New Scientist

WEEKLY March 31 - April 6, 2018

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Entries for $250,000 Ryman Prize now open

We're looking for the best ideas in the world.

The Ryman Prize is an international award aimed at encouraging the best and the brightest thinkers in the world to focus on ways to improve the health of older people.

The world's ageing population means that in some parts of the globe, the population aged 75+ is set to triple in the next 30 years.

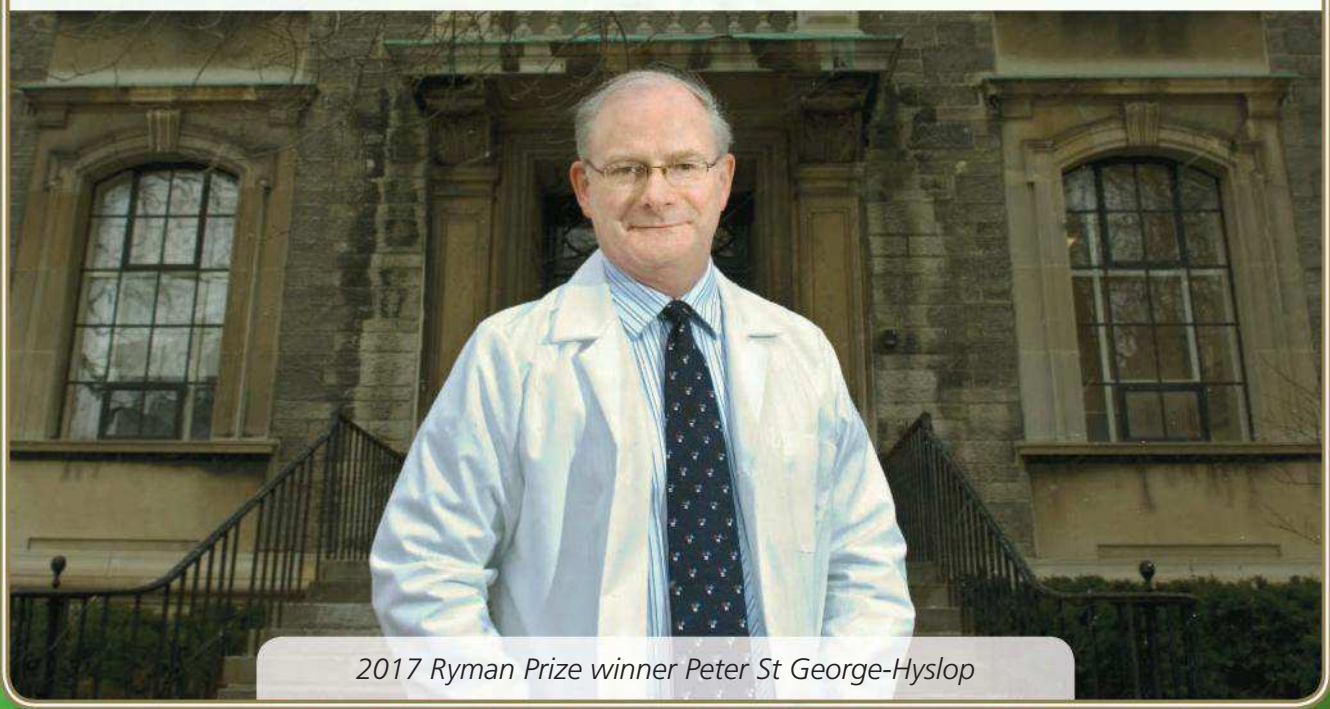
The Ryman Foundation is offering a NZ$250,000 (US$180,000) annual prize for the world's best discovery, development, advance or achievement that enhances quality of life for older people.

The 2017 Ryman Prize was won by Professor Peter St George-Hyslop for his pioneering research into neurodegenerative disorders including Alzheimer's Disease, Parkinson's and frontotemporal dementia.

If you have a great idea, or have achieved something remarkable like Peter – we'd love to hear from you.

Entries for the 2018 Ryman Prize close on August 31, 2018.

Go to www.rymanprize.com for more information



2017 Ryman Prize winner Peter St George-Hyslop

www.rymanprize.com

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Fair's fair

Tackling inequality means first understanding the problem

WHEN the primatologist Frans de Waal wrote in 2010 that "Robin Hood had it right – humanity's deepest wish is to spread the wealth", he captured a prevalent mood after the great financial crash of 2008.

This also reflected results emerging from the laboratories of neuroeconomists, which found that humans are egalitarian to a fault. And so our prevailing assumption was that income inequality is a recent aberration: that we are at heart noble, benevolent beings with an altruistic aversion to inequality.

Humans are also gullible to a fault, and we like hearing what we want to hear. More recent research shows there is no such thing as inequality aversion; we actually quite like inequality, even when we lose out (page 28). What we want is fairness – the harder-to-measure sense that any excess an individual makes stands in fair proportion to what they put in.

These insights should not be misinterpreted as a scientific justification of the status quo. The levels of inequality that people are comfortable with are much less than those seen in the US, UK and elsewhere. There is no doubt that curbing the pay excesses of those at the top can contribute to a greater sense of fairness.

But if equality of opportunity, not equality of outcome, is the ultimate goal, only longer-term fixes will do: better education and training and, yes, an increased emphasis on the role of scientific knowledge in a fair society. ■

Hype becomes reality

BILL CLINTON and Tony Blair announced the first draft of the human genome sequence in 2000. This was "the first great technological triumph of the 21st century", said Blair.

Maybe so, but since that early fanfare, the impact on our lives has been negligible. Rather than laying bare the blueprint of our bodies, that draft human genome sequence was merely a first step. Deeper understanding – and new medical treatments – requires many more sequenced genomes, as well as cheaper and faster sequencing methods.

Now, 18 years on, we are getting a glimpse of what genetically tailored medicine might look like. The time – and money – it takes to sequence a person's entire genome has fallen sufficiently for doctors to use it to diagnose rare conditions in very sick children (page 6).

After years of hype and subsequent disappointment, the human genome is finally making good on its promise. ■

Genomics saves lives

Sick children are now getting the right treatment thanks to DNA sequencing

Clare Wilson

SUPERFAST DNA sequencing is saving children's lives. The technique has helped doctors in London quickly diagnose rare disorders in 10 critically ill children, enabling clinicians to give better treatment and protect some from life-threatening complications.

It took over a decade and around $2.7 billion to fully sequence the first human genome, but recent advances in technology have sped up the process and led to a fall in price. A team at London's Great Ormond Street Hospital for Children has now used rapid whole-genome sequencing to diagnose children with unknown illnesses in intensive care, as these children often have rare genetic conditions.

"These kids are so incredibly ill," says Hywel Williams at University College London, who worked with the doctors. "They may have trouble breathing, their heart may not be working well." In such cases, it is hard to know what the cause is, he says. "But if you can find a genetic diagnosis, it really helps the clinicians."

Preventing harm

The team cut the time it takes to give a genetic diagnosis from weeks to as little as four days by changing the settings on DNA-sequencing machines, using faster analysis software and getting hospital staff to prioritise urgent DNA samples.

Of the 24 children whose genomes were sequenced, 10 received a diagnosis. This led to an immediate change of treatment for three children (*bioRxiv*, doi.org/cmsg). For one child who had failing kidneys, genomic sequencing revealed that the cause was a rare mutation, which also leads to recurrent kidney tumours. As a result, doctors realised they needed to remove both kidneys, before tumours could develop.

A child with a ruptured spleen was found to have vascular Ehlers-Danlos syndrome, which weakens internal tissues. Up until diagnosis, clinicians had suspected the child's parents had been the cause of their injury, but the DNA results avoided a police investigation. A third child had a hormone disorder, and doctors changed how they managed the condition after diagnosis.

When a child has serious and unexplained medical symptoms, it can often lead to repeated painful diagnostic procedures (see "Quest for diagnosis", right). To keep costs down, doctors usually get only one or several genes sequenced at a time. There are thousands of genetic diseases, and as it can take weeks to get the results from each test, families can endure years of uncertainty.

But Williams's team has shown that rapid genome sequencing is possible and cost-effective. It cost £5600 to analyse each child's genome – only a little more than the cost of a day in intensive care.

"It's pretty clear it's going to transform intensive care practice," says Stephen Kingsmore of the Rady Children's Institute for Genomic Medicine in San Diego. "For the families this is totally miraculous."

"It's clear this is going to transform intensive care. This is totally miraculous for families"

While four days for sequencing and analysing a genome using standard hospital equipment is impressive, Kingsmore's team has managed even faster results using specialist sequencing equipment that isn't yet widely available. Their fastest time to a genomics-based diagnosis is 19.5 hours.

MAX FAULKNER/FORT WORTH STAR-TELEGRAM/TNS/ABACAPRESS/PA IMAGES

Gun violence research

US CONGRESS has passed its 2018 spending bill, which included the largest research budget increases in nearly a decade.

It also clarified that the US Centers for Disease Control can study the causes of gun violence under the 1996 "Dickey amendment". The wording of this rule – intended to prevent the CDC from doing research that promoted gun control – has been hard to interpret. But no dedicated funds for gun research were announced.

The bill was passed on 23 March, the day before hundreds of thousands of people rallied across the US for tighter gun laws (pictured, left).

NASA, the National Institutes of Health and the National Science Foundation all got increased budgets, as did climate and clean energy programmes at the Department of Energy and the National Oceanic and Atmospheric Administration.

The Environmental Protection Agency's budget remained level, contrary to the vast cuts President Donald Trump had suggested.

Nature's collapse threatens society

BIODIVERSITY will fail everywhere if we carry on as we are. The biggest victims will be people, because we rely on the natural world.

An assessment of Earth's wildlife warns that exploitable fish stocks on

SEBASTIAN ROSE/GETTY

Very ill children often have an unidentified genetic problem

His team has reported using this technology to get diagnoses for 18 out of the 42 critically ill children whose genomes they sequenced (*bioRxiv*, doi.org/cmsf). In one case, they were able to diagnose a rare form of epilepsy in a newborn baby, leading to successful treatment that prevented the baby getting severe brain damage.

A diagnosis is valuable even if a child's condition is fatal, says Williams. "If you know there's nothing you can do then you don't have to keep doing biopsies and you can make them more comfortable – that's a real godsend," he says.

Not all children who have their genome sequenced get a diagnosis, because we don't yet know all the genetic variants responsible for various conditions. However, knowledge is growing, thanks in part to efforts such as the UK's 100,000 Genomes Project, which is sequencing the DNA of people with rare diseases and cancer. ■

QUEST FOR DIAGNOSIS

"They call it a diagnostic odyssey," says Louise, whose 8-year-old son Scott has an unknown condition that causes epilepsy and learning disabilities.

The search for a diagnosis can dominate the lives of children with unknown conditions. Scott has had his brain activity monitored many times – a process that requires him to stop taking his epilepsy medication. This leads to more seizures, and can result in a week's stay in hospital. Biopsies can require general anaesthetic. "It's awful for such a young child to have to go into hospital yet again, and to have the pain when they come round afterwards," says Louise.

When Scott was 4, his family decided not to have any further invasive tests. "We needed to live some form of normality," says Louise.

The family has now agreed to have Scott's genome sequenced as part of the UK's 100,000 Genomes Project. If a genetic variant that has caused his condition is identified, the family may finally have a diagnosis, which could mean he gets better treatment.

Asia-Pacific coastlines will collapse by 2048. Half of all Africa's mammals and birds face extinction by 2100, as do 37 per cent of Europe's freshwater fish.

The Intergovernmental Platform on Biodiversity and Ecosystem Services, the biodiversity counterpart of the Intergovernmental Panel on Climate Change, makes the claims in four reports assessing biodiversity in the Americas, Africa, Asia-Pacific, and Europe and Central Asia.

The reports emphasise that human survival could be jeopardised. Nature provides services worth trillions of dollars, like food, shelter, water and clean air. If these "ecosystem services" aren't protected, we will lose them.

A fifth report on Monday claims that land degradation, driven by farming, is harming the well-being of 3.2 billion people: two-fifths of the population.

Facebook boss forced to grovel

"THIS was a breach of trust, and I'm sorry we didn't do more at the time." That was part of a full-page advert run in nine UK newspapers by Facebook chief Mark Zuckerberg on Sunday.

The social media firm's boss was forced to apologise over revelations that data firm Cambridge Analytica obtained private information on millions of Facebook users without their permission. The UK's Information Commissioner's Office has since completed a search of Cambridge Analytica's London headquarters.

Over the past week, Facebook's share price has plunged and a #DeleteFacebook movement has sprung up. Some high-profile users distanced themselves from the platform, including SpaceX and Tesla CEO Elon Musk, who removed his companies from Facebook. As other people went to delete their accounts, some found that Facebook had logged their call and text messaging records. Facebook said this was an opt-in feature for Messenger and Facebook Lite on Android.

Weapons treaty gets its first test

THE chemical weapons treaty is to be put to the test. The poisoning of former spy Sergei Skripal and his daughter has prompted the UK to demand a "clarification" from Russia under article 9 of the 1997 treaty. It has never been invoked before.

Another never-used provision would let the UK inspect Russian facilities at short notice.

Last week, a UK judge ruled that the Organisation for the Prohibition of Chemical Weapons can take blood from the victims and have it analysed by two independent labs. Despite rising diplomatic tensions, Russia's delegate to the OPCW has called this approach "legitimate". Russia has also asked for samples.

Vladimir Uglev, a former Soviet chemist who helped develop Novichok agents in the 1980s, has said traces in the blood would show if the toxin came from a batch his lab made – if it can be compared. To allow that, Russia would have to send samples to the independent labs. Nothing it has said so far suggests it will do so.

US is seeking smart killer drones

David Hambling

THE US Army wants to develop small drones to automatically spot, identify and target vehicles and people. It may allow faster responses to threats, but it could also be a step towards autonomous drones that attack targets without human oversight.

The project will use machine-learning algorithms, such as neural networks, to equip drones as small as consumer quadcopters with artificial intelligence. Current military drones have little onboard intelligence, sending raw video back to analysts who pick out and identify targets.

At the moment, you can have dozens of people monitoring the video feed from military drones, who then decide what action to take, says Paul Scharre at the Center for a New American Security, a think tank in Washington DC.

The US Army already fields miniature drones that can highlight moving objects or pursue a target autonomously once the operator locks on to it with the camera. Several thousand have been used in Afghanistan, Iraq and Syria. But the new project goes much further. It will detect, recognise, classify, identify and target, which covers the entire process from finding a person to aiming weapons at them.

