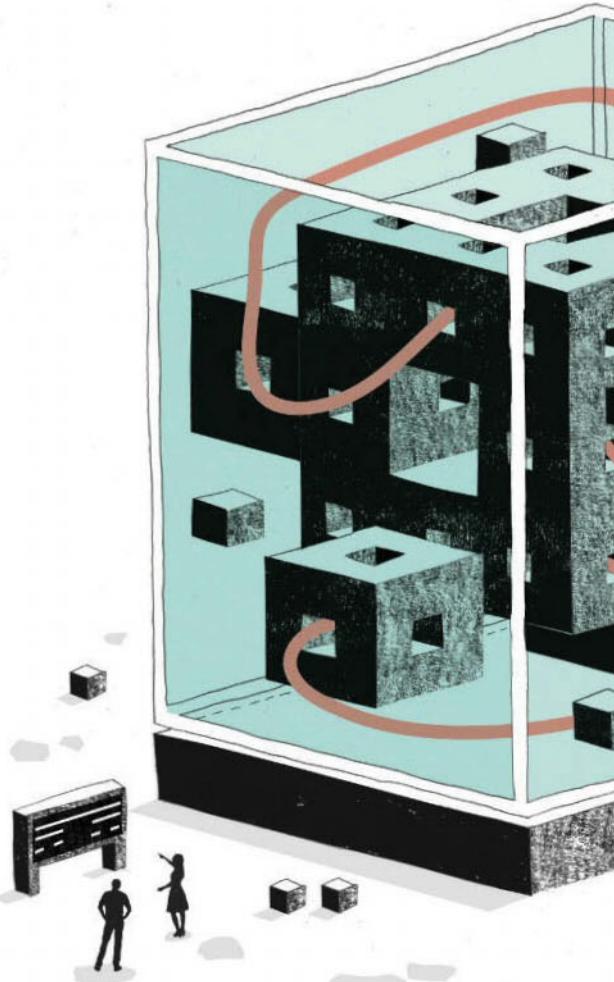
CAN'T COMPUTE

That flexibility allows us to think outside the box, while remaining firmly inside it. Because we are predicated on contradiction, we see contradiction everywhere. The defining feature of reality, however, is that it admits no contradiction. Take the way quantum objects apparently act as waves or as particles according to how we choose to measure them, a confusing duality physicist Richard Feynman called "the only mystery" of the quantum world. In all probability, the basic building blocks of reality are neither wave nor particle, but something else entirely. It's just something that we lack the experience or cognitive ability to express.

Logic, and the mathematics that builds on it, is supposedly our way out: a cleaner, neutral language for a trained brain to describe in abstract terms what it cannot visualise. That's all very well – until you encounter the logical limitations of mathematics itself.

These start with well-known injunctions such as never to divide a number by zero. Why not? Because if you do, you can begin to do things like prove $1 = 2$. If maths is the language of a flawless universe, we can't allow that – so we don't. "If you want mathematics to continue without contradictions then you have to somehow restrict yourself," says Yanofsky.

And sooner or later, we come to the end of the road. As Austrian mathematician Kurt Gödel showed in the 1930s, any system of logic containing the rules of arithmetic is bound to contain statements that can be neither proved nor disproved. It will remain "incomplete", trapped in the



same inconsistency as we are (see "An unknowable problem", right). Gödel incompleteness is a mathematical expression of the logical-illogical statement "this statement is false". The fundamental truth is there is no way for anything, be it a simple sentence, a system of logic or a human being, to express the full truth about itself (see "Can I know myself?", page 40).

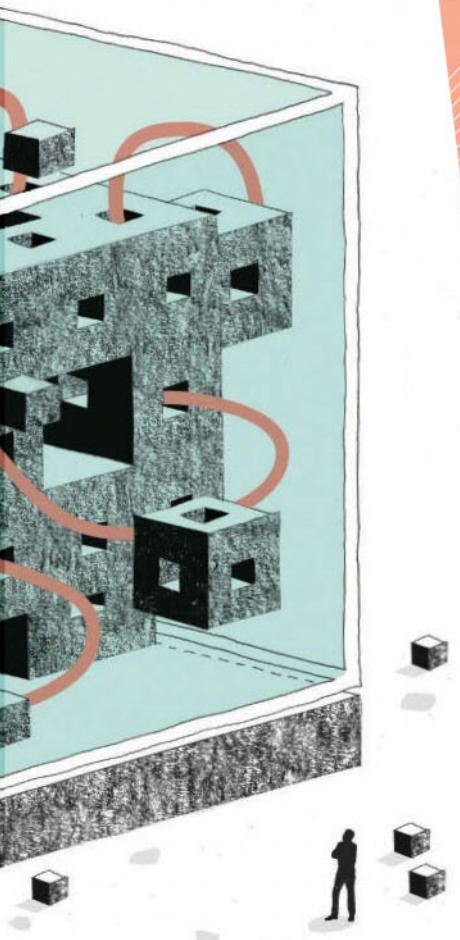
This problem of self-reference is endemic. Gödel's contemporary Alan Turing showed that you cannot ask a computer program in advance whether it will run successfully.

Quantum mechanics sprouts paradoxes because we are part of the universe we are trying to measure (see "Is everything knowledge?", page 41).

So the sobering truth is that we can build the most powerful telescopes, microscopes and computers we want, but we will never overcome the limitations of our minds. Our perspective on reality will always be skewed because we – and the jumbo shrimp – are part of it. **Richard Webb**

JAMIE MILLS

80 HOW MUCH CAN ONE PERSON KNOW?



AN UNKNOWABLE PROBLEM

It is perhaps the strangest result in all of mathematics: a simple statement whose truth is impossible to prove. Only we can't prove that.

This "continuum hypothesis" has to do with what sort of infinities exist. Infinity is not a single thing; there are in fact infinite levels of infinity. The lowest is the "countable" infinity of the whole numbers - 1,2,3,4,5 and so on. Another, bigger infinity is the "continuum" infinity of the real numbers - all the countable numbers plus all the other ones with any number of decimal places in between.

In 1878 set theorist Georg Cantor hypothesised that the countable infinity and the continuum infinity

are neighbouring rungs in the ladder of infinities; there is no other infinity between them. He strongly suspected this was the case, but couldn't prove it.

And no one has been able to since. Attempts to prove or disprove the continuum hypothesis have instead revealed the existence of a "multiverse" of different mathematical worlds, all producing the sort of logical structures that correspond to physical reality, but differing in whether the continuum hypothesis is true or false. That is perhaps an indication that mathematics is itself only part of a much larger logical structure we have yet to reveal.

ARISTOTLE, of course, was the "last man to know everything" - everything useful to know about the world during his lifetime. No wait, it was Leonardo da Vinci. Or was it Goethe, or his equally brilliant Teutonic contemporary Alexander von Humboldt?

The trope of the last universal polymath is a common one - along with the idea that, as our compendium of knowledge grew, at some point it outstripped the capacity of one brain to house it.

If so, that happened a long time ago, says Chris Stringer, a palaeoanthropologist at London's Natural History Museum. "Given the diverse environments in which humans lived even before migrating from Africa, I doubt that any one human could have maintained all the required information needed to survive across the human range."

A similar "experiential" limit still applies, but in today's world the sheer amount of raw information to be processed undoubtedly far outstrips the capacity of any one person to process it. A human brain has roughly 100 billion neurons connected in labyrinthine ways by 100 trillion synapses. According to a 2015 estimate from the Salk Institute near San Diego, that amounts to an information storage capacity measured in petabytes - millions of gigabytes. By comparison the Large Hadron Collider, the particle smasher at CERN near Geneva, Switzerland, pumps out some 30 petabytes of data in just one year. Small wonder one paper published jointly by the two main LHC collaborations, ATLAS and CMS, credited 5000 people with producing and analysing the data.

Such comparisons are, of course, facile. Creating knowledge is about a lot more than assimilating data, and your brain is not an empty petabyte memory stick. If it were, you would send it back to the shop, disappointed by its slow upload rate.

And this is the rub when it comes to

A fighter jet embodies more than one person can know

working out how much any individual brain can know: we have never filled one up. We invariably reach a time limit before we reach a processing limit. Take hyperpolyglot Alexander Arguelles. Already competent in over 50 languages, he says, "Give me total freedom of time... and I could conceivably do 100 languages" - at the expense of everything else in his life, though.

César Hidalgo at the Massachusetts Institute of Technology has dubbed the amount a person can realistically learn in their lifetime a personbyte. The knowledge you would need to throw a beautiful clay pot is less than 1 personbyte. But if you want to build an F-22 Raptor fighter jet complete with on-board missile-guidance systems, you're going to need many thousands of personbytes. Aristotle wouldn't know where to start.

We shouldn't let our brains' meagre bandwidth get us down. If the amount and complexity of human knowledge has increased over time, so the means of acquiring it have steadily improved too, with spoken language, written language, the printing press and now the internet. In that profusion of information, the barrier to progress lies not in the quantity of knowledge our brains can hold, but in its quality. Sean O'Neill



LOCKHEED MARTIN PHOTO BY ERIC SCHUZINGER

9 CAN I KNOW MYSELF?

WHOMI? The question resonates down to us from antiquity: the injunction "know thyself" was, according to the 2nd-century Greek traveller Pausanias, inscribed on the forecourt of the Temple of Apollo at Delphi. "It is a classical philosophical ideal," says philosopher Thomas Metzinger of the University of Mainz, Germany. "We should expand our own knowledge about ourselves wherever and whenever we can."

But is it even possible to gain a true picture of our self that corresponds with reality? We are within ourselves, so any attempt to build a full picture is naturally fraught with our own cognitive biases and problems of self-reference (see "How much can we ever know?", page 38). A big part of our self-perception is tied up with how others see us - yet we can never fully know the biases that cloud their perception.

Philosophical investigations, plus scientific observations of human behaviour, have at least allowed us to delineate the question of what the self is a little more sharply. And it turns out there's not one way of doing so, but several.

First, there is the phenomenal self. This corresponds to our sense of existing, and that there is a distinct entity in our mind that experiences this existence. This self is very real to each of us: it's a sense of being a body situated in the here and now, and also of being a person existing over time.

But it is not always a reliable source of true knowledge about who we are. Someone suffering from the rare neurological disorder Cotard's syndrome, for instance, has the distinct and disturbing experience of non-existence - a subjective self-knowledge clearly at odds with the truth. And every night, most of us dream. "In a dream we can have a robust sense of

self while being completely deluded about who and where we are," says Metzinger.

A more sophisticated type of self-knowledge comes with the epistemic self. This creates a sense of self that knows it knows. The epistemic self is aware of the working of the phenomenal self, potentially making us more aware of our motivations. "It is simply the discovery of a new way of being related to oneself," says Metzinger.

THE GRAND DELUSION

Suppose you are sitting in a mind-numbing meeting and start fantasising about an exotic vacation. Your phenomenal self wanders with you into this dream world, but as you snap back to the reality of your meeting and become aware you've been daydreaming, your epistemic self flashes into action, only to disappear again as your mind focuses (or wanders) once more.

Enhancing the epistemic self is the aim of mindfulness and meditation. Doing so can give you greater mental autonomy, "the capacity to stop or better control what you are thinking, feeling, doing", says Metzinger.

In assessing our capacity for self-knowledge, however, most of us suffer from a grand delusion: that our self somehow exists apart from our material body. Most philosophers and neuroscientists today think that this sort of "ontological" self is a fantasy: there is no self separate from the brain that interacts with it. The "I" that we feel is an outcome of the material processes that constitute our brain and body: when the body dies the "I" goes with it.

That may not be the desired end to our philosophical journey of self-knowledge. But then again, as Metzinger says, "Nobody ever said that this will lead to enchanting or emotionally attractive results." Anil Ananthaswamy

"At night, we dream – we have a robust sense of self while being completely deluded about who and where we are"



10



LESSANDRO INCARNAZAO / STOCK PHOTO

IS EVERYTHING KNOWLEDGE?

“FROM bit.” This phrase, coined by physicist John Wheeler, encapsulates what a lot of physicists have come to believe: that tangible physical reality, the “it”, is ultimately made from information, or bits.

Concepts such as entropy in thermodynamics, a measure of disorder whose irresistible rise seems to characterise our universe, have long been known to be connected with information. More recently, some efforts to unify general relativity, the theory that describes space and time, with quantum mechanics, the theory that describes particles and matter, have homed in on information as a common language.

But what is this information? Is it “ontological” – a real thing from which space, time and matter emerge, just as an atom emerges from fundamental particles such as electrons and quarks and gluons? Or is it “epistemic” – something that just represents our state of knowledge about reality?

Here opinions are divided. Cosmologist Paul Davies argues in the book *Information and the Nature of Reality* that information “occupies the ontological basement”. In other words, it is not about something, it is itself something. Sean Carroll at the California Institute of Technology in Pasadena disagrees. Even if all of reality emerges from information, he says, this information is just knowledge about the universe’s basic quantum state.

So we have to drill deeper. In quantum mechanics, an object’s state is encoded in an abstract mathematical entity known as a wave function. This wave function doesn’t itself say anything definite about that state. Rather, it gives you probabilities of finding the object in a particular state – of pinpointing a particle in a certain location, say.

But is the wave function itself ontological or epistemic? Is the uncertainty the wave function represents a true reflection of reality’s state – or just our state of knowledge about it? “One of the most

controversial things about quantum mechanics is the status of the wave function,” says Sheldon Goldstein, a theorist at Rutgers University in Piscataway, New Jersey. “There’s total disagreement about that.”

The answer depends on which of many different philosophical interpretations of quantum mechanics you plump for. In the most prevalent “Copenhagen” variation, the wave function is epistemic. Not only that, but it represents a state of knowledge that is fundamentally limited. There is no way we can know what’s happening in reality without looking: there is nothing in the mathematics that represents, for example, a particle’s trajectory over time. When we do look, by making a measurement, we find the particle somewhere, and the wave function is said to have “collapsed” into a definite knowledge state.

WHO COLLAPSED THE UNIVERSE?

There are other interpretations of quantum mechanics in which the wave function is itself something real. In this case, though, it doesn’t exist in the familiar dimensions of space and time, but rather exists in some higher-dimensional “configuration” space that contains information about the positions of particles.