"This does sound like they are moving very close to lethal autonomous weapon systems," says Stuart Russell at the University of California, Berkeley, who has recently raised concerns about such drones.

The Pentagon's directives seem to commit it to ensuring human oversight of drones. But Russell doesn't find this very reassuring. "At best, the drone shows a target to the human and the human says 'yes' or 'no', which is known to be a problematic system design, because the human stops exercising judgement very quickly," says Russell.

Many studies of safety systems, including one from the Technical University of Berlin in 2008, show that operators tend to gradually reduce the number of times they check a machine's output and start to place more trust in the machine than in their own senses, a tendency known as automation bias. "And of course, it would be very easy to leave the human out," says Russell.

Scharre, formerly a special operations reconnaissance team leader in the US army, doubts that the US military wants autonomous weapons. He does see other issues, though.

"The problem with AI is that it's brittle," says Scharre. "It can go from super-smart to super-dumb in an instant, making mistakes that are jarringly stupid for a human." One famous example is a 3D-printed plastic turtle that AI systems repeatedly identify as a gun, even though there is no resemblance in human eyes.

Small drones that can spot and identify objects already exist. "The military is basically trying to import the technology from the commercial sector," says Nabin Sharma at the University of Technology Sydney, in Australia. "The tech is out there, and it will be widely available whatever the US Army does."

A US Army spokesperson would not comment on the project at this time. ■

Drones with human overseers are frequently used in combat

SENIOR AIRMAN CORY PAYNE/USAF/REX/SHUTTERSTOCK

Calorie drop gets you ready for hibernation

DRAMATICALLY cutting the calories you consume may extend your life, and now we have an idea why. After more than a year on a calorie-restricted diet, resting metabolism seems to change.

Calorie restriction has been shown to extend the lifespan of flies, mice and even monkeys. Such findings have prompted some people to choose to eat between about 15 and 18 per cent fewer calories than the daily recommended limit, in the hope they will live longer. There is some evidence that such people have better blood cholesterol and glucose levels.

Leanne Redman of Pennington Biomedical Research Center in Louisiana and her colleagues assigned normal or calorie-restricted diets to 53 adults. For two years, 34 of these people ate 15 per cent fewer calories than usual, while the others ate as much as they wanted.

In the second year of the study, those eating fewer calories burned 10 per cent less energy – their metabolic rate – during sleep, and had lower night-time body temperatures (*Cell Metabolism*, doi.org/cmrx).

Blood samples revealed a 20 per cent drop in damage to cells caused by the by-products of metabolism, known as cellular oxidative stress, which is thought to be a hallmark of ageing.

Redman thinks the body adapts to low-calorie diets by lowering its resting metabolic rate. This may be an evolutionary mechanism to save energy when food is scarce, as is seen in animals that hibernate.

"The body may adapt to fewer calories by lowering its resting metabolic rate, as hibernating animals do"

Luigi Fontana of Washington University in Missouri says this slowing of metabolism might not be what increases longevity in lab animals. Changes in how cells sense the availability of food are likely to be more important, he says.

Even if caloric restriction is found to extend human lives too, it isn't for everyone. Side effects can include loss of libido and feeling cold. Andy Coghlan ■

Space plants could live off astronaut urine

ASTRONAUTS on a mission to Mars or beyond may be able to survive on plants watered with their own urine. Our liquid waste is 95 per cent water. The other 5 per cent is composed of nutrients such as nitrogen, potassium and phosphorus, which may pose harm to humans over the long term – but not to plants.

Using computer models of dwarf wheat and soya plants, a team led by Federico Maggi at the University of Sydney in Australia calculated how these plants take up nutrients from human urine. They modelled crops growing in natural soil – rather than artificial – in a chamber with a ventilation system and both urine and water injectors.

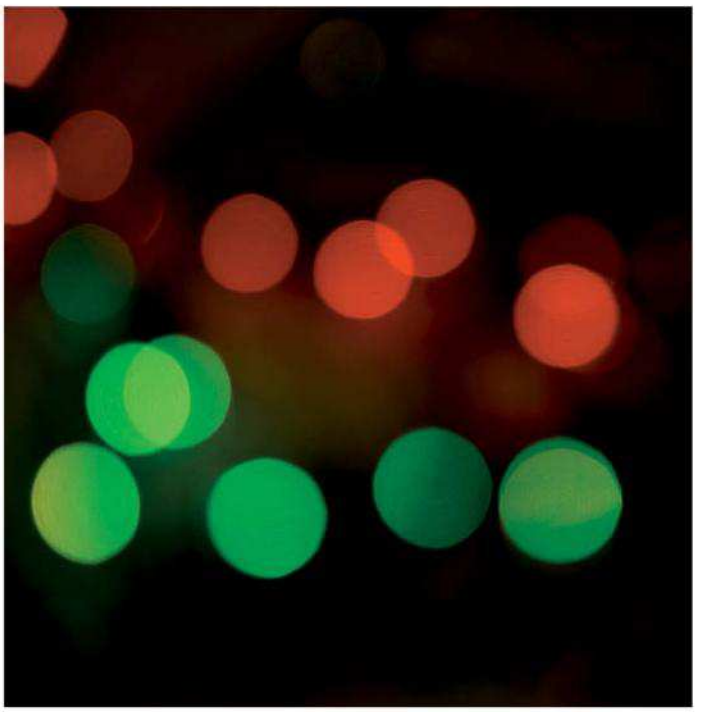
Over a simulated 20 years, urine largely met the plants' nutritional needs without high levels of harmful by-products or emissions, such as carbon dioxide or ammonia (*Life Science in Space Research*, doi.org/cmsj).

It isn't just the urine that makes this system work – soil is key. Thanks to long-lived microbes, soil can adapt to different conditions better than hydroponic and aeroponic systems.

"If you're trying to operate independently and grow food, plants need fertiliser. And the only fertiliser available would be [human] wastes," says Abraham Noe-Hays at the Rich Earth Institute in Brattleboro, Vermont.

He notes that urine may not provide enough nutrients because many are expelled in faeces. "Because urine contains most, but not all, of the nutrients, you wouldn't be able to maintain a plant agroecosystem indefinitely with only recycling the urine. You'd have to supplement that with nutrients to make up the difference," Noe-Hayes says.

He concludes that astronauts would probably have to get comfortable with recycling their own faeces as well, which comes with risks related to bacteria that urine doesn't have. Swapna Krishna ■



YULIA BABKINA/ALAMY STOCK PHOTO

Implants may one day change colour to warn us of cancer

Biological computer made from human cells

THE world's most complex biological computer, made from a group of engineered cells, could one day be implanted into the body to detect diseases and deliver treatments.

In 2012, Martin Fussenegger at ETH Zurich in Switzerland and his colleagues engineered two kidney cells to become a biological circuit capable of simple mathematics. One of the cells was able to compute a form of addition: the presence or absence of each of two chemicals would switch on a reaction inside the cell that would make it glow different colours. The other cell worked in the same way but could subtract.

This kind of biological circuit is reminiscent of a simple logic circuit in a computer. In theory, it could be used to make a skin patch glow in the presence of an infectious agent, for example.

Most biological reactions in the body aren't that simple, though, says Fussenegger. They rarely rely on "one input and one output" – instead, multiple inputs lead to different outputs. For instance, a high level of calcium in the body in the presence of a specific hormone may suggest one disease, but a high level of calcium along with another hormone might indicate a completely different condition.

"Together, these nine human cells form a fully programmable, multicellular circuit"

To be more practical, biological computers would need to be able to perform more complex mathematics. However, it is hard to pack multiple computations into a single cell.

To get around this, Fussenegger and his team have engineered a multicellular system, in which different cells each perform a separate computation, and pass on the results to each other.

The system has nine cells, each containing a chemical cascade that responds to three chemical inputs – reminiscent of an AND, NOT and OR system in a traditional electronic circuit.

These cells coordinate their activities by releasing chemicals like histamine that pass from one cell to the other. Together, they form a fully programmable, multicellular circuit that can respond to multiple inputs(*Nature Methods*, doi.org/cms6).

"Although it is not at a stage yet where we can test in animals, we believe it is the most complex biological computer ever assembled," says Fussenegger.

"This work addresses one of the most pressing limitations in synthetic biology – a lack of programmable devices," says Ángel Goni-Moreno, a synthetic biologist at Newcastle University, UK. He says that traditionally, a synthetic circuit inside a cell will always perform the same function, but Fussenegger's multicellular approach enables you to programme the circuit and achieve different computations just by connecting the nine cells in different configurations. "It is very powerful," he says.

In the future, a biological computer like this could be used to monitor more complex medical conditions. For example, it could respond to a rise in calcium, a drop in a hormone and an increase in a biomarker, which together would signal the presence of a specific type of cancer, says Fussenegger.

The team wants to develop a single implant for in situ diagnosis. The idea is that such an implant would continuously monitor all the chemical reactions in the body, and either treat any problems it detects, or help diagnose them and alert the user to seek appropriate treatment. **Helen Thomson** ■

Neanderthals stole up on sleepy bears

Joshua Rapp Learn

OUR ancient relations may have ambushed huge bears just as they were waking from hibernation – then stolen their caves.

"These cave bears were hunted and butchered by Neanderthals," says lead author Marco Peresani at the University of Ferrara, Italy.

Peresani and his colleagues have excavated the Rio Secco and Fomane caves in northern Italy. They have analysed more than 1700 bones, most of which belong to about 50 cave bears that lived 50,000 to 43,000 years ago.

Cave bears dominated Europe during the last ice age but are now extinct. Comparable to grizzly bears, they could weigh more than 600 kilograms. "I think they were the most dangerous mammals in the ice age period," says Peresani.

Neanderthals and cave bears would have met often, he says, as they competed for the same caves. And it seems the Neanderthals were able to take the bears down.

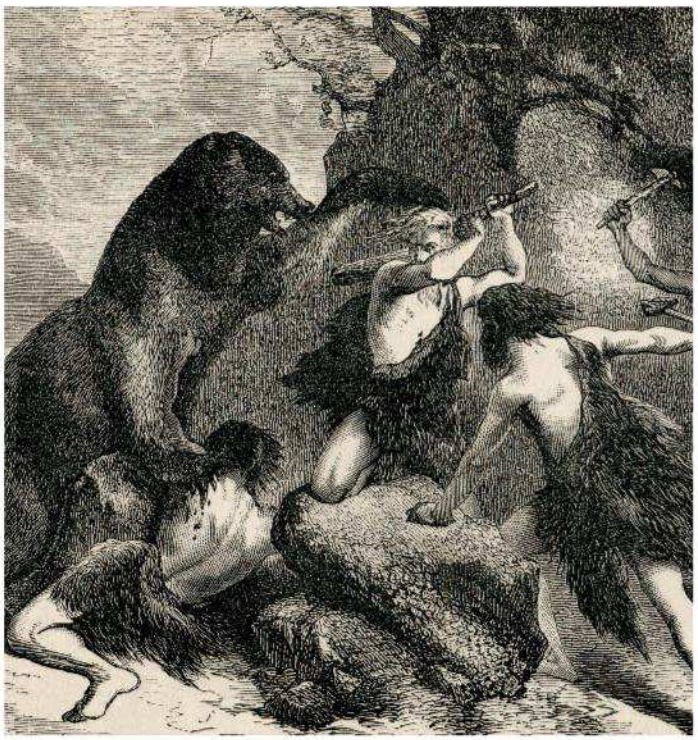
There were cut marks on the bones and hundreds of stone tools in the caves. Certain bones had bite marks matching Neanderthal teeth, and others may have been cooked. Some long bones seem to have been banged about, perhaps to extract the tasty marrow inside (*Journal of Archaeological Science*, doi.org/cmsd).

It is likely that the Neanderthals were mostly after the bears' pelts, says Peresani. However, bear meat would have been a nice change from the ibex and birds they normally hunted.

The bones included those of adults, cubs and newborns. That is key, since many bears give birth near the end of winter as they come out of hibernation. Neanderthals must have targeted the bears just at this moment, says Peresani. The females, while massive, would have been weak after birth and hibernation.

Bear penis bones were also found in one cave, suggesting that the Neanderthals sometimes tackled adult males as well.

The Neanderthals may have come to these caves in spring, heading up from Italy's plains to get stones for tool-making. Once they had killed the bear owner of a cave, they may have used it for months. "They were nomads," says Peresani. "They knew the landscape very well and the resources available based on the seasons."



UNIVERSAL HISTORY ARCHIVE/UIG VIA GETTY IMAGES

Our long-extinct cousins knew just when to strike

As well as the bear remains, the team found teeth from a hominin baby in one cave. Perhaps a Neanderthal child lost their first teeth while chewing bear flesh.

Peresani hopes to extract DNA from the teeth. This could tell us more about how Neanderthal genes equipped them to survive the ice age, and whether modern humans and Neanderthals interbred at this time.

The vast numbers of bear bones imply that Neanderthals often succeeded in killing the animals. But the bears outlasted them. The last reliably dated Neanderthal remains are from 40,000 years ago, suggesting they died out just a few thousand years after the most recent cave remains. However, cave bears survived another 20,000 years before going extinct. ■

Wearable scanner snaps moving brains

FOR the first time, babies and young children will be able to have their brain activity scanned, thanks to a portable scanner. This could also be useful for imaging the brains of people with movement disorders and other conditions that mean they can't undergo traditional scans.

Magnetoencephalography (MEG) involves analysing the brain's electrical activity via the magnetic fields it generates just outside the skull. Until now, MEG has involved keeping very still inside a scanner.

Now, Richard Bowtell at the University of Nottingham, UK, and his colleagues have designed a portable MEG device that is worn like a helmet, allowing people to move freely during scanning. They tested the device on four people while they moved their fingers and got results similar to those achieved using a standard MEG scanner (*Nature*, doi.org/cmrw).

The volunteers were then scanned while drinking tea or playing a ball game – neither of which is possible in a typical MEG scanner.

The device was made portable by replacing traditional sensors, which require a heavy and bulky cooling system, with miniature ones that detect the brain's magnetic field in a different way. These sensors can be attached directly to the scalp using a 3D-printed helmet that can be personalised to fit any size of head.

"You can scan brains during more natural interactions, such as two people speaking face-to-face"

The wearer can't wander too far though: the scanner only works inside a special room that helps counteract Earth's natural magnetic field. But there are still plenty of possible applications, says Bowtell. "It could be used to analyse brain activity while people navigate, for instance," he says. "You can also have more natural interactions between people – two people each wearing a scanner and speaking face-to-face."