All of this creates immense problems – not least when we come to consider the quantum state of the universe. If the universe’s wave function only collapses into a definite state when someone makes a measurement, who or what is making that measurement on the universe, and what is the universe doing when no one’s looking?

It’s here that we begin to encounter the seemingly fundamental barrier of self-reference (see “How much can we ever know?”, page 38): we cannot achieve complete knowledge about the universe because we ourselves are part of it. Knowledge may be everything, but we’re stuck working out whether everything is knowledge.

Anil Ananthaswamy

India's wildlife avenger

In January, India's largest ever wildlife haul made headlines with the rescue of 6000 turtles. **Aravind Chaturvedi** explains how his police team busted the gang behind the illegal trade



PANOS



PROFILE

Aravind Chaturvedi is an Additional Superintendent of Police for the Special Task Force in Lucknow, Uttar Pradesh, where he focuses on wildlife crime

Earlier this year, you helped in the rescue of live freshwater turtles in Uttar Pradesh.

What happened?

The plains of the Ganges river in Uttar Pradesh are frequented by poachers who catch turtles and sell them for their meat. Some families have traditionally made their livelihood this way for centuries. We have been working on such cases for six or seven years, and have found a concentration of this trade at an organised-crime level. In this case, the traffickers were flower sellers who brought flowers from the market in Kolkata to Uttar Pradesh via a night train. They would sell their flowers in the morning, but on their return to Kolkata they were bringing three or four bags full of turtles back with them.

How many turtles were being trafficked?

It was about 40 kilograms of turtles in each bag – so up to 160 kg per person. We started intercepting the suspects' cellphone calls. One trader had a flower shop but at the back of his house was a big pond where he used to keep the turtles. We recovered 400 kg of live turtles from there.

What happened after you recovered the turtles?

After we seized the first haul of turtles, another phone intercept revealed that a crime kingpin was sending even more to Kolkata in trucks. We wanted to strike when they were about to be loaded into a truck, so we waited for a couple of nights in cold fog, thinking we would get lucky in the middle of the night. An arrest is always a tense moment: these people sometimes carry weapons. When we did swoop, one suspect fled, taking advantage of the darkness and terrain. He is still wanted in the case. But in total, we recovered over 4 tonnes of live turtles. It was very satisfying.

How serious is the problem of wildlife crime in India?

It's a big problem. There's a sizeable illegal trade in India in all sorts of wildlife. The

biggest trade is in birds, but nobody seems to care about that. In every city in India you will find a bird market – where all the illegal birds are bought and sold.

Does the Special Task Force you are part of only deal with wildlife crime?

No, if there is a heinous murder in the city, for example, me or my team will visit the scene of the crime with local police. We don't shape the investigation – our sole aim is to work out the facts of a case: who did it? We collect evidence and advise other investigators.

But wildlife crime is your team's focus?

Yes. Wildlife is my responsibility, but it's my passion also. I'm a pet lover and while growing up there wasn't a single day that we didn't have pets at home. Whenever one of our dogs grew older, my dad would get a puppy.

Is there a case you were involved in that you are most proud of?

That was in 2007, when we recovered three tiger skins, 75 kg of tiger bones and other contraband, along with the poachers, traffickers, traders, cash and some of the poaching equipment – all in one go. This is apparently the only case in India where all these things were seized at once.

How did you track down the group involved in the tiger trade?

We had been bugging people connected to the main suspect, Shabbir Hasan Qureshi, for three or four months. We identified a group of suspects travelling from a place called Katni, in the state of Madhya Pradesh. It's on the edge of a vast area of jungle where some tiger reserves are situated. We guessed they had taken a train after comparing information from cellphone interceptions and location data associated with a phone number to train timetables. We got to their destination before them and I told my officers to let the traders enter the building they were travelling to. ➤

Meeting turtles at a rescue center in Kukrail Forest Reserve, outside Lucknow city



Did you arrest them there and then?

After an hour or so we entered the premises. We found Qureshi, his two sons and several others. They had one of the skins on display. It was an enormous tiger. There were two more tiger skins and a huge amount of bones. We asked them to arrange the bones in the shape of a tiger from jaw to tail. They were so expert that they made three tigers.

Of the 16 people we arrested, all were given the maximum sentence of seven years in prison.

What other evidence do you gather from cellphones?

Wildlife criminals have a tendency to take photographs of the contraband that they will send via email or WhatsApp to the trader, so that they can bid for it. Incredibly, from the tigers to the turtle cases, we find pictures stored in their cellphones.

Have any of your targets ever slipped through the net?

There is one example. Bordering Nepal there is a world famous tiger reserve, Dudhwa National Park. Because the river here changes its flow every year after heavy rainfall, the area becomes inaccessible for months. The local people in Pilibhit have techniques to cross it. Poachers collude with them and get them to bait tigers. They leave out a goat with poison in the armpit and wait for the tiger to eat it.

There is one criminal who is trying to get to Nepal with tiger skin and bones. He knows we cannot reach him because of the difficult terrain – we don't have any helicopters or facilities like that in that area.

How difficult is that for you as an investigator?

Because the border with Nepal is completely porous, we have trouble in these areas. It's a challenge that motivates me to come up with new plans to nab this person.

What angers you most about the mistreatment of wildlife you have encountered?

The killing of pangolins, for their valuable scales, is very common in India. It mostly occurs in the central part of the country

"Arranging the bones in the shape of a tiger from jaw to tail, they made three tigers"

where there is dense forest. What many do after killing a pangolin is burn it, which makes the scales easy to remove. But fire causes the scales to lose their shine. We had one telephone intercept in which a person was suggesting to a poacher that it is not necessary to burn the pangolin, you just pour boiling water on it while it is still alive. Then the scales will come out easily. That was so painful to hear.

Is your job emotionally demanding?

I cannot tolerate any cruelty to animals and my blood boils when I see what these people do. Wildlife crime is the only police work in my career that rarely gives any pleasure; in 99.9 per cent of cases, when you recover contraband the animal is already dead. It is a loss not only to our ecosystem, but it also feels like a personal loss to me.

What is the best way to tackle wildlife trade?

The important thing is to break the connections between poacher, trafficker and trader. It is a mistake to think that, say, rabbits being killed in the forest is not very important. The same set of people might one day kill a tiger and transport contraband through the same linkages. And my team has traced the bird and pangolin trade from central India to Myanmar, crossing whole countries and thousands of kilometres. That is concerning to us.

Do you think you are having a positive impact, ultimately?

It is a heartening thing that there has been an increase in the wild tiger population recently – although I am not claiming any personal contribution to it. Many other agencies, not only us, have done valuable work in this field. Collectively, we are having an impact on wildlife crime. I have no doubt. ■

Interview by Chris Baraniuk

The power of virtual

A fascinating and clever exploration of the therapeutic uses of virtual reality struggles with the real world, finds **Stewart Pringle**

Ugly Lies The Bone by Lindsey Ferrentino, National Theatre, London, to 6 June

THE play *Ugly Lies The Bone*, which opened at London's National Theatre recently, is more than just a survivor story. It is a visually arresting meditation on a therapy that uses virtual reality.

VR exposure therapy, trialled in 1997 by Albert Carlin and Hunter Hoffman at the University of Washington Human Interface Lab, produced Spiderworld. This allowed a phobic individual to interact with the object of their fear – in this case, a 3D arachnid. After 12 sessions, the person's symptoms seemed to disappear.

The team went on to develop SnowWorld, a VR Antarctic landscape. The snowball-flinging snowmen and frolicking penguins had a serious purpose: to ease the pain of burn victims and others in extreme, chronic discomfort. Those using SnowWorld reported a pain reduction of more than 30 per cent – better than morphine.

With the UK debut of US writer Lindsey Ferrentino's play, the National Theatre brings the tech centre stage after investing heavily in VR for some years. This culminated last year with the opening of its in-house Immersive Storytelling Studio. Hidden from public view, it is a digital experimental playground for theatre makers.

Enter Indhu Rubasingham's production of *Ugly Lies The Bone*, and the story of Jess, a smart, ex-teacher turned soldier returning to her sleepy Florida town after a tour of duty in Afghanistan. An explosive device has blown up beneath her, leaving her skin



MARK DOUET

a patchwork of painful grafts and scar tissue. She is barely mobile and lives in constant pain.

In a lab, an unseen therapist takes Jess into a SnowWorld built to her own specifications, and gamified to provide a sensory distraction from pain, as well as something to strive for. As her return to civilian life throws up only disappointment, Jess invests more and more time and emotional energy on this virtual paradise, where she can walk, run and climb without pain.

The VR element, realised

"At its most fearless and at its most interrogatory, the play is a work of real power"

Trapped in her own tech paradise, injured Jess is close to VR addiction

through projection rather than individual headsets, is both the most intriguing and most developed element of the play. Thanks to a spectacular video design from Luke Halls, frozen landscapes, aerial city shots and nerve-shredding flashbacks to the war in Afghanistan are brought to life with pixel-perfect clarity.

Fascinating questions about the efficacy and therapeutic goals of exposure therapy are posed but Ferrentino never quite grapples them to the ground. Therapy sessions are interspersed with vignettes from Jess's life back home, and though there is a

pleasing contrast between the simulation's gleaming snow-capped peaks and the drab convenience stores and ugly decor of her home town, the result is the VR sequences often bookend a far more conventional, occasionally shallow homecoming drama.

The setting – the dying town of Titusville on Florida's "Space Coast" – poses smart questions, too, this time about the decline of the space programme. The town prospered from shuttle launches, but is now almost dried up, as the US turned its attention away from the stars to the oil fields, stoking war zones in the Middle East. In a play focused half on the potential of escape into brave new worlds, and half on the shrunken life Jess now faces, the irony is palpable.

At its most fearless (when Jess struggles into a dress, whimpering in pain, trying to distract herself by humming a happy tune) and at its most interrogatory (when she hovers on the brink of VR addiction), *Ugly Lies The Bone* is a work of real power. But its grip on the real world, on its characters and the deeper implications of its narrative, is tenuous.

Jess is played with sardonic wit pulled taut over red-hot emotion by Kate Fleetwood, but other characters tend to be stereotypes. Olivia Darnley finds little to do as Jess's bubbly sister Kacie, while Ralf Little and Kris Marshall's likeable buffoons as Jess's dozy ex and Kacie's equally dozy boyfriend feel sketchy and ill-defined.

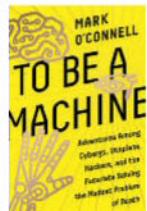
Somehow *Ugly* never quite matches the flawless fidelity of its immersive visuals. ■

Stewart Pringle is a writer, critic and dramaturge based in London

In debt to mortality

Predictions and politics make dark bedfellows, says **Brendan Byrne**

To Be a Machine: Adventures among cyborgs, utopians, hackers, and the futurists solving the modest problem of death by Mark O'Connell, Doubleday/Granta



THERE was a lot of futuristic hype surrounding cryonics company Alcor. When Dublin-based journalist Mark O'Connell

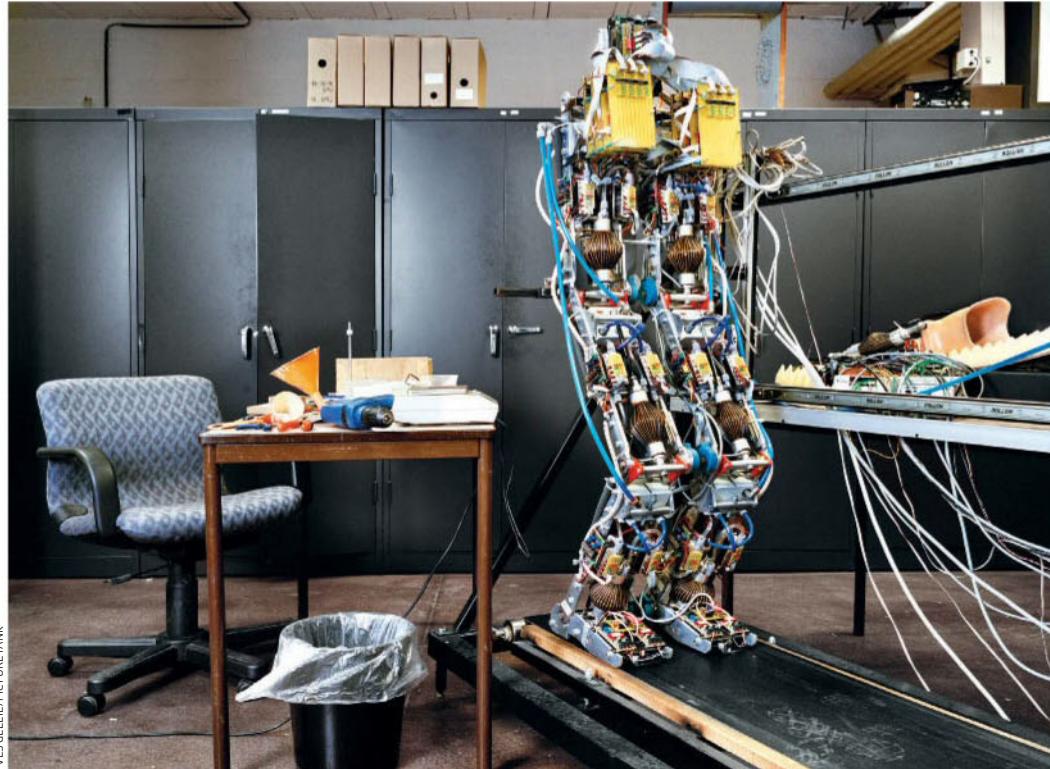
travelled to its facility in Arizona, he found himself "surrounded by corpses in an office park, between a tile showroom and a place called Big D's Covering Supplies".

In his book *To Be a Machine*, new father O'Connell invokes the twin spectres of death and child-bearing in an attempt to make sense of his subject – but he also manages to be staggeringly funny. He explores the intersecting practices of body modification, cryonics, machine learning, whole brain emulation and AI disaster-forecasting.

The "transhumanist world view", O'Connell writes, casts "our minds and bodies as obsolete technologies, outmoded formats in need of complete overhaul". He worries more about the collateral damage such a future will inflict, less on the world views of the supposed visionaries who supply the ideas. Not that the two can be separated.