It makes it possible to scan toddlers and babies as well, to study their development, he adds. Helen Thomson ■

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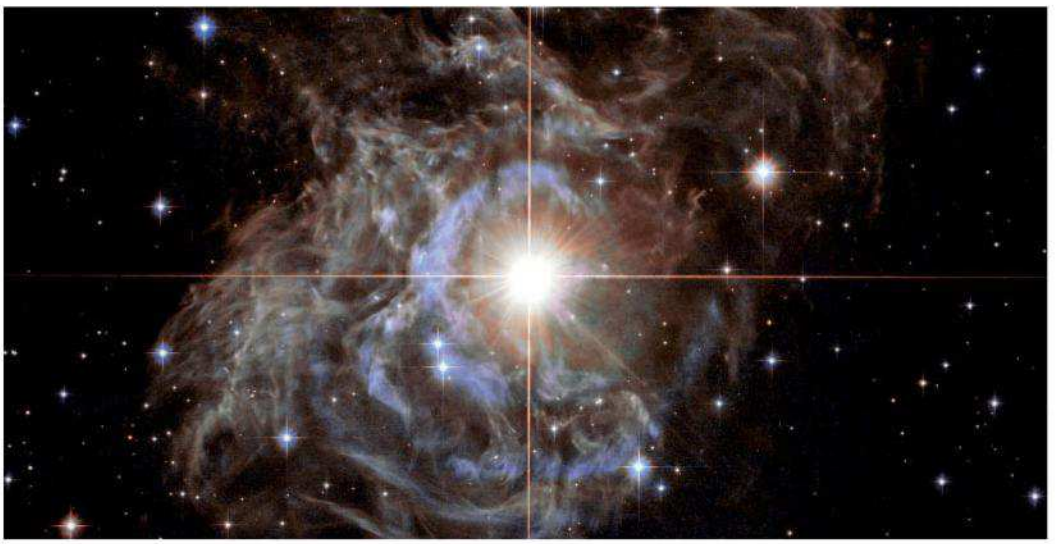

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Dark radiation may end cosmic puzzle

The invisible stuff around stars and galaxies could be decaying

Anil Ananthaswamy

IF SOME of the dark matter in the universe is decaying into undetectable radiation, it would solve a niggling mystery about the rate at which our universe is expanding. It would also have major implications for the hunt for dark matter.

Cosmologists use precise measurements of the cosmic microwave background (CMB), the radiation left over from the big bang, to calculate the rate at which the universe is expanding, called the Hubble rate. When they compare the rate as calculated based on extrapolating the CMB with the rate given by observing galaxy clusters in the nearby universe, the results are off by about 10 per cent.

"It's not a strong enough discrepancy to call it a crisis, but something may be going on," says Torsten Bringmann at the University of Oslo in Norway. "And it is not going away. It's stuck with us for the last two or three generations of experiments."

He and his colleagues wondered whether a strange model of dark matter could explain the discrepancy.

Astronomers don't observe dark matter directly, they infer its presence through its gravitational influence on stars and galaxies. The standard model of cosmology assumes that the amount of dark matter has remained constant from about 50,000 years after the big bang. But, "it's by no means clear that this is true", says Bringmann. So, what if it weren't?

"We assume that dark matter has remained constant, but it's not clear that this is true"

An alternative model of dark matter posits that it is slowly decaying into undetectable dark radiation. Variations in the CMB can be linked to fluctuations in the density of dark matter when the CMB was formed about 380,000 years after the big bang, so looking at the CMB data puts a limit on how much can have decayed around that time. Bringmann's team found that it only allows for a few per cent of the dark matter to have turned into radiation.

But even this small amount of dark matter decaying to dark radiation would resolve the tension between the two Hubble rate measurements. It would increase the CMB-derived value and bring it in line with the rate based on observations from the local universe (arxiv.org/abs/1803.03644).

Miguel Zumalacarregui at the University of California, Berkeley, says the finding warrants further study. "It is important to explore the alternatives," he says. "If the tensions persist we might not only rule out [the standard model of cosmology], but also get a handle of whatever new physics is needed to supersede it."

If dark matter is indeed decaying, it would have far-reaching implications for all the experiments that are searching for so-called weakly interacting massive particles (WIMPs), the current favoured type of dark matter. In most models of WIMPs, the particles don't decay. "It would immediately imply that a whole class of vanilla WIMP dark matter scenarios would be ruled out," says Bringmann. ■

Medicine for poorly koalas is killing them

CURING chlamydia in koalas can be just as deadly as the disease itself, and now we know why.

In humans, chlamydia is a common infection and can cause reproductive health issues. But for koalas it is more serious: the strain that infects them is often lethal. It is transmitted during sex and, more commonly, through pap: a faecal product that females use to wean their joeys. A vaccine is in the works but it is not ready yet.

For now the best option seems to be antibiotics to kill the infection. But koalas often suffer serious side effects from antibiotics, so Katherine Dahlhausen at the University of California, Davis, and her colleagues tried to find out why.

They gathered faecal samples from sick koalas and scanned them to see what microorganisms were present. Like many other animals, koalas have "friendly bacteria" living in their guts that help them digest food.

The team found that antibiotics had little effect on most of the friendly bacteria, but one species was often wiped out: *Lonepinella koalarum* (*PeerJ*, doi.org/cmrv). This species is crucial because it breaks down harmful tannins, allowing the koalas to digest the tough eucalyptus leaves that make up most of their diet.

Without *L. koalarum* to detox the tannin, the koalas starve to death.

Dahlhausen says other gut bacteria may also be involved.

No known antibiotic kills chlamydia and leaves the friendly bacteria alone. We could feed koalas a probiotic diet to restore *L. koalarum*, but research on this is in its infancy. "Faecal transplants may be the best method for offsetting the detrimental effects of antibiotics," says Dahlhausen.

The rise in koala chlamydia is partly due to stress caused by habitat loss, says Deborah Tabart, CEO of the Australian Koala Foundation. "The solution is to reduce clearing of forests so that koalas do not get sick in the first instance." Bob Roehr ■

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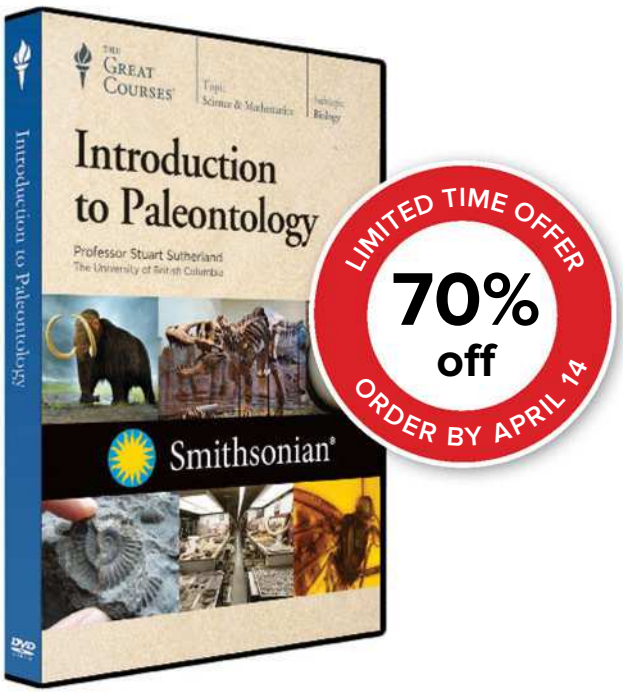

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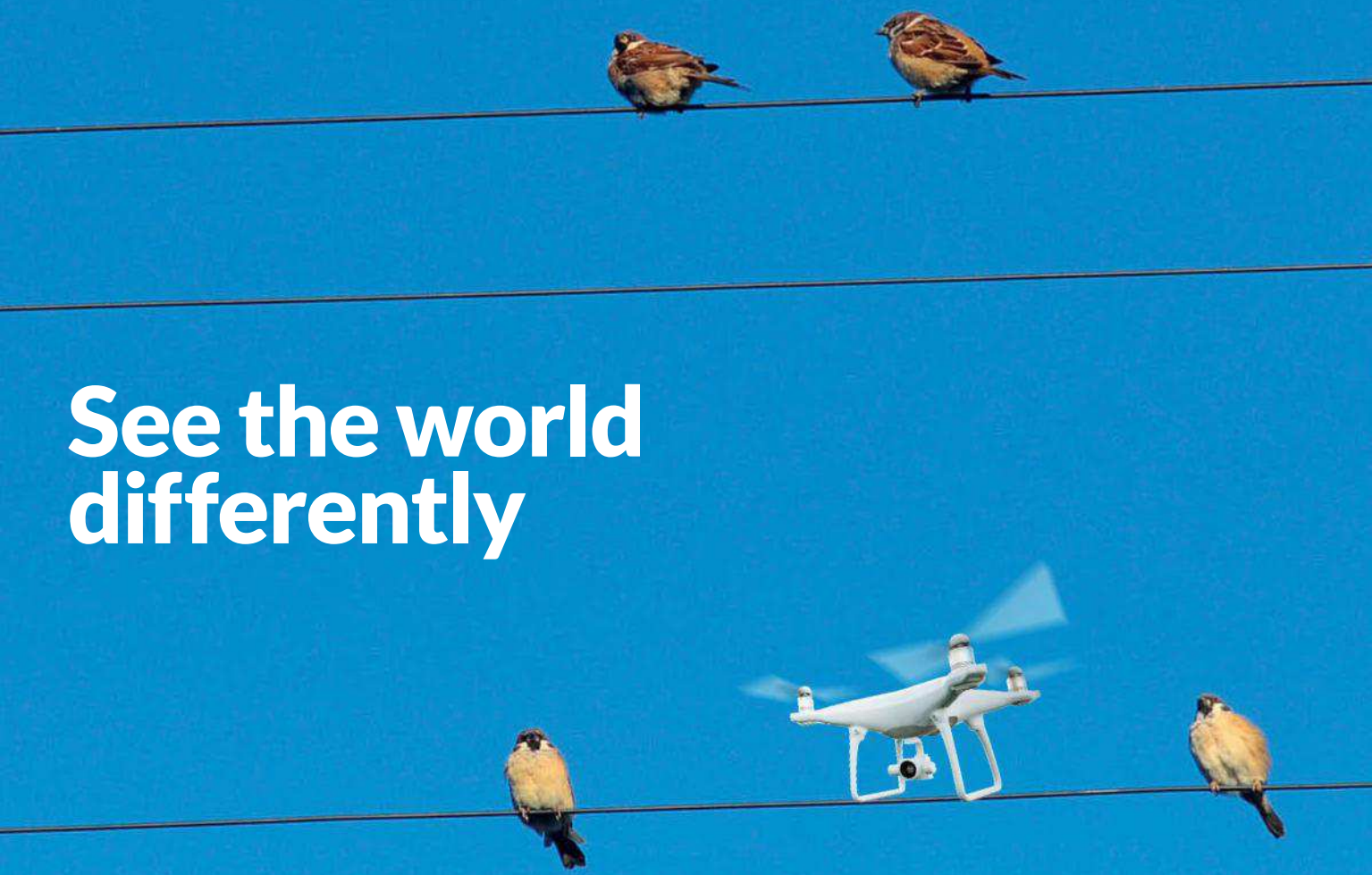

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NewScientist

Silkworms made immune to disease

Michael Le Page

SILKWORMS can now fight off a lethal virus after being given an immune system found in many bacteria. The same approach could protect other animals and plants from viral diseases.

The silk industry suffers huge losses from a virus called Bombyx mori nucleopolyhedrovirus (BmNPV). "It would be incredibly important to have virus-resistant silkworm," says Fritz Vollrath at the University of Oxford.

The key could be CRISPR. It is known as the genome-editing tool revolutionising biology, but it evolved in bacteria as an immune system to protect against viruses.

In these bacteria, CRISPR proteins first recognise the DNA of invading viruses, using "guide RNAs" that match the DNA sequence. They then cut up the viral DNA, preventing the virus making more copies of itself.

Zhanqi Dong at the State Key Laboratory of Silkworm Genome Biology at Southwest University in Chongqing, China, and his colleagues gave silkworms the genes for the CRISPR protein Cas9, plus guide RNAs targeting BmNPV sequences. They then exposed silkworms to the virus.

The genetically modified silkworms only succumbed when given a dose 1000 times greater than that which killed ordinary silkworms (*Frontiers in Microbiology*, doi.org/gc4t8m). No other team trying to create virus-resistant silkworms has come close to that level of success.

Geneticists have long worked to create disease-resistant plants and animals, with some successes. In 1998, the papaya industry in Hawaii was saved by a GM variety resistant to the ringspot virus.

But what protects one organism against one virus seldom works for other situations, so creating virus-resistant plants and animals can take years of trial and error. By contrast, the CRISPR immune system should work in most plants or animals. Only the guide RNAs must change, which is easy.

CRISPR won't fight infectious bacteria or fungi, but it should work against lots of viruses. The Cas9 protein that Dong's team used only cuts up DNA, so it would only work against viruses that use DNA. But other proteins can target RNA. In February, a team in Saudi Arabia reported that it had protected tobacco plants from RNA viruses using a recently described CRISPR protein called Cas13a that cuts RNA (*Genome Biology*, doi.org/gct2s8).

The potential downside of Dong's approach is that the CRISPR protein and guide RNAs must be continuously produced in every cell. If the CRISPR protein targets silkworm DNA by mistake, it could make the animal ill.

However, the good news is that many teams are reporting no detectable effects for the host animal when guide RNAs are carefully designed. Dong's team found none in the silkworms.

Jennifer Doudna at the University of California, Berkeley, whose 2012 work helped spark the CRISPR revolution, says other teams have created mice whose cells permanently express Cas9. "The mice seem fine," she says.

Other groups are modifying silkworms so their silk is more like spiders'. This is famously strong, but it is hard to farm spiders. ■

The silk industry is plagued by a silkworm-killing virus

VCG/VCG VIA GETTY IMAGES

Sucking drinking water out of thin air

FRESH water pulled from the sky. It is an ambitious goal, but to win the Water Abundance XPrize, teams have to extract 2000 litres a day from the atmosphere in a cheap and sustainable way.

The five teams through to the finals were announced last week by XPrize, the non-profit that organised the competition. These had been whittled down from an initial field of 98 based on their prototypes.

Final testing will happen in July. Teams must produce the water using renewable energy at a cost of no more than 2 US cents per litre. Whichever group extracts the most water at the lowest cost will receive $1.5 million.

The World Health Organization states people need at least 20 litres of water a day for drinking and basic hygiene, but increasing demand from growing populations and the impact of climate change means global fresh water supplies are rapidly depleting.