Throughout the text, it is difficult to ignore Peter Thiel, a Silicon Valley billionaire and an adviser to Donald Trump. While Thiel, who "takes human growth hormone daily and has signed up for cryonic freezing", is not featured directly, the longevity start-ups he funded are, including

YVES DELIE/PICTURE TANK



Halcyon Molecular, 3Scan, MIRI, the Longevity Fund and Aubrey de Grey's Methuselah Foundation.

Another pervasive presence is Nick Bostrom, an Oxford University philosopher. But while Thiel wants to extend life, Bostrom is worried about its eradication.

"The race to achieve AI first will be tight, pushing corporations to disregard security"

He is best known for his 2014 book *Superintelligence*, which brought thought experiments about AI security to public notice. O'Connell finds it disquieting to see the likes of Elon Musk and Bill Gates effusing about this book.

"These dire warnings about AI were coming from what seemed like the most unlikely of sources: not from Luddites or religious catastrophists, that is, but from the very people who seemed to most personify our culture's reverence for machines."

Musk and Thiel's recent OpenAI project attempts to address such existential threats by freely disseminating its research. This is meant to encourage the rise of multiple AIs, whose balance of power will keep any non-benign ones off-balance. While Bostrom agrees that this plan will decrease the threat from a world-eating "singleton", he worries that "winning the AI race is incompatible with using any

Transhumanists think that bodies are obsolete technology

safety method that incurs a delay or limits performance". If basic information is made public, the race to achieve AI first will be tight, pushing corporations to disregard security.

Given Musk's public admission that he is trying to move Trump to the left, rumours that Mark Zuckerberg is considering a presidential run and the fact that many users are deleting the Uber app after the company broke the taxi strike at JFK Airport, Silicon Valley can no longer claim to be apolitical. And there seems to be something about transhumanism that draws out reactionaries. As

O'Connell observes, in one sense the whole ethos of transhumanism "is such a radical extrapolation of the classically American belief in self-betterment that it obliterates the idea of the self entirely. It's liberal humanism forced to the coldest outer limits of its own paradoxical implications."

Thiel is – strangely for a former libertarian – a planner. In his 2014 book *Zero to One*, Thiel writes of the dot-com bubble as both "a peak of insanity" and "a peak of clarity": "People looked into the future, saw how much valuable new technology we would need to get there safely and judged themselves capable of creating it." Depicting how private enterprise failed to bridge the gap between aspiration and realisation, Thiel seems here to be arguing for total mobilisation of the state.

Shooting for the moon

Thiel favours taking huge risks to achieve miraculous results. He champions the government-funded space race and rails against "incrementalisation" in scientific and civilizational achievements. At the time of writing, Jim O'Neill, the managing director of Thiel's Mithril Capital, is one of Trump's main candidates to head the Food and Drug Administration. O'Neill thinks that drugs should be approved not by safety but by efficacy. Thiel himself has criticised the FDA for being overly cautious, stating five years ago, "I don't even know if you could get the polio vaccine approved today" – a sentiment shared by the president.

If the low-safety "moonshot" approach favoured by Thiel and the futurist frat houses O'Connell describes is applied on a national level, and longevity research funded by a Silicon Valley billionaire does pay huge dividends, a new question emerges: immortality for whom?

Thiel is notoriously anti-competition, writing in *Zero to One* that only becoming a

monopoly "can allow a business to transcend the daily brute struggle for survival", since "competitive markets destroy profits". A monopoly price for life extension suggests a future in which we will all be in monetary debt to mortality, working forever to pay off our incoming years.

During a recent public lecture, genomics pioneer Craig Venter discussed his new company that aims to use genetic sequencing to provide "proactive, preventative, predictive, personalised" healthcare. According to Venter, 40 per cent of people who think they are healthy are not – they have undiagnosed ailments such as tumours that have not metastasised or cardiovascular conditions. And he says his method can predict Alzheimer's 20 years before its onset, and a cocktail of soon-to-be-marketed drugs can prevent it. Thanks to this \$25,000 genome-physical, Venter himself was diagnosed with prostate cancer and operated on.

Can any imaginable public healthcare provision pay for such speculative treatments? Or will there be a widening gap between those who can afford to stay healthy and those who will have to shoulder early-onset penury in the face of their time-limited humanity?

In response to questions about such inequality, Thiel offers little comfort. "Probably the most extreme form of inequality," he told *The New Yorker* six years ago, "is between people who are alive and people who are dead."

Jonathan Swift's satirical letter "A modest proposal" responded to an equally cold-blooded ideology, in his day. But a field whose pioneers sport names like T.O. Morrow (Tom Bell's 1990s soubriquet), FM-2030 and Max More demands something different from O'Connell – an unexpected, often funny effort of restraint. ■

Brendan Byrne is a writer based in Queens, New Jersey

Blood and guts in space

Sci-fi's epic futures take their toll on the human frame, finds **Abigail Nussbaum**

The Stars Are Legion by Kameron Hurley, Saga Press

The Fortress at the End of Time by Joe M. McDermott, Tor

Binti: Home by Nnedi Okorafor, Tor

GALAXY-SPANNING "space operas" have always been near to science fiction's heart. Even the chilliest of them – Olaf Stapledon's *Last and First Men*, published 87 years ago – can still bring a lump to the throat.

But where most space opera exists at a remove from humanity, Kameron Hurley's *The Stars Are Legion* is fleshly and messily organic. There is a fairly simple narrative at work: Zan, an amnesiac general, is tasked by a conniving and secretive princess to save the disintegrating Legion. But if the novel doesn't amount to more than the sum of its parts, those parts are so inventive and bizarre that they are more than enough to be going on with. In one scene, hero Zan patches a tube with a length of intestine sliced out of a nearby corpse.

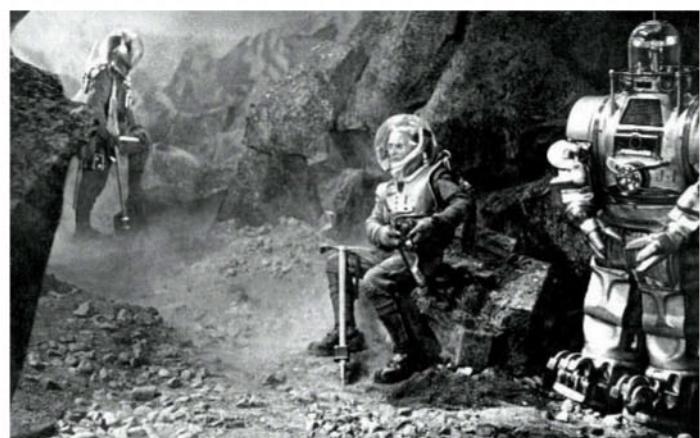
Machines will help get us into space, but at what price?

It's a jaw-dropping bit of shorthand for the frightening vulnerability of Hurley's characters.

Joe M. McDermott's *The Fortress at the End of Time* shares with *The Stars Are Legion* a sense of being trapped in a predatory environment beyond which lies only the vast coldness of space. Ronaldo Aldo is a soldier transported to the Citadel, the last line of defence against hostile aliens with whom humanity has fought a terrible war. Most of Aldo's fellow officers, however, are more interested in internal politics and personal enrichment.