"What we're trying to do is to unlock this hidden source of water in a cost-effective and sustainable way," says Zenia Tata at XPrize.

The finalists have a variety of solutions. London-based Veragon already builds machines that condense water from the air by cooling it, and has teamed up with Imperial College London start-up ThinAir to supercharge the process with new materials. Laura Dean, who leads the team, says they expect to produce more than 5000 litres of water a day.

"Whichever group extracts the most water at the lowest cost will receive $1.5 million"

Indian team Uravu is focused on a simple, low-maintenance solution using a silica gel whose structure lets it passively suck water vapour from the air. The idea is to collect water at night, then during the day solar collectors channel heat from the sun to warm the gel. This releases the vapour again, which is cooled back into water. The machine produces 10 to 15 litres of water a day, but multiple units can be linked together to meet the 2000-litre benchmark. Edd Gent ■

POPPERFOTO/GETTY IMAGES

One of Captain Scott's Antarctic expeditions uncovered strange ice

Scott's dirty ice may solve mystery

Colin Barras

HOW did life survive when Earth turned into a giant snowball hundreds of millions of years ago? A bizarre region of "dirty" Antarctic ice, discovered a century ago by British explorer Captain Robert Scott's team, might hold clues.

There is evidence that Earth saw astonishingly severe ice ages between 717 and 636 million years ago. Some say conditions were so extreme that ice reached the equator and our planet effectively became a giant snowball.

If it happened, Snowball Earth creates a puzzle. We know complex life and maybe animals appeared before the glaciations. So how did they survive when Earth was frozen over?

Roger Summons at the Massachusetts Institute of Technology and his colleagues have found a solution.

It lies in a corner of Antarctica explored by Scott's Discovery Expedition between 1901 and 1904. Famously, Scott died in Antarctica in 1912 after being beaten to the South Pole.

Scott's team found a region of the McMurdo Sound ice shelf that was littered with large deposits of salt and marine animal remains, from sponges to shellfish. It was, according to the team's geologist Hartley Ferrar, a "freak of nature which is difficult to explain".

Geologists now have an explanation. Water freezes onto the base of the ice and evaporates from the top, so over time each layer of ice moves upwards. Animals and mud from the shallow sea below are frozen into the base of the ice and carried upwards. They concentrate at the surface when the ice they were trapped in evaporates, creating a thick layer of dirty ice.

"If these places exist on Earth today, they must have been prolific on an ice-covered planet"

There are also small ponds in the dirty ice, although it isn't clear why they stay liquid. Summons says that these ponds teem with life, from bacteria to more complex microbes. This life endures thanks to the flow of material through the ice, he says. "You've got a continuous flow of phosphate and trace elements."

Summons and his colleagues argue that similar communities may have existed during Snowball Earth (*Geobiology*, doi.org/cmq2). "If these places exist on Earth today, they must have been prolific on an ice-covered planet. Wherever you have shallow continental shelf and sea glaciers, there must have been dirty ice."

Warwick Vincent at Laval University in Canada and his colleagues were the first to argue that life survived Snowball Earth atop the ice. "Dirty ice is a compelling analogue for Snowball Earth ecosystems," he says.

Life might even have thrived and evolved on Snowball Earth, if modern dirty ice is any guide. "This is not just an invisible microbial world, eking out an existence at the edge of life," says Vincent. "It's the polar equivalent of an Amazonian rainforest."

"The important thing is that such environments would have been extensive on Snowball Earth, approximately 12 per cent of global surface area," says Paul Hoffman at Harvard University. ■

Mercury's big cousin found in distant system

AN EXOPLANET remarkably similar to Mercury has been found, and it might shed light on why our diminutive neighbour has such a big heart.

Mercury has an immense iron core that makes up roughly 70 per cent of its volume. That's massive compared with Earth's, which is just 30 per cent of its volume. But without another planet like Mercury in the solar system, astronomers have had a difficult time describing how such a wacky world formed.

Now, Alexandre Santerne at Aix-Marseille University in France and his colleagues have discovered an exoplanet that seems like a bigger version of Mercury. This larger cousin is called K2-229 b and lives in a planetary system 340 light years away (*Nature Astronomy*, DOI: 10.1038/s41550-018-0420-5).

Santerne and his colleagues have studied the exoplanet with the La Silla Observatory in Chile. Although its radius is only fractionally larger than Earth's, it is 2.59 times the mass of our planet. The team modelled the planet to work out how it might have formed and found that it must have a massive iron core and a thin silicate mantle – making it more like Mercury than any planet discovered thus far.

One idea credits extreme heat for making planets turn out like Mercury. Consider K2-229 b, where it reaches a sizzling 2033 kelvin, or 2057°C. "Imagine Earth eight times hotter," says David Ciardi at the California Institute of Technology. "All of the atmosphere would evaporate; all the water would boil off and the surface rocks would probably melt and soften." Heat could easily vaporise the outer layers of silicate-rich rocks, leaving mostly metal behind.

Another hypothesis says a giant impact could shatter a planet, sending the mantle flying and leaving a world that was more core than not. Models can recreate this scenario for Mercury. If they work for K2-229 b, it will lend weight to this idea. Shannon Hall ■

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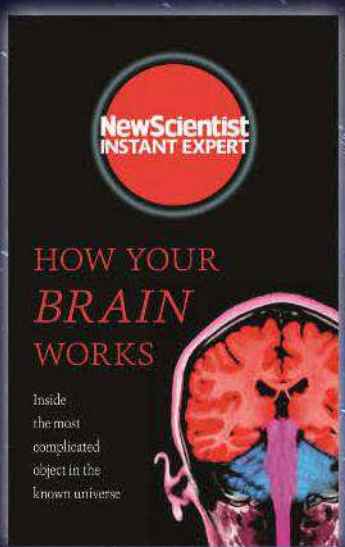

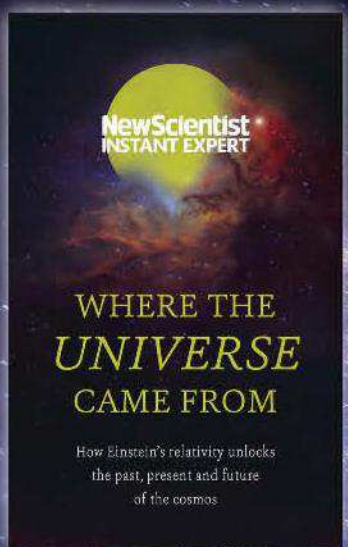

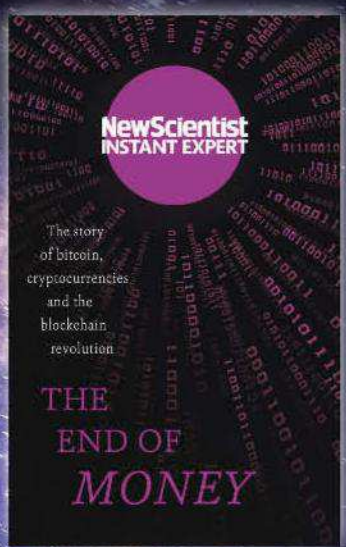

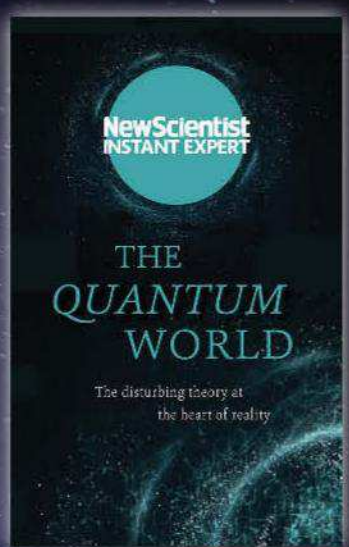

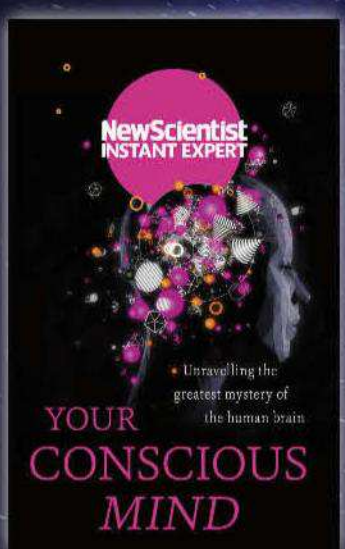

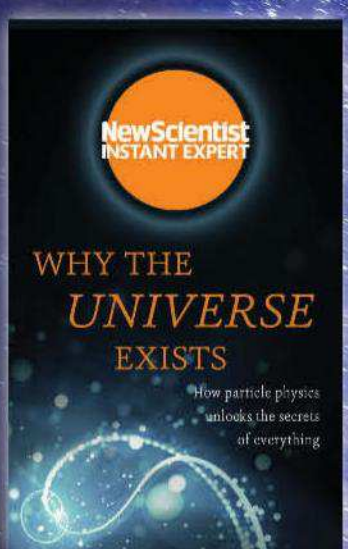

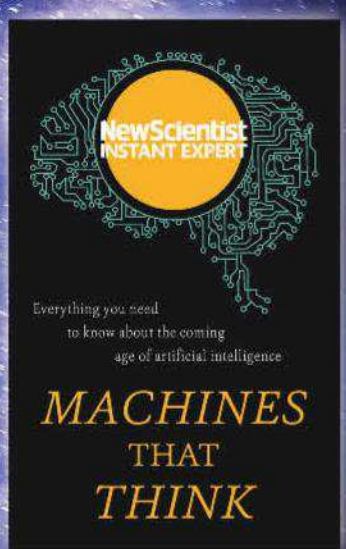

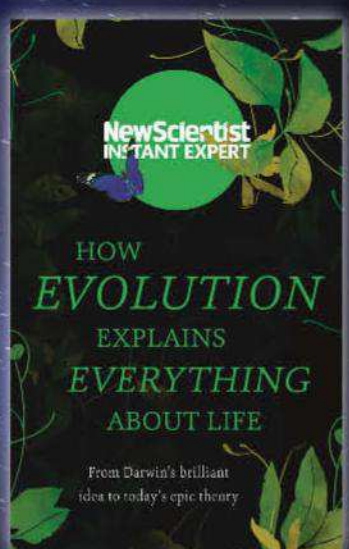

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People all over the world are receiving effective HIV treatments and more treatment options are in the pipeline. Now, global health organisations want to end the AIDS epidemic

The future of HIV

ISTOCK / GETTY IMAGES PLUS

IN 2015, the Joint United Nations Programme on HIV/AIDS (UNAIDS) launched an ambitious target: to end the AIDS epidemic by 2030. The aim is that no child will be born with HIV and anybody already infected will be treated with medicines that give the best opportunity for healthy living.

This goal is in stark contrast to the early days of the epidemic, when the virus wreaked havoc. In the 1980s and 90s, an HIV infection was almost always fatal. But treatment has come a long way since then.

Today, nearly 21 million people around the world receive life-saving antiretroviral therapies, which can reduce the amount of the virus in the blood to undetectable levels. And scientists have even greater ambitions: some are developing vaccines, others are formulating long-acting treatments and still more are working on a cure. "HIV has changed from a deadly disease to a manageable disease," says Jens Lundgren at the University of Copenhagen in Denmark, who has been working on HIV care and research for the past 30 years.

Until recently, HIV's spread was rapid because it is easily transmitted via contact with infected blood and other body fluids. The most common routes of infection are through sex and shared needles.

But the risk of transmission can now be substantially reduced with antiretroviral medicines. Bruce Richman, who was diagnosed with HIV in 2003, says the treatments have changed his life. "For much of the time I had HIV, I isolated myself and had a sense of fear and shame," he says. "Because I had a fear of transmitting HIV, I feared getting close to romantic partners."

But that changed in 2012, when Richman's doctor informed him that his antiretroviral treatment had reduced the amount of HIV in his blood to undetectable levels. The news was a revelation and Richman realised he no longer needed to hide.

Keen to spread the word, he started a campaign to publicise the life-changing effects of antiretrovirals and their impact on transmission rates. He called the campaign U=U (Undetectable = Untransmittable). His aim was to change the way people understand what an HIV diagnosis means, encourage those who are infected to keep up with their treatments and help lift the enduring stigma of HIV. "It improves the lives of people with HIV, and opens up social, sexual and reproductive lives that we didn't think were possible," says Richman.

Since 2016, the U=U campaign has teamed up with 570 other organisations in 71 countries to share the message. "In most of these countries people have been taught to fear HIV and people with HIV," says Richman. "Now we're turning a corner."

"Eliminating AIDS as a public health threat by 2030 is potentially achievable"

The impact of this and other prevention strategies and campaigns has begun to reduce new infection rates. In 2016 in London, four sexual health clinics saw a 40 per cent fall in new HIV infections among gay men compared with 2015. And the number of new diagnoses in San Francisco has dropped by more than 50 per cent since 2006, in large part because of this "treatment as prevention" approach, also known as TasP.

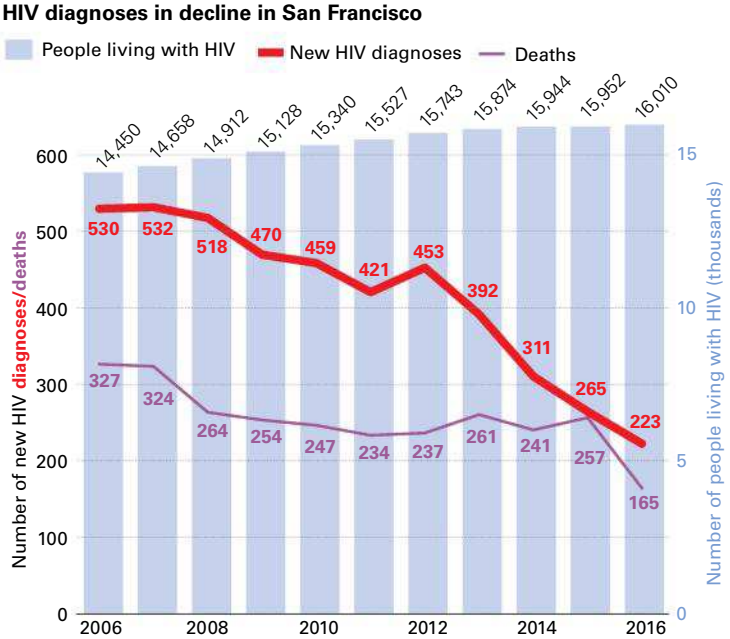
But more work is needed, for example, on a vaccine. For some other viruses, vaccines work by mimicking the biochemistry of people who seem to be naturally protected from infection. "For HIV, we don't have a good naturally protective correlate to work with," says Lundgren.

Another difficulty is the lack of a good animal model for human HIV infections. Potential vaccines that show promise in monkeys infected with the similar simian immunodeficiency virus (SIV) have not been successful in human clinical trials.

There are also hopes for an HIV cure, but this has been harder to come by than expected. The main problem with trying to cure HIV is that there is a latent reservoir of the virus in the body.

That is why the leading strategy in the hunt for a cure is the "kick and kill" approach. This

HIV diagnoses in decline in San Francisco



SOURCE: SAN FRANCISCO DEPARTMENT OF PUBLIC HEALTH

The future: prevention, treatment and cure?

aims to kick HIV out of cells that act as a reservoir and then kill the virus.

While focusing on such scientific problems to make a cure a possibility in future, researchers at pharmaceutical company Gilead are also making progress when it comes to the potential for longer-acting treatments. At the moment, antiretroviral drugs must be taken on a daily basis and this can prove difficult for some.

Winston Tse, a senior scientist at Gilead, is working on a treatment that looks to be particularly potent and could take the form of a long-acting injection. He and his colleagues have set their sights on a protein that surrounds and protects the HIV RNA genome which is essential to viral life including its ability to infect new cells. The team is developing compounds that interfere with this protein and so inhibit the ability for the virus to replicate.

"Such a treatment could help with compliance, as well as lessening the emotional burden of taking daily HIV treatment," says Tse.

It is this focus on prevention and treatment that make the UNAIDS goal potentially achievable – eliminating AIDS as a public health risk by 2030. "I would love a cure, but I'm investing my time into the strategy of testing, treating and prevention, because I think that's the way to end this epidemic," says Richman.

Lundgren agrees. "We have the tools, we have the drugs, we have the tests," he says. "If we push resources, we can control it."

For more see: @GileadSciences

Date of preparation: March 2018
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SCOTT TINDALE

Pregnant female ray forced to fend off courting males

FOR the first time, giant devil rays have been filmed courting in the waters of New Zealand. It seems males start pursuing females while they are still pregnant.

In March 2017, recreational fisherman Scott Tindale of the International Game Fish Association in Albany saw a heavily pregnant female giant devil ray (*Mobula mobular*) being pursued by four males. The female swam ahead of the males and repeatedly changed direction, as if trying to throw them off. She mostly swam at or near the surface, preventing the males from getting on top of her.

Tindale described the incident to biologist Clinton Duffy of the Auckland War Memorial Museum in New Zealand (*New Zealand Journal of Zoology*, doi.org/cmfs).

"She must have been close to giving birth, judging by the size of her," says Duffy. The rays may mate soon after birth. "Many sharks and rays are thought to have a resting period between pregnancies, but this behaviour suggests that is not the case in giant devil rays."

Such rapid mating is not unheard of, says Guy Stevens at the Manta Trust in Dorchester, UK. Female reef manta rays can become pregnant hours after giving birth. "This was documented with a female manta in captivity, where food is always plentiful and energy expenditure is minimal, and I see it in the wild quite a lot as well," he says.

Giant devil rays are endangered, so knowing where they breed is crucial, so the sites can be protected.

Boosted smear test finds extra cancers

A SIMPLE smear test for cervical cancer can now pick up ovarian and endometrial cancers too.

These cancers are difficult to treat because they often spread to other parts of the body before symptoms arise.

Lucy Gilbert at McGill University Health Centre in Montreal, Canada, and her colleagues wondered if the Pap test, which is used to screen for cervical cancer, could be adapted to detect these.

They found that the Pap brush also picks up cancer cells that have shed from the ovaries and endometrium and pooled at the cervix. Analysing certain genes in these cells enabled them to detect 33 per cent of ovarian cancers and 81 per cent of endometrial cancers in Pap test specimens collected from 627 women already diagnosed with these diseases.

To improve the accuracy of the test, the researchers used a Tao brush that reaches beyond the cervix to collect cells closer to the ovaries and endometrium. This boosted the detection rate for endometrial cancer to 93 per cent. Using the Tao brush in combination with a blood test pushed up the ovarian cancer detection rate to 63 per cent (*Science Translational Medicine*, doi.org/cmqx).

Pacific Garbage Patch fattens up

THERE is even more plastic in the Pacific than we thought. At least 79,000 tonnes are floating in the Great Pacific Garbage Patch, up to 16 times as much as was estimated in 2014.

The Garbage Patch is an area of 1.6 million square kilometres between Hawaii and California, where plastic debris accumulates.

Laurent Lebreton of the Ocean Cleanup in Delft, the Netherlands, and his colleagues gathered data from aerial surveys and ships' nets, and fed it into a computer model. This showed there is 1 kilogram of plastic per square kilometre in outer regions, rising to over 100 kg/km^2 at the centre (*Scientific Reports*, doi.org/cmqq).

"The Great Pacific Garbage Patch is getting denser with floating plastic," says Lebreton.

Some may be flotsam washed to sea in the 2011 Tohoku tsunami. Of pieces found with "made in" labels, a third came from Japan.

Epilepsy drug may also treat baldness

EXISTING treatments for male pattern baldness come with downsides such as reduced sex drive. Now, researchers are seeing whether valproic acid – used to prevent epileptic seizures – could do better, after anecdotal reports that some balding men regained their hair while taking it.

Hyungil Jung at Yonsei University in South Korea and his colleagues tested the drug on male mice whose fur had stopped growing. After shaving the animals, the researchers delivered the drug every day in microscopic needles that dissolve after being inserted. The mice grew back all their fur over the next four weeks (*Biomaterials*, doi.org/cmq3).

The team now hopes to show that this works in people.

Water, not soap, removes stains

LATHER, rinse and rinse again. That's how to get rid of deep stains, says a study of fluid dynamics within fabric-like pores.

Detergents contain a surfactant, an ion-containing substance that binds to dirt particles, loosening them from fabric. But this doesn't explain how dirt deep in the pores between fibres is removed, as only about 0.1 per cent of flowing water reaches there. It should take a lot of rinsing to remove dirt, but it doesn't.

To find out why, Sangwoo Shin at the University of Hawaii at Manoa and his team made channels about 50 micrometres wide in a polymer. They then filled them with tiny polystyrene beads in a soap solution to mimic dirt particles on a fabric that has gone through a wash.

When the polymer was "cleaned" by dousing it in soapy water, only particles near the channel mouths washed away. But the next step – using flowing, non-soapy water – removed most particles, even those deep down, after about 10 minutes (*Physical Review Applied*, doi.org/gc5sm6).

The fresh water created a gradient in the concentration of surfactant along each channel, with the uneven distribution of its ions producing an electric field. This drew soap-bound beads sitting deep in the channel upwards to where the ions were less concentrated.

BLEND IMAGES/ALAMY

Super-quick supernova peaks in just two days

THE quickest supernova we have ever seen went from invisible to super bright in only 2.2 days. It is the first of these speedy stellar explosions that has been observed thoroughly enough to help us figure out exactly how they work.

Supernovae are massive explosions that happen when a star burns out. They usually take weeks or months after the death of the star to reach maximum brightness, and even longer to fade away. But Armin Rest at the Space Telescope Science Institute in Baltimore, Maryland, and his colleagues found one in data from the Kepler Space Telescope that rose to peak brightness in less than 53 hours and faded back to half that brightness in 6.8 days (*Nature Astronomy*, DOI: 10.1038/s41550-018-0423-2).

Often, quick supernovae are dimmer than their longer-lasting counterparts, so they can be explained through a weaker mechanism, like a star that only partially exploded. But this one, called KSN 2015K, was just about as bright as a regular supernova, so the team thinks it may have started out dim and then received an extra boost.

One possibility is that before the star went full supernova, it expelled a dying breath, releasing a dense shell of gas. When the star exploded within this shell about two months later, the initial explosion would have been invisible to us. But the debris that it spewed would quickly slam into the gas surrounding it and create a powerful shock wave. Then, the kinetic energy from the explosion would be converted into the blast of light that Kepler detected.

Gel helps prevent cancer relapses

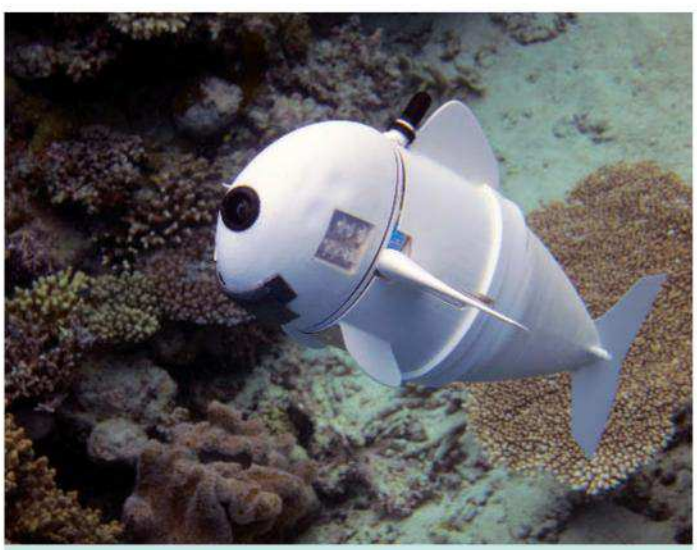
FORTY per cent of people who have had cancer see it return within five years of tumour removal, but a gel may change that.

By rebooting the immune system, the gel purges any cancer cells left after surgery and those that have spread elsewhere.

The gel, created by Michael Goldberg of the Dana-Farber Cancer Institute in Massachusetts and his colleagues, is placed in the cavity left when a tumour is surgically removed. It releases substances that activate white blood cells and interferon proteins that help the body defend itself against cancer.

More than 100 mice implanted with human breast cancer were given the gel after surgery. In 65 per cent of them, the gel eradicated any cancer that subsequently spread (*Science Translational Medicine*, doi.org/cmqz). Only 10 per cent of mice who received surgery but not the gel survived to the end of the three-month experiment.

The gel also worked in mice given skin and lung tumours, indicating that it could work for many cancers. "We hope it will be tested in patients in the not-too-distant future," says Goldberg.



KATZSCHMANN ET AL., SCI. ROBOT. 3, EAAR3449 (2018)

Robot swims with the fishes

IT MOVES like a real fish, flapping its tail from side to side – and doing so allows this robot to study marine life up close.

Current autonomous or remotely operated submersibles usually have propellers, which disturb wildlife. But this soft robotic fish, called SoFi, can get among the real things. Videos of test dives in Fiji's Rainbow Reef show the robot skirting over coral beside fish that seem unfazed by the mechanical interloper.

SoFi is operated by a human diver via a waterproofed Super Nintendo controller and an ultrasound transmitter. Its lithium battery allows it to swim for 40 minutes at a stretch, while capturing videos.

The robot can alter its buoyancy and handle depths of up to 18 metres. The electronics are packed into SoFi's head, surrounded by baby oil to stop water getting in (*Science Robotics*, doi.org/cmqr).

"To our knowledge, this is the first robotic fish that can swim untethered in three dimensions for extended periods of time," says Robert Katzschmann, one of the team at the Massachusetts Institute of Technology behind SoFi.

KIRILL KUDRYAVTSEV/AFP/GETTY

The online arm of the law

With cybercrime on the rise, politicians are calling for new laws. We just need to enforce the old ones, says **Sally Adee**

OVER the past few years, crime statistics in England and Wales have risen dramatically, following decades of steady decline. According to the UK's Office for National Statistics (ONS), crimes have near-doubled since 2015.

It's not that there has been a recent crime spree – this isn't about a rise in acid attacks or knife crime. Rather, it was only in 2016 that the ONS began estimating cybercrime figures, exposing how criminal operations are increasingly moving online. After all, why rob a bank when you could hack someone's account or steal their bitcoins?

The ONS says there were 6.2 million crimes committed offline in 2016, and 5.6 million cybercrimes, with similar figures in 2017. Even those numbers may be optimistic when it comes to capturing the true impact of online crime. "There's no clear agreement on how to define cybercrime," says Frank Pace, a security researcher and EU law enforcement specialist. With the problem only likely to get worse, is it time to radically change our approach to tackling online crimes?

Computer exploits once available only to the most tech-savvy crooks are now easily accomplished by anyone with a kit sold on the dark web, complete with instructions.

"We already have laws against libel, theft and basically everything else that is now cyber-enabled"

Clearly, we need to tackle this fast-growing problem. Prime Minister Theresa May recently suggested taking a look at the UK laws around cybercrime to combat online harassment and intimidation. France last week also announced plans to fine social media firms for failing to take down hate speech, following a similar law introduced in Germany at the start of this year.

But the internet enables a lot more than just harassment – phishing attacks, identity theft and cryptocurrency scams are all either exacerbated or created online. Then there are mass data

leaks; take the current row over the actions of UK data analysis firm Cambridge Analytica (see "Felons on Facebook?", below). Some say there should be bespoke laws criminalising each.

"Nonsense," says Mark King at European e-identity organisation EEMA. "We already have laws against libel, theft, impersonation and basically everything else that is now cyber-enabled."

Rather than new laws, we need a better way to track the problem. Part of the reason we are likely to be underestimating the scale of cybercrime is that many instances go unrecorded, says King. Scam victims often don't bother going to the police, and some cybercrime is simply unnoticed, for example when your device is infected with malware.

Inspector gadget

Even when people do go to the police, they can encounter officers who aren't specifically equipped to deal with digital crimes. We have all heard the stories of detectives who ask why victims of online abuse don't just turn off the computer, but this goes beyond fallible individuals.

"The entire reporting system is not fit for purpose," says King. You can't forward a suspected phishing email to the police, because it will get caught by their spam filters. Most police departments don't have dedicated computers or other ways of processing this kind of evidence.

"If the police are a problem, the prosecutors are a bigger problem, and the biggest problem of them all are the judges," says Marc Goodman, a former advisor to the FBI and Interpol and author of the book *Future Crimes* – many have no idea how cybercrimes are perpetrated.

In an effort to change this, the City of London announced plans last October to create a dedicated cyber-court dealing with online financial crimes and fraud. "There's plenty of precedent for specialist courts," says Patrick Curry, who runs the British Business Federation Authority, which develops authentication and identity standards. "We already have divorce courts, family courts, and the US even has special veterans courts."

The idea is that judges will already be familiar with how the online world works, so prosecutors don't have to do the equivalent of explaining automotive engineering to the person presiding over a car theft case. There will be 18 court rooms equipped with isolated computers capable of demonstrating evidence without the risk of spreading malware.