Somewhere between McDermott's sterility and Hurley's effusiveness lies *Binti: Home*, Nnedi Okorafor's sequel to her Hugo Award-winning 2015 novella *Binti*. Okorafor's assured Afrofuturist vision is enriched here, as Binti learns that even her insular community, an ethnic minority in Namibia, has its own mysterious subgroup, with access to possibly alien technology. ■

Abigail Nussbaum is a writer based in Tel Aviv, Israel



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An ideal candidate should have a strong background in biochemistry and/or molecular biology, and relevant experience in cancer genetics and epigenetics. The candidates with prior hands-on experience in sequencing-based platforms (Ion Torrent PGM sequencer, MiSeq/HiSeq, RRBS, ChIP-Seq, MeDip and RNASeq etc.) and other array-based platforms will be given preference.

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Qualifications:

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Send curriculum vitae and names and addresses of three references to **Dr. Jonathan H. Jaggar**, Maury Bronstein Endowed Professor of Physiology, Department of Physiology, University of Tennessee Health Science Center, 894 Union Avenue, Memphis, TN 38163, USA. email : jjaggar@uthsc.edu.

Website : <http://physio1.uthsc.edu/~jaggar/index.php>

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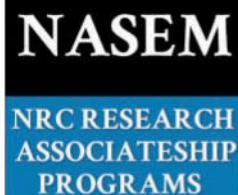
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EDITOR'S PICK

The final frontier is on our own finite planet



From Bryn Glover, Kirkby Malzeard, North Yorkshire, UK
I was bemused by the comparison between the world of Charles Darwin and that of Elon Musk implied in Leah Crane's article on privately funded exploration (11 March, p 25). In Darwin's day, the prevailing ethos of so-called free-market capitalism

treated the planet as a limitless resource, and its atmosphere and oceans as an equally limitless repository for waste. Western nations were exploiting their empires where the only inhibitions to development were the insignificant interests of a few unimportant indigenous peoples.

Today we realise that all relevant aspects of our planetary existence are decidedly finite. The needs of the planet must be at the forefront in any decisions about consumption.

It is especially poignant that this notion of entrepreneurial exploitation of space has appeared in the same week that the United Nations warned of the impending deaths of millions from starvation – which could be avoided with a mere fraction of the investment proposed for vanity space projects.

Ownership and control of robotic production

From David Flint, London, UK

Sumit Paul-Choudhury is right to say that a robot tax is only the beginning (4 March, p 25). He notes it could be spent on a basic minimum income. It should.

Pragmatically, this would compensate people for work lost to robots – provided that we take other measures to spread reduced employment. Morally, it would express the truth that robots and AI systems are not the work of one person or company but arise from our shared scientific heritage.

From Nigel Johnson, Nether Stowey, Somerset, UK
I would go further than Paul-Choudhury on the economics of robots. Those who own and control them would have great

economic power by virtue of the wealth they create. They would be able to hire PR firms and lobbyists, clever accountants and lawyers.

They could buy large tracts of the media, plus many politicians and the odd political party. I very much doubt they would ever pay tax on their robots. Any universal basic wage would most probably be eroded to a meaningless level, as those who own the robots vilify it for supporting a class of "skivers and shirkers".

The only way to ensure that mass AI-driven automation has a beneficial rather than disastrous effect on society is to find a way for us all to share in ownership of the robots.

From Ralph Smith, Mistley, Essex, UK
It's good to see fresh thinking about the impact of technology on economic organisation.

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 "You don't want to do that, little buddy. Not now. Stay in the sea where it's safe"

Wendy Stevens offers advice to the fish that seem to be evolving into land-dwellers (25 March, p 18)

Another possibility is for private individuals to own robots and rent them to the firm.

Regulating capitalism is really not Stalinism

From Daniel Rollison,
London, UK

Fred Pearce contrasts a "market-based view of nature" with the observation that "collectivisation hardly treated the steppes of the Soviet Union well, creating conditions for famine worse even than the American dust bowl" (11 March, p 44). This implies the same error that has been holding back US environmental policy for decades: the claim that any alternative to a Western ideal would necessarily turn into a communist nightmare.

Many European countries have restricted the freedoms both of individuals and companies for the

common good and are better for it. Polarising the debate into cold war dichotomies helps no one.

Choice and altruism in the balance

From Christian Besson,
Briançon, France

Niall Firth gives as an example of "effective altruism" the case of Greg Lewis choosing to work on public health policies rather than becoming a doctor (25 February, p 22). Some would probably argue that the health service already has too many policy-makers and not enough doctors, so adding one more makes the balance worse.

From Ian Boyle,
Ballarat, Victoria, Australia

Greg Lewis projects a doctor's effectiveness over an entire career, concluding that a doctor of "average ability" could expect

to "save" only four lives, or the equivalent thereof. It is a truism of medicine that doctors mostly cannot "save" lives anyway, since we are all going to die at some point. What modern medicine can and does do is buy people time, and improve the quality of their life during that time.

From David Roffey, Mosman,

New South Wales, Australia

I think Greg Lewis seriously underestimates the impact his working as a doctor has on people's lives. Consider what would happen if every medically trained person went to work for hedge funds and just paid their tax plus £600 to a relevant charity.

The editor writes:

■ It is implicit that an effective altruist goes where there are shortages. If there were a shortage of doctors like Greg Lewis, the

next effective altruist would maximise their effectiveness by filling that gap.

Emissions accounting must include exports

From Christopher Jessop,
Marloes, Pembrokeshire, UK

Is the news about UK carbon emissions dropping (11 March, p 6) as good as it first seems? The figures serve only to emphasise how much manufacturing has moved overseas.

The UK still consumes huge amounts of carbon-intensive stuff, but no longer makes it. Fossil fuel is consumed on our behalf by overseas manufacturers, air freighters and shipping lines.

And what about the "carbon intensity" of the fuels we import? Losses connected with obtaining methane from under the North Sea, for example, were quite ➤



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low. Now we mostly import methane as liquefied natural gas, consuming additional energy in liquefaction and shipping. Surely international agreement should oblige consuming nations to declare their true "carbon footprint" to the rest of the world?

Quantum entanglement we can understand

From Brian Horton, West Launceston, Tasmania, Australia
Stuart Clark suggests that quantum weirdness is like you and I starting together before parting, then as soon as one of us finds we have odd socks we know that the other, now a long way away, also has odd socks (4 March, p 28). This all makes perfect sense to me.

Imagine we start off with two red and two green socks between us. We become entangled in a dark room, then put on our socks and go our separate ways. As soon as an observer notices I have one red and one green sock, she knows instantly what colour socks you are wearing.

Since this example is so clear,

does it mean that I now fully understand quantum theory, or does it mean the analogy is not quite adequate?

Reframing quantum mechanics in relativity

*From Dieter Gold,
Voiron, France*

You regularly run articles about the search for a unified theory of physics. Such efforts always seem to involve trying to quantify general relativity (for example 4 February, p 28) or attempting to find a carrier – namely the graviton – for a gravity field that obeys quantum mechanical rules.

It seems to me, as far as I understand this, that general relativity does not describe gravity as a field. There is "just" a 4-dimensional geometry that depends on the masses in the space under consideration. Forces then follow this geometry.