In Hangzhou, China, a cyber-court opened last August to hear disputes arising from online shopping, defamation, copyright infringement and loans. It was created mainly to take on the rising number of legal cases relating to e-commerce, largely by putting the entire process online. Everything from discovery of evidence to judgments happens digitally – people even receive their verdicts on the platform. If a written record is necessary, a speech recognition system automatically transcribes the trial.

However, this court only addresses disputes inside China. London's cyber-court is billing itself as a place where cases can be brought internationally. However, practising cross-border law throws up a number of hurdles.

For example, last month a British man who had extorted children and teenagers online was sentenced to 32 years in jail. It took law enforcement agencies across multiple countries five years to track down enough evidence to prosecute him, as the treaties that let them share data require months of paperwork.

"If criminals use an anonymising service like a proxy, the chances of prosecution plummet"

"Right now these requests are done by sending diplomatic pouches to the state department or the foreign ministry for review," says Pace. "It's all based on 19th-century law."

Improvement may be coming soon. The US Cloud Act and the European Union's e-evidence proposal both seek to clarify what counts as lawful use of overseas data and reconcile different laws around how evidence is obtained when different countries' laws clash. The UK should even be able to take advantage of these laws post-Brexit.

However, not all countries will play along. Just as Switzerland and the Cayman Islands offer tax havens to people who want to hide their money, some states are becoming cybercrime havens, says Curry: "Think of Ukraine, Russia, China. Here you can pay-off local law enforcement and if they don't cooperate with authorities in affected countries, well, tough."

Ultimately, even if local law enforcement is willing to cooperate, obtaining evidence in online cases is very difficult. If criminals use an anonymising service like a proxy, the chances of prosecution plummet, no matter how clued up the judge is. "You can have all the special courts and special experts you want," says Curry. "If the evidence isn't there, what's the judge going to be able to use to make a ruling?"

That opens the floor to a very uncomfortable question – should we stop letting people be anonymous on the internet? "Specialist courts strike me as a pretty lame idea," says Lawrence Sherman, an experimental criminologist at the University of Cambridge. Especially, he says, when compared with a recent proposal to redesign the internet to require identification of all users. Under this system, all online information would be assigned a "handle" that could be tied to your real-world identity, making anonymous crime much more difficult. Curry and King also point to proposals to give people ID cards for the internet, using biometrics that tie us to specific devices.

Such suggestions go against the Wild West ethos on which the internet was originally built, but they would solve the problem of hauling someone known only as "Haxx0r420" into the dock. With cybercrime only set to rise, perhaps it's time we brought some lawfulness to the online frontier. ■

FELONS ON FACEBOOK?

Earlier this month, we learned that 50 million people may have had their data swiped from Facebook and used by UK data analysis company Cambridge Analytica. Facebook has suspended the firm from its platform, but has a crime been committed?

Following these reports, UK data watchdog the Information Commissioner's Office applied for a warrant to raid the offices of Cambridge Analytica. Meanwhile in the US, multiple government entities including the Federal Trade Commission are now investigating Facebook.

All are likely to be looking for evidence that federal or state privacy laws were broken, but this may not be straightforward. Existing regulations around data harvesting are notoriously open to interpretation, and many depend on what users knew about how their data was shared.

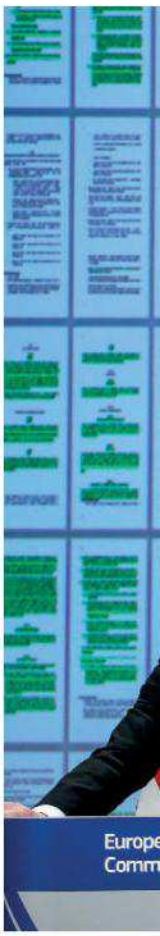
British data protection laws make it illegal to sell personal data to a third party without consent, so a lot will depend on who consented, and what data was sold to whom.

Putting all this information together in a timely fashion will require cooperation between the two countries, which could prove difficult (see main story).

It is unlikely that new laws will be needed in the wake of this breach of trust, but many are clamouring for better clarity, enforcement and ability to send evidence across national boundaries.

Brexit's big to-do list

A year after the process of leaving the European Union began, the UK is about to tackle key outstanding issues. Experts set out the priorities



DARIO PIGNATELLI/BLOOMBERG VIA GETTY IMAGES

Lots to talk about: UK Brexit secretary David Davis with the EU's chief negotiator Michel Barnier

ENVIRONMENT

Fiona Reynolds is chair of think tank Green Alliance and master of Emmanuel College, University of Cambridge

ONE thing will shape the UK's physical environment more than any other after Brexit: what happens to farming. The UK loves its countryside, yet what is there today has been influenced by 40 years of European policy as well as the toil of generations of farmers.

Yes, sheep are still farmed in the hills and grain in the lowlands, but the Common Agricultural Policy (CAP) has changed the countryside – not for the better.

There are glimpses of a post-Brexit future: environment secretary Michael Gove proposed funding farmers who create public benefits such as hedgerows and woods. But questions remain. First, how much money will such ideas get? The CAP dispenses £3.5 billion a year in the UK – £800 million of it on "green" and non-food production farm support. So anything less than £1 billion for environmental improvements would be business as usual. Far more is needed to see a real boost.

Second, what rules will apply to farmers who don't enhance the environment? For example, there is no clue yet how tough the proposed curbs on pesticide or fertiliser use will be. In another 40 years, the UK countryside may look very different. Whether it is better for nature, is more attractive and has greater public access depends on the framework established before Brexit.

IMMIGRATION

Jim Al-Khalili is a professor of theoretical physics and chair in the public engagement in science at the University of Surrey, UK

UNCERTAINTY over immigration has been having a detrimental impact on UK research as well as recruitment to the National Health Service. The lack of clarity on EU nationals' work and residency rights has created uncertainty and fear, deterring some researchers and medical staff from coming to the UK and persuading others to leave. A transition deal may ease this situation for a while, but it is a patch at best.

Ultimately, the UK must quickly rebuild its reputation as a welcoming place that is open for business and able to compete for the mobile international talent it needs. If it doesn't, its position as a world leader in science, medical research and technological innovation is at risk. There could be disastrous economic impacts.

"It is important for the UK to rebuild its reputation as a welcoming nation for the global talent it needs"

The government needs to do two things: in the short term, it must amend visa rules and improve the message it sends migrants to provide confidence during the Brexit transition. Then, in the longer term, it needs to create a streamlined immigration system that facilitates frictionless movement to support research, innovation and healthcare.

FOOD

Rosalind Sharpe is at the Centre for Food Policy at City, University of London

BREXIT will profoundly affect the UK's food supply – albeit more in terms of food governance than food security. Governance refers to the rules and standards that maintain the safety and quality of the food the nation eats. These complex arrangements depend on those people working in environmental health, trading standards, public analysis, veterinary and crop science, plant breeding, pharmaceuticals, food technology and more.

The governance "food web" has long been enmeshed in rules developed by European authorities, with UK input. It must now be disentangled, given extra staff and resources, and redesigned so it can function outside the EU. Positive signs include the creation of 1200 posts at the Department for Environment, Food and Rural Affairs since June 2016 and a pledge to "optimise sustainable food production". But a promised 25-year food plan was shelved, and there has been scant reference to food in Brexit plans.

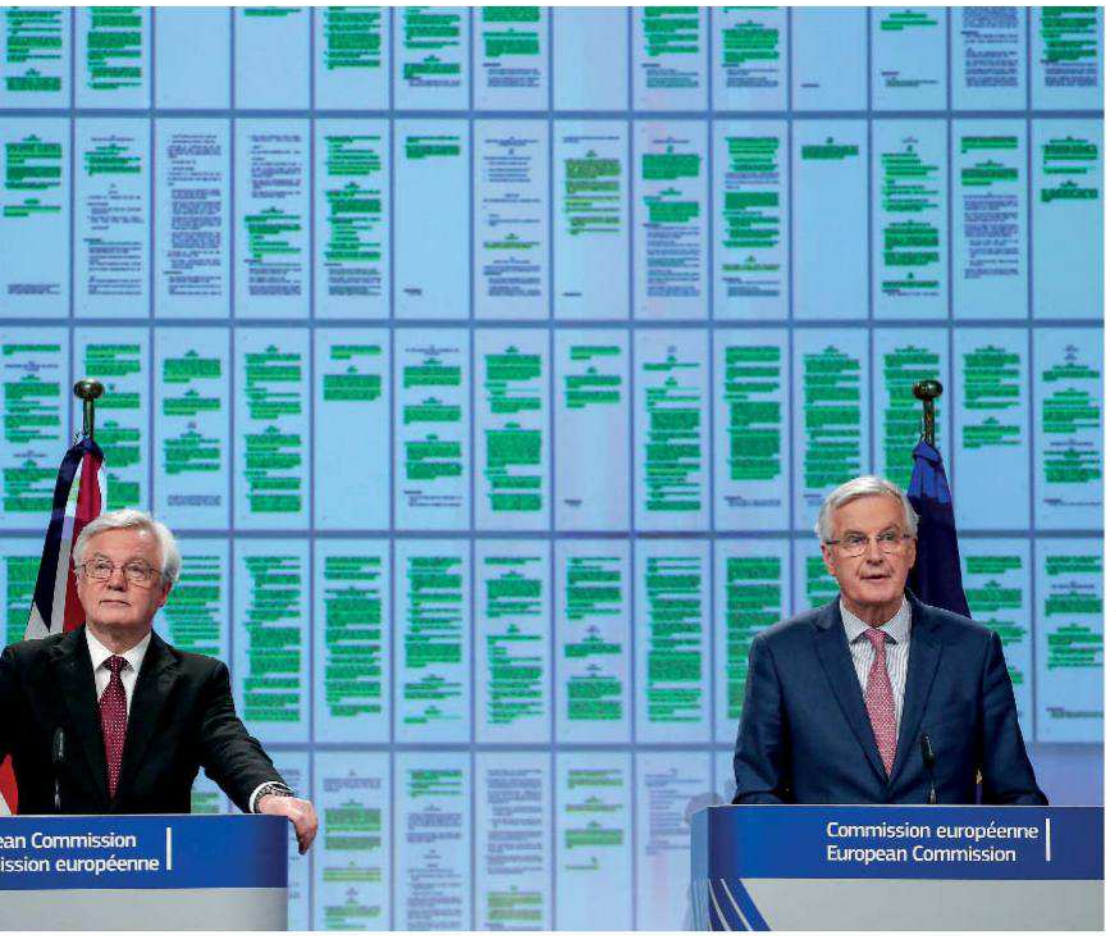
Many fear that trade deals could allow imports from places with lower standards and cheaper labour. If that happens, many UK farmers will face ruin. In food terms, Brexit requires policy-making that is visionary and meticulous, taking in all these factors, the big picture and the long-term view, but also paying attention to practicalities and human-scale impacts.

AVIATION

Paul Marks is a technology, aviation and space-flight writer in London

APTLY, perhaps, for a business that plies the frigid stratosphere, civil aviation may feel the cold breeze of Brexit sooner than most industries. Because the UK has to renegotiate various pan-European aviation agreements, it could be hit on a number of fronts, from confidence in booking flights to compensating passengers for delayed journeys to the right to fly over other nations.

While many tough talks are still needed to sort out these issues, there is one overarching Brexit pledge that the government would be wise to make good on soon: negotiators should focus on ensuring that the UK remains a member of the European Aviation Safety Agency. Based in Germany,



EASA tests and certifies the airworthiness of planes allowed to fly in the EU. As Europe's version of the US Federal Aviation Administration (FAA), it long ago subsumed the expertise behind that certification process from member states.

It would make no sense for the UK to create a competing safety regulator of its own when the best it could do is replicate EASA regulations, says the UK Civil Aviation Authority. Between them, the FAA and EASA have engineered a global aviation industry that is enjoying an unprecedented period of safety: that is a prize nobody should be willing to risk slipping away.

On a related note, European plane-maker Airbus, whose wings are made in the UK, worries how Brexit will affect its supply chains. Reassurances must be a priority.

NUCLEAR OVERSIGHT

Tom Greatrex is the chief executive of the Nuclear Industry Association

OVER four decades, the complex relationships, arrangements and processes tied to the UK's membership of the European Atomic Energy Community (Euratom) have been agreed and honed. Under Euratom's umbrella come the inspection of fissile material, the coordination of fusion research, the facilitation of overseas trade and oversight of the European common nuclear market for staff, services and material.

Almost by accident, and with seemingly little grasp of the scale and scope of the task of recreating this set-up and renegotiating treaties, the government decided to leave Euratom alongside its EU exit.

It is now engaged in the unenviable task of trying to disentangle and replicate 45 years of collaboration.

The government has to show the International Atomic Energy Agency (IAEA) that the UK can take on Euratom's inspections role. It must then negotiate nuclear cooperation agreements with third countries to replace those the UK is party to as a Euratom member, and to agree funding arrangements for future fusion research and a future trading relationship with the EU.

All of this will take time, people and resources. With no deal with the IAEA yet – and that is the basis for much of the rest of what must be put in place – there is a real danger of time running out.

The priority must be for the Brexit transition period to also apply to Euratom.

CLIMATE CHANGE

Eloise Scotford is a professor of environmental law at University College London

MANY areas of environmental law are poised to be left diluted or with governance gaps on Brexit day. Climate change is different. The UK has its own world-leading legislation in the Climate Change Act 2008, which sets an ambitious agenda for action on the issue.

However, there is a Brexit catch. Many of the government's current initiatives for meeting carbon budgets involve implementing EU measures and schemes, most notably through membership of its Emissions Trading System.

"The UK has its own world-leading climate change legislation. However, there is a Brexit catch"

A critical task for the government is to work out how to maintain ambitions allied to EU initiatives so its domestic climate commitments are met. Whether the UK will remain a member of this trading system is a fraught issue that needs resolving, for UK industry participants as well as for the scheme's integrity.

Beyond Brexit, climate campaigners want stronger commitments in light of the Paris Agreement's goals to limit the global average temperature rise to 1.5°C and to achieve a "balance" of greenhouse gas emissions and removals by the second half of the century. The UK was an effective partner within EU institutions to inform this global vision. Brexit means it must re-establish its climate diplomacy with the EU and the rest of the world.

The government culled its Department of Energy and Climate Change, its official carbon-cutting plan is out of date and questions are mounting about how it will fill the void of EU climate policy post-Brexit. There is lots to be done before the UK quits the EU. ■

Look into my eyes

STARE at this picture for too long and you could become hypnotised. This extreme close-up, with only those incredible emerald eyes in focus, has a distinct otherworldly feel.