Why not try to describe quantum mechanics following the geometry of general relativity, instead of the other way round? There are certainly very difficult problems to tackle here. Quantum

uncertainty adds complications. But are there efforts to seek a unified theory along this path, despite such difficulties? Are there fundamental barriers?

The editor writes:

■ A few researchers do advocate trying to describe quantum fields geometrically. But quantum theory's success in describing three of the four fundamental forces, plus the uncomfortable mathematical singularities general relativity generates on small scales, mean this remains a minority pursuit.

Water on Mars could have existed as a cocktail

*From Richard Corbett,
Corpacach, Highland, UK*

Mars needn't have been warmer for water to have carved its features (18 February, p 25). An alternative explanation is that something was once present that allowed water to remain liquid at very low temperatures, but is now gone. Ammonia seems plausible: mixtures with water can be liquid at around -100°C at a pressure of

1 atmosphere. Ammonia has a far higher vapour pressure than water. I think it would be lost much more rapidly by ultraviolet degradation or through erosion by the solar wind.

The bestiary of the spectacle could pay

*From Bob Cory,
Altrincham, Cheshire, UK*

Olive Heffernan looks at the risk that funding de-extinction would take away from existing work to conserve species (11 March, p 24). Does the cost of resurrecting mammoths or other extinct creatures need to come out of the conservation budget?

The potential income from zoos wishing to exhibit creatures as spectator attractions is likely to be substantial, even if it does nothing for real world conservation. Renting a panda from the Chinese government, for example, costs hundreds of thousands of pounds per year.

Is Donald Trump cooking up his own cleverness?

*From David Ridge,
London, UK*

Bob Cory suggests that Donald Trump's behaviour is not stupid, and that his books show cleverly calculated promotion of brand Trump (Letters, 18 March). But does Trump write his own books?

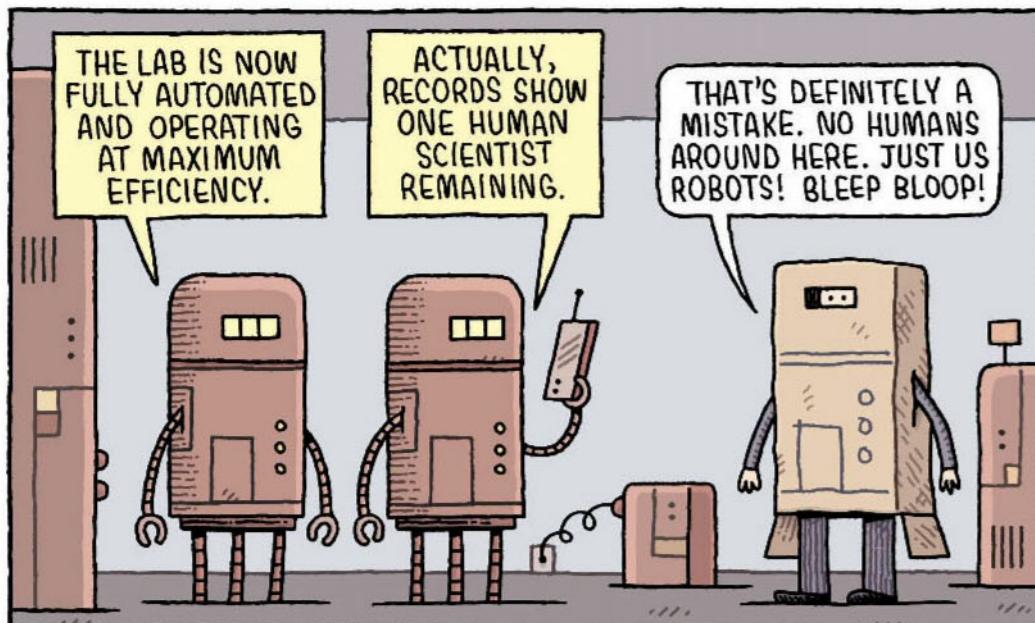
For the record

■ The Institute for Advanced Study is an independent research centre based in Princeton, New Jersey (18 March, p 43).

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TOM GAULD



OLD SCIENTIST

What was New Scientist talking about in April's past?



WE DON'T claim to predict the future in the pages of *New Scientist*, so it is without shame that we look back at our reports of bright ideas that have since gone dark. Back in 1975, plans for the Channel Tunnel were so sketchy that we didn't even know what sort of tunnel it would be. So in our 28 April issue, we considered the engineering problems involved, and how they

might be solved. This wasn't the tunnel in use today, mind, but one of the many proposals that preceded it. We suggested that drilling could be avoided by building a big tube in sections on land and sinking it piece by piece into a trench on the seabed. That idea didn't catch on, although it turned out to be political will, rather than rock, that posed the most difficult obstacle: tunnelling operations had just started when the British government pulled the plug in 1975 (see photo). It would be 35 years before the successor tunnel opened for trains.

In our 10 April 1975 issue, we were once again looking forward to something that is now everyday reality, and we had become more assertive in our opinions. Pity they were wrong. Flat-screen televisions, we announced, would be of "doubtful advantage" and like "electronic watches, they are likely to be one of the sales gimmicks of the 1980s". Instead, flat-screen TVs are in most homes in the developed world, and the technology has given us not only phones that tell the time, but also a new generation of those gimmicky electronic watches.

We displayed greater shrewdness in our 16 April 2005 issue, asserting that "biometric passports look more likely to delay international travel than speed it up", following insistence from the US that visitors' passports have a chip containing fingerprint and other information. The European Union was dawdling, citing "security and interoperability" issues. Biometric passports are now, of course, ubiquitous, and next time you're shuffling along in an immigration queue you can at least remind yourself that *New Scientist* told you so. **Mick O'Hare** ■

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

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FLAT Earthism is on the rise, as basketball superstar Shaquille O'Neal has announced that he too cannot accept the world is round. O'Neal was speaking in defence of Cleveland Cavaliers star Kyrie Irving and several other NBA players, who revealed their geodesic doubts last month.

Feedback imagined that O'Neal would only have to stand on tip toe to see Earth's curvature, but he insisted on his podcast: "I drive from Florida to California all the time, and it's flat to me. I do not go up and down at a 360-degree angle." Is this Dadaist humour from the courts, or is basketball in the grip of geometric conspiracy theory? We can only surmise that an intervention from the Harlem Globetrotters - who must surely accept reality - is needed.

A STRANGE pattern is emerging among talent show presenters in the UK, who are adopting a rather visceral approach to motherhood. Last week Feedback heard news of the latest celebrity diet involving small portions of

weird, unappetising foods: singer Bo Bruce, host of *The Voice UK*, revealed she was popping pills containing the dried mincemeat of her own placenta.

Now we discover that the creative use of human remains in interior design goes beyond the decor of the Sawyer clan in *The Texas Chainsaw Massacre*. Step forward singer Rochelle Humes, one-time host of *The Xtra Factor*, who posted a photo on Instagram showing her newborn's framed umbilical cord, looped and twisted to make the word "love". We can only imagine Humes has two more children planned, to complete the trifecta with "live" and "laugh" frames.