The animal is a yellow pygmy goby (*Lubricogobius exiguus*). Found throughout the Indo-Pacific, at just 2 centimetres long they live up to their name. "They often live in discarded bottles, which makes them relatively easy to approach, as they rarely stray far from their adopted homes," says photographer Tony Wu.

Wu found this particular fish sitting near the opening of a small hole in the sand at a depth of 21 metres, near the south-western tip of Shikoku Island in Japan. He thinks it may have made its home in a sea urchin skeleton buried in the sand. Its mate was probably hiding inside the hole – these gobies are usually seen in pairs – but there was no way to be sure without disturbing the fish.

Over the course of half an hour, Wu was able to approach to within several centimetres. "The fish retreated several times, but in each instance it returned, seemingly more comfortable with my presence," he says.

To highlight the emerald eyes of the goby against the yellow of its body, Wu used a constant light rather than an underwater flash. That allowed him to find the exact angle at which the contrast between the two colours was strongest.
Michael Le Page

Photographer
Tony Wu
naturepl.com

The inequality delusion

The gap between rich and poor is often said to be a defining issue of our age. That's odd, given that people are not actually bothered by inequality, says cognitive scientist **Mark Sheskin**

YOU are probably aware that there are high levels of inequality in the world and that inequality is getting worse. But it is unlikely that you appreciate just how unequal things are. So here is a way of visualising it. Take the wealth of the eight richest people on the planet and combine it. Now do the same for the poorest 3.5 billion. The two sums are the same, £350 billion. Correct: just eight people own as much wealth as half of the world's population.

That is just one of many eye-watering measures of inequality. Consider that in the US, almost 85 per cent of the wealth is owned by just 20 per cent of the population, and the bottom 40 per cent own just 0.3 per cent of it. In 1960, a chief executive in the US typically earned 20 times as much as an average worker. Today it is more like 354 times.

Most people find these numbers shocking, even obscene, and inequality has become one of the world's most serious issues. Early in his second term, President Obama called it "the defining challenge of our time"; Pope Francis has described it as "the root of social evil". The general public also rank it highly. When the Pew Research Center asked people in 44 countries whether they thought the gap between rich and poor was a "big problem", a majority in all 44 said it was. A majority in 28 said it was a "very big" problem.

The idea that inequality needs to be reduced now almost goes without saying. I agree – but my training as a cognitive scientist warns me we should be careful how we go about it. Some fights for equality, such as against racial prejudice, are morally straightforward. But the battle against economic inequality isn't so simple.

As surprising as it might seem at first, some economic inequality is actually morally good. I recently explored this issue in the journal *Nature Human Behaviour* with two of my colleagues at Yale, Christina Starmans and Paul Bloom. We concluded that a crucial step in fighting inequality is realising that it is not all bad. If we want to beat inequality, we must first distinguish between the bad sort and the good sort.

Egalitarian to a fault

The dislike of economic inequality supposedly runs deep in human psychology. The trait we call "inequality aversion" emerges early in development and is found across many cultures, from city dwellers in the US to villagers in Peru and Uganda.

Laboratory studies confirm that inequality aversion is a strong motivator of behaviour. For example, when people are asked to divide money among themselves and fellow subjects in experiments, they have a clear preference for equal distribution. This desire for equality is so powerful that people often choose to receive smaller but more equal rewards over larger but more unequal ones, and in other cases prefer surplus resources to be thrown away rather than distributed unequally.

There is, however, a paradox. A separate body of research finds something quite different. When people are asked about the ideal distribution of wealth in their country rather than among a small group of individuals in the lab, they are actually quite relaxed about inequality.

In one influential study, for instance, researchers asked a representative sample of 5500 Americans about their ideal distribution of wealth in the US. On average, people said that the richest 20 per cent should hold 30 per cent of the wealth, and the bottom 20 per cent just 10 per cent. When forced to choose between high levels of inequality and complete equality, most chose the former.

The authors concluded that most Americans desire greater equality, but not to the extent of living in a completely equal society (see "Deep divisions", page 30). Similar results have been found in many other countries, and in people from all points on the political spectrum.

This body of research casts serious doubt on inequality aversion. In fact, my colleagues and I argue there is no evidence that people are actually bothered by economic inequality.

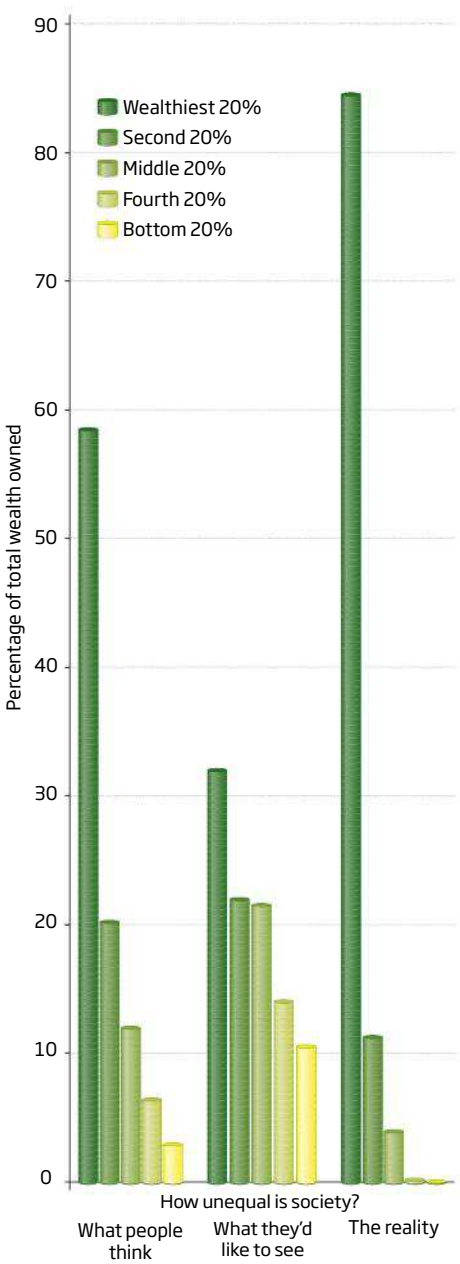
How can these apparently contradictory findings be reconciled? Is one wrong and the other right? No. We think they are both correct. They can be explained by a dislike not of inequality, but of something that is often confounded with it: economic unfairness.

Equality and fairness seem like the same ›

IKER AYESTARAN

Deep divisions

Americans think US society is much more equal than it actually is and would like it to be more so – but they don't want total equality



SOURCE: DOI: 10.1038/s41562-017-0082

thing, but are subtly different. For example, when grading student papers, teachers give better marks to better papers. Likewise, if you and I co-run a bakery at which you work four days a week and I work the other three, you would expect to receive four-sevenths of the profits. A school that gave all students the same mark regardless of merit, or a bakery at which you work more than me but are paid the same, would be equal, but not fair. This is what we call "unfair equality". The opposite of this, fair inequality, strikes most people as the better option. When fairness and equality clash, people prefer fair inequality over unfair equality.

This preference can explain the apparent paradox of why people opt for equal distribution in the lab, but unequal distribution in the real world. Most of the lab experiments don't distinguish between fairness and equality. If you are simply asked to allocate some money to yourself and somebody else with no consideration of merit – say, who worked hardest – then an equal outcome is also the fairest outcome. Giving yourself most of the money and your peer less feels wrong not because it is unequal, but because it is unfair.

Some lab studies do take this into account, and find that our aversion to unfairness is stronger than our aversion to inequality. For example, when asked to divvy up five erasers to two boys as a reward for cleaning their rooms, most people – even young children – want to give them two erasers each and discard the surplus. But when told that one boy worked harder, they happily give him the extra eraser.

This intuitive liking of fairness can explain many apparent puzzles that inequality aversion cannot. For instance, even though current economic conditions in wealthy nations lead to a preference for reducing inequality, in various other societies across the world and across history – the USSR, for example – concerns about fairness have led to anger about too much equality. People are also generally happy with gross inequalities created by national lotteries. If everyone knows that the outcome is random, one person receiving millions and everyone else nothing seems entirely fair and reasonable.

There are many reasons why we might prefer a society with some wealth inequality. One is a hope that we will become one of the wealthier people ourselves. Another is that it promotes industriousness and social mobility.

But a more important motivator is the intuitive judgement that it is inherently right for valuable contributors to be more highly compensated. As an example, I think that a scientist who develops a medicine that saves many lives, or a writer who creates a story enjoyed by millions, should have more wealth than me. They have earned it.

This intuition for fairness is deeply ingrained, and recent evolutionary analyses have elucidated where it comes from. First, take a moment to appreciate just how different human achievements are from those of other species, from arranging our social interactions into democracies to developing technologies to send people and robots into space. You might also think of less noble "achievements" such as wars or factory farming. What features of the human brain allow us to achieve these large-scale outcomes?

Working together

Some common-sense answers include our capacity for language or advanced reasoning, but these are of little use without a commitment to fairness.

To see why fairness is so important, imagine someone marooned on an island, such as Tom Hanks's character in the movie *Cast Away*. However articulate and clever this unfortunate person is, they will struggle to survive. It is only when we look at humans in a group, cooperating, that we stand out from other species. As historian Yuval Noah Harari put it in his bestseller *Sapiens*: "One on one, even 10 on 10, we are embarrassingly similar to chimpanzees. Significant differences begin to appear only when we cross the threshold of 150 individuals, and when we reach 1,000-2,000 individuals, the differences are astounding."

Fairness is what allows humans to work together in large groups. Wouldn't you prefer to team up with someone who puts in at least a fair share of the effort and takes at most a fair share of the reward, rather than somebody who is lazy or greedy? Likewise, others will prefer to interact with you if you have a reputation for fairness. Over our evolutionary history, individuals who cooperated fairly outcompeted those who didn't, and so evolution produced our modern, moral brains, with their focus on fairness.

This trait benefits everyone. Indeed, those who benefit most are sometimes those who receive the least from it. As a concrete example, imagine that we are hunter-gatherers living 20,000 years ago, and that fishing trips are best done by two people. You are a skilled fisher. Each day, you need to

CHRIS STEELE-PERKINS/MAGNUM PHOTOS

Western society is more unequal than it has been for decades

decide whether to go fishing with another skilled fisher with whom you are likely to jointly catch 16 fish, or me, an unskilled fisher with whom you are likely to catch only 10. If everyone demands equal divisions, then you will always choose the other skilled fisher instead of me. But rather than being left to starve, I might argue for the virtues of fairness, and suggest that I will only take two fish. So you can go out with either me or the third person and still end up with eight fish.

Despite our strong evolution-based motivation for fairness, people often act quite unfairly. This shouldn't come as a surprise: we have many competing motivations that trade off with one another. One of them is greed.

Thus, if we want to achieve greater fairness, it is important to know how and why the motivation for it increases or decreases. Many studies have shown that it depends on context. Most notably, the motivation is quite high when people know they are being evaluated by others who can choose whether to interact with them in the future. Likewise, being in an environment in which it is common to interact with strangers – and in which any given one of them is a potential partner – leads to higher levels of fair behaviour.

Even small environmental cues can have large effects: in one study, participants played an economic decision-making game called either "the community game" or "the Wall Street game". Although the actual content was identical for everyone, individuals in groups told they were playing the community game made more cooperative decisions and expected the other players to do the same.

Such research on how people think about fairness has obvious ramifications for contentious social issues such as executive pay, taxation and welfare. Fair inequality appears to be a desirable, even natural, state of affairs. What level of it should we seek?

As a cognitive scientist, my role is not to make such judgements, only to point out facts that might be useful for people who do. But I am also a person who wants to see the world become a better place. In advancing the fight against unfair inequality, I find the ancient military treatise *The Art of War* useful. In it, Sun Tzu advises that: "If you know your enemies and know yourself, you will not be put at risk even in a hundred battles."

> "If inequality is a desirable state of affairs, what level of it should we seek?"

I think this advice is essential: knowing how we all think about fairness and equality, and where these judgements come from, is vital for properly combating unfair inequality, and for recruiting others into the fight. Consider, for example, the fact that people in economically developed nations are often appalled by the wages and working conditions in developing countries, leading to calls for boycotts on certain products. It may be that this is a misapplication of our sense of fairness: considering what is a fair wage in an area requires knowing things such as local costs and the alternative jobs available. It would be unfortunate if misjudgement meant people in developed nations acted to eliminate valued jobs in developing nations.

Such considerations will become even more important over time, as economic progress moves us further from our evolutionary past. The best hunter or gatherer in a group couldn't possibly be a million times more productive than average, but it is entirely possible that people like Elon Musk or Oprah Winfrey contribute more than a million times as much to society as I do. Should we reward them proportionately? Or should there be a maximum that any one person can have? In other words, what are the limits of fair inequality and unfair equality?

Similarly, if in the future our economy can produce abundant wealth with machines rather than people doing most of the work, what will be the fair way to distribute the wealth they create?

The fight against inequality is most certainly a fight worth having. The distribution of wealth in countries such as the US is heavily skewed away from what people consider to be fair, let alone equal. Working out what constitutes fair distribution will require us to answer many difficult moral and practical questions, but this will become easier the more we understand the psychology of how people judge equality and fairness.

There are staggering levels of inequality in the world, and wide agreement that these should be reduced. But we should aspire to fair inequality, not unfair equality. ■

Mark Sheskin is a cognitive scientist at Yale University

Beetlemania

Let's hear it for a multitalented supergroup that has conquered the world, says entomologist **Richard Jones**

WHEN biologist J. B. S. Haldane was asked by a theologian back in the 1940s what we could infer about the mind of the creator from the works of creation, he supposedly replied, "an inordinate fondness for beetles". The story is almost certainly apocryphal, but it reveals both an undeniable truth and an open question. Judging by their sheer numbers, God is certainly fond of beetles. But just how fond?

The number of beetle species is just onelacuna in our knowledge of these extraordinarily successful creatures. Another is what makes them quite so successful. As we slowly fill in the gaps, we are beginning to appreciate the unique insights these insects can give us. Whether we want to understand evolution, the workings of the biosphere or how plate tectonics has shaped the continents, beetles hold the answers.

But let's deal with the numbers question first. New beetle species have been described at an average rate of about four a day since 1758, when Carl Linnaeus started cataloguing plants and animals using the two-part Latin scientific names we know today. Towards the end of the 20th century, there was general agreement that the total count was heading towards 400,000 species, based on specimens housed in the world's museums and carefully documented in 250 years of scientific journals and monographs. Compare that with 5500 mammals, 10,000 birds, 85,000 molluscs and 250,000 plant species, and it is clear that in diversity beetles far outstrip any other multicellular organisms, perhaps quietly brushing aside nematode worms.