While commending these women's dedication to a zero waste lifestyle, Feedback can't help feeling that spelling out words in human entrails ought to feature on the résumés of TV serial killers rather than TV talent show hosts. Consequently we are moved to warn future entrants to

PAUL MCDEVITT

Dark chocolate aficionado Mark Ribbands was delighted to find that his bar of Fortnum and Mason's Beyond the Abyss contains "a minimum of 100% cocoa solids".

such programmes that when the judges say they want their pound of flesh, they might just mean it.

FOR some time, Feedback has been dimly aware of Anthony William, the self-described "medical medium" who performs diagnoses and offers alternative treatments with the help of a spirit guide, in lieu of any actual medical qualifications.

This week we find ourselves inexplicably drawn to his website, which offers testimonials from the great and the Goop (as Gwyneth Paltrow's mystic lifestyle brand is - inevitably - linked to William).

Craig Kallman, CEO of Atlantic Records, declares that "Anthony is a magician for all my label's recording artists, and if he were an album, he would far surpass *Thriller*". Feedback imagines that artists signed to Atlantic might be less than thrilled if their healthcare coverage turns out to be administered by a magician; we're sure Feedback readers can suggest more apposite album titles.

A PROMOTIONAL email from Whitsand Bay Hotel has a surprising bonus for those exploring the rugged coastline of Cornwall, informing recipients that "2 children under the age of 12 are included in this Special offer". Ian Henderson writes: "It turns out you have to take your own."

ON ELEMENTAL spelling, Keith Perring noted that element Tennessine (Ts) would only help "forming the plurals of certain slang terms" (11 March).

"I have to politely disagree" says Danny Shrestha, "and surge forth with Tennessine, Uranium, Nitrogen, Americium and Iodine."

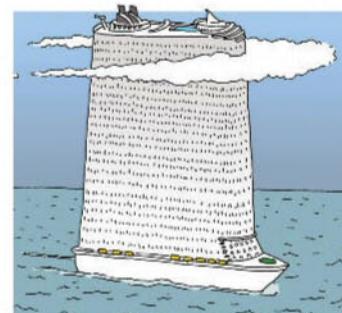
MEANWHILE, Pete Scamper thinks the versatility provided by elements with symbols that contain more than one letter shouldn't be neglected. "When I taught chemistry, I used to challenge my students to identify the foodstuff made from a particular list of elements," he writes. "The list begins promisingly: carbon,

hydrogen, oxygen, then less probably: cobalt, lanthanum and tellurium".

NATIONAL GEOGRAPHIC has turned its lens on that curious migratory species, the cruise ship vacationer, in a profile of the world's largest ocean-going resort. But Martin Edwards is left perplexed over the description that The Harmony of the Seas is "taller than Mount Rushmore".

"The faces on the Mount Rushmore monument are only 18 metres tall, which means that the 18 decks need be only one metre each," he writes. "But if the claim is that the ship is taller than Mount Rushmore itself, then each deck will be close to 100 metres high, and the vessel would be a hazard to aircraft."

On the plus side, if it's raining on the lower decks, Martin says it may be sunny on the upper deck, if a bit cold for swimming.



STARTING at the back of *New Scientist* – as we're certain all connoisseurs of the magazine do – Matthew Campbell then moves leftward to the lighter material.

"I was disturbed to discover there that 'Feedback is one of six behavioural addiction factors,'" he writes (4 March). "Do you think I should go cold turkey on *New Scientist*?" Sounds unappetising, Mat – and Feedback is worried this means our column falls foul of the Psychoactive Substances Act.

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.

The strangest cut

Why, when I transfer my low-fat spread onto my knife, does it form this pattern (see photo), especially when taken from a new tub?



When the knife moves across the spread it doesn't slide as smoothly as you might think, but repeatedly slips then gently sticks. This leaves a telltale, wave-like pattern on the spread in the tub, which you can see beneath the knife. This is appropriately called "slip-stick" (or sometimes stick-slip). It happens when two substances slide past each other with a jerking motion. This jerk is difficult to feel with a knife on spread, but is easily sensed when both materials are hard solids.

The screech of brakes is the result of slip-stick and so is the sound of a bow on the strings of a cello. You can annoy others with slip-stick by drawing your finger

across a blown-up balloon or a knife between the prongs of a fork.

The fold forms on the knife best if the spread is initially flat, which is usual with a new tub. Try it yourself by holding your tub at an angle to the light as you drag the knife across: it's easy to see the wave pattern on the surface.

*David Muir
Edinburgh, UK*

■ This is an example of "chattering", seen by machinists turning metal on a lathe or milling machine. The cutting tool should produce a smooth surface, but instead vibrates so that the cut varies in a regular way in depth and shape, creating a pattern on the top. This has several causes, but one is a tool not rigidly held on the machine, allowing it to judder. A machinist's cutting tool is the reverse of table knife, therefore.

The knife has a long, flexible blade and, in general, is not held rigidly in the hand. As it passes over the margarine it "chatters", so that it digs in, releases and repeats. That said, the questioner must have a good grip and a steady hand to achieve the regular layers that the photograph shows!

*John Davies
Lancaster, UK*

■ Your correspondent has actually made a tiny model of a mountain range as produced in geology by "thin-skinned thrusting". This is where two tectonic plates collide. One

thrust fault breaks and a second is carried over the top, creating a stepped pattern of hanging walls and footwalls (or steps and slopes). Each fault block tends to be a similar width, depending on the strength of the material.

A whole set of thrust faults is known as an "imbricate" system. There are good examples in the Canadian Rockies, the Appalachians in the US, the Alps and the Moine thrusts in the Scottish Highlands.

Geologists model these faults in the lab using a box compressed from one side and filled with layers of various materials to model the effects, such as sand, flour, clay or putty, but not yet (as far as I know) low-fat spread.

*Simon Cains
High Wycombe,
Buckinghamshire, UK*

■ The spread is an invert emulsion: a grease matrix that, like butter, contains watery droplets but far more of them than butter. Emulsions of microscopic water droplets crowded within a viscous matrix tend to be surprisingly stiff – the

"The spread and the knife actually make a model of a mountain range created by colliding tectonic plates"

droplets interfere with the flow, so that the spread stays put after settling into the tub or onto bread.

Scooping distorts the droplets into shapes that follow the pattern of flow, so that suddenly

they lubricate the matrix instead of resisting it. Stop pushing, and the droplets' surface tension elastically reforms them into spheres that again resist flow. Such emulsions are called "thixotropic": force them to flow and they become fluid, but they set abruptly when the force stops.

The juddering that produces those successive mounds is therefore understandable.

Whenever stiff spread retards the knife's progress, forces build up until they overcome resistance and soften some material, so a "scoop" forms and slips back over the blade. There it stops and congeals while the knife collects the next scoop, which then pushes its predecessor further back. And so on, in turn, until you have enough on your knife, or until you stop to wonder what's going on.

*Jon Richfield
Somerset West, South Africa*

This week's question

RISING DAMP

I work on farms in the fens of East Anglia, UK, where the water table is quite high. Even when there has been no rain, the fields seem dry when tides at the coast are low. At high tides, the water seems to rise and make the field wet. We all know that the moon affects tides at sea, but can it also affect the height of the water table quite far inland?

*Gidon Bahiri
Downham Market, Norfolk, UK*

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Professor Dame Carol Robinson

2015 Laureate for United Kingdom

By Brigitte Lacombe



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