In 1982, however, this emerging consensus was shaken to the core. Entomologist Terry Erwin was conducting a census in the Panamanian rainforest, hauling fogging machines up into the canopy and retrieving the insects that fell from the branches in bins and sheets below. From just one evergreen tree species, *Luehea seemannii*, he collected 1200 species of beetle, some unknown to science. Using simple mathematics and modest assumptions about how some beetles were specific to certain trees, he extrapolated the number of beetle species present in all 50,000 known tropical tree species. It came out at around 12 million.

Using slightly different ecological assumptions, others came up with anything ›

Whether earth, sky or twig, there are few domains beetles haven't conquered. Top left: giant jewel beetle, *Euchlora gigantea*. Main picture: ox beetle, *Strategus aloeus*. Below: darkling beetle, *Hegemona lineata*

ALEX WILD TOP: NHM IMAGES

from 3 to 33 million beetle species. This was bonkers. Not only was the deity's love of beetles far more ardent than anyone thought, but our estimates of that ardour were now at odds by more than an order of magnitude. Although arguments still rage, most models seem to agree that there are at least a few million beetle species.

So why are beetles so successful? We have long had ideas, but only recently did they gain some experimental backing.

Beetles began to proliferate in the Carboniferous period between 350 and 300 million years ago. At some point the front pair of wings of their precursor beetloid acquired a leathery texture, while the hind pair remained delicate and membranous. The tough front wings gave protection to the folded back wings when the creature shimmied into a tight crevice under a bit of loose cycad bark or a fallen tree fern. With the insect still able to fly at will, these structures became indispensable armour – the elytra, or wing cases, of modern beetles.

In what has become an instant classic of the entomological literature, in 2016 David Linz of Indiana University Bloomington and his colleagues tested the importance of the elytra

Terry Erwin's rainforest fogging experiments revealed undreamed-of beetle diversity

MARK MOFFETT/MINDEN PICTURES/ALAMY

Global players

A range of unique behaviours allows beetles to thrive in very different environments across the planet

Head-stander beetles
Onymacris unguicularis

In the Namib desert of southern Africa, where annual rainfall can be as little as 2 millimetres a year, drought-resistant head-stander beetles make up a large chunk of the endemic biodiversity. They survive by basking in the mists that wash in from the Atlantic Ocean, condensing meagre droplets of water on hydrophilic bumps on their wing cases, or elytra. Then they tip their head downwards to channel the water along hydrophobic grooves towards their mouth – the only drinks these creatures ever get. Examining the microsculpture of the beetles' elytra may yield useful and practical technologies in a century when access to fresh water is likely to be one of the defining geopolitical struggles.

Hazel leaf-roller
Apoderus coryli

This striking black and red weevil, found throughout Europe and Asia, does exactly what it says on the tin. The female uses her long bulbous head to manipulate a sliver of hazel leaf that is still attached to the tree into a neat, burrito-shaped package for her egg. The hatched larva feeds in secret on the still-living greenery, pupates within and falls to the ground to begin its adult life when the trees lose their leaves in autumn.

FROM LEFT TO RIGHT:
ANN AND STEVE TOON/ALAMY; JAN VAN ARKEL/ NIS/ MINDEN PICTURES/ALAMY; NICK GARBUTT/SUPERSTOCK; NATURE AND SCIENCE/ALAMY; TAKASHI KOMATSU

by exposing beetles to various environmental stresses. Surgically trimming the wing cases from the red flour beetle, *Tribolium castaneum*, they measured damage over time to the membranous hind flight wings, survival against attack by *Pardosa* wolf-spiders, whether the beetles dried out in low humidity, and how the beetles coped in -4°C cold for 24 hours. In all cases, morbidity and mortality were greater in the trimmed beetles than in intact specimens. The elytra really were life-saving armour.

Beetles enjoyed one other lucky break: the advent of flowering plants between 120 and 100 million years ago. Their emergence seems to have led to beetle species increasing 600-fold. Today, the main plant-feeding beetle groups are the Phytophaga – leaf beetles, longhorns and weevils. Their 135,000 species, making up 80 per cent of all catalogued herbivorous beetles and half of all herbivorous insects, mostly feed on flowering plants. They will feast on just about any plant part, too, from tubers, roots, shoots and bark to leaves, buds, flowers, seeds and fruits.

But in certain temperate parts of South America, South Africa, Australia and New Zealand, a few ancestral species – just 225 in total – feed on "primitive" non-flowering plants such as conifers and cycads, which dominated Earth's earlier flora. The nutrient-rich, pollen-bearing male cones (strobili) of conifers are the staple of most of these insects.

Beetles' hardiness and dietary flexibility means they have come to thrive in a quite extraordinary range of environments. A world away from the exuberant beetle throngs in the cloud forests of Central America, for example,

> "Beetles' persistence and ubiquity make them unique witnesses of ecological change"

beetles form the main plank of biodiversity in one of the driest places on Earth, the Namib desert (see "Global players", below). Wherever they occur, their ubiquity and persistence make them unique witnesses to ecological continuity and the mechanisms of environmental change.

Perhaps the best studied beetle fauna – in fact, perhaps the best studied of any fauna anywhere – is found in the British Isles. Both the progenitors of the theory of evolution by natural selection, Charles Darwin and Alfred Russel Wallace, were avid coleopterists, and many have walked in their footsteps since. The UK and Ireland have, in global terms, a small, well-catalogued tally of beetle species, at just over 4000. A crushing ice sheet covered the islands as recently as 13,000 years ago, and rising sea levels then cut them off from continental Europe before many beetles could recolonise.

In the UK, "saproxylic" wood and fungus-eating beetles are being used to identify truly ancient woodlands in a citizen science project. Such woods are usually those reckoned to have had continuous tree cover since at least 1600, although this is hard to confirm as maps are barely accurate until the mid-19th century. The uninterrupted supply of different timbers of all ages being recycled by fungi, and in all stages of rot and decay, offers an intricate complexity of microhabitats and niches for beetles that occur nowhere else.

Dryophthorus corticalis, for example, is a small earth-brown weevil that lives, often with the scarce tree ant *Lasius brunneus*, under crusty fungoid oak bark. The weevil is known only from a narrow band of land between ›

Giraffe weevil
Trachelophorus giraffa

On the island of Madagascar, natural selection has gone berserk to give us these bizarre apparitions. The female uses her long head and thorax for leaf-folding adventures like those of the hazel leaf-roller (see left). The males have even more extreme necks, pictured, which they use for head-bobbing courtship displays and territorial competitions on sun-dappled leaves. This affable headbanging seems unique to the Malagasy branch of the family: similar, much stouter species in continental Africa and shorter-necked but longer-headed relatives in South-East Asia aren't known to indulge in it.

American burying beetle
Nicrophorus americanus

Trapping programmes using rancid meat in the eastern US have confirmed that this brightly coloured beetle is critically endangered. It was once a familiar sight, working in male-female pairs to excavate the earth from under the carcass of a small bird or mammal, and rearing its young on the decaying flesh. Intensive agriculture and human encroachment seem to be to blame for its decline, mainly because they encourage scavengers like raccoons and skunks that eat the carrion before the beetles can use it. The beetle is now gone from 90 per cent of its 1920s range.

[No common name]
Eocorythoderus incredibilis

Discovered in 2012, this incredibly cute "dung" beetle hasn't fed on mammalian dung for countless millions of generations, though it has some scarab beetle as a distant ancestor. Flightless and nearly blind, it lives deep in Cambodian termite nests, where it seems to scavenge in its hosts' fungus gardens. The termites are seemingly happy to transport it about using a carrying handle in the form of a raised node on the beetle's back, as in the picture; quite what they get in exchange for their generous hospitality is unknown.

Richmond, Windsor and Slough to the west of London. Then there is the Moccas beetle, *Hypebaeus flavipes*, found on just a few old trees in Moccas Park national nature reserve in Herefordshire near the Welsh border.

Surveys of nearly 600 scarce and highly restricted species, and the richness and variety of their communities, have now been turned into an interactive online league table of Britain's top 200 ancient woods for saproxylic beetles. Not surprisingly, some of the largest, best known and best documented ancient woodlands score highest, with the royal hunting grounds of Windsor Forest and the New Forest in the south of England jostling for top position. But 76th on the chart is Sydenham Hill Woods deep in suburban south-east London, a suspected remnant of the medieval Great North Wood. Just a few kilometres away, at number 127 on the list, is Downham Woodland Walk, a wooded footpath zigzagging through a 1930s housing estate. It is no doubt the remains of an ancient shaw hedgerow following Elizabethan field boundaries. Easily threatened by development or habitat corruption, the beetles of such fragments are evidence of genuine relic communities, ones that need protection and proper management.

The way individual beetle species tend to inhabit specific ecological niches makes

REDMOND DURRELL/ALAMY

Every gardener's best friend: ladybirds or -bugs are more than just pretty faces

them particularly good indicators of overall ecosystem health around the world. Diversity in a water beetle community indicates good freshwater quality, for example, whereas agricultural run-off and industrial contaminants can leave ditches lifeless or with just a few common pollution-tolerant species.

Beetles can also tell us things that other species cannot. On chalk downs, limestone pavements, sandy heaths or maritime cliffs, the presence of scarce, specialised plants is a welcome sign of a healthy ecosystem. But plants may reappear after years or decades from seeds that have lain dormant. The presence of equally scarce, plant-dependent beetles with their short, mostly annual, life cycles signifies genuine ecological continuity.

Conservation efforts rely on these formal appraisals of what species occurs where, and why. *Drosophila* fruit flies may be the geneticist's choice of lab animal, and butterfly-counting transect walks may be popular and useful, but nothing beats beetles as a yardstick for changes to the planet over time. A classic example is the way Victorian travellers were struck by the similarity in brightly coloured chafer and jewel beetles in West Africa and South America, and their dissimilarity either side of the Wallace line between the South-East Asian islands of Borneo and Sulawesi. Plate tectonics later gave an explanation: when beetles were proliferating, these continental areas were joined in the first case, and widely separated in the second.

Today beetles are the coal-mine canaries for climate change. By comparing cold-adapted ground beetle faunas collected from Ecuadorian mountains in 1880 with those from the 20th and 21st centuries, we have learned that the unique communities of the high-tundra "paramo" habitat have been diminishing, pushed further up the warming slopes. Eventually, many of these species, adapted over millions of years, may run out of mountain. Meanwhile, in the Netherlands, a survey between 1980 and 2004 of two-spot ladybirds showed how blacker, "melanic" forms that were better adapted to colder temperatures inland are being displaced by the red spotty forms that used to be found only on the balmier coasts.

With their awe-inspiring diversity, handsome, chunky forms and often bizarre life histories, beetles are colourful guides to ecological change, helping us understand that the world revolves not around us, but around much smaller, more important creatures. But they sound a warning note, too. A report earlier this month from the International Union for the Conservation of Nature says that nearly a fifth of saproxylic beetles in Europe – those very symbols of ecosystem continuity – are in danger of extinction, following the continued loss and fragmentation of ancient woodland landscapes.

When it comes to the question of the true number of beetle species out there, the sad fact is that we shall almost certainly never know: our less-than-exemplary custodianship of the world's biodiversity means that, if we continue as we have been, most will be extinct before we find or name them. ■

Evolution pioneer Alfred Russel Wallace's beetle collection is in London's Natural History Museum

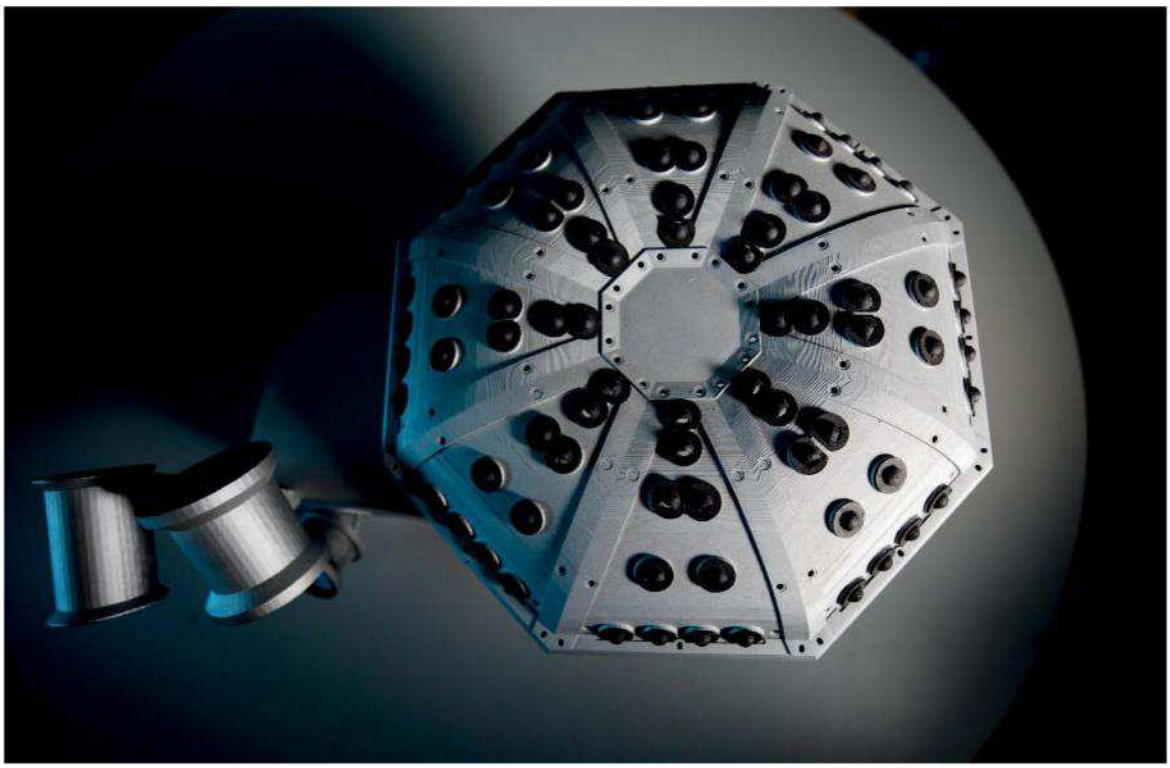
NHM IMAGES

Richard Jones is an entomologist and writer based in London, and author of *Beetles* in the New Naturalist series (William Collins, 2018)

MISSION ICARUS

The Parker Solar Probe is about to take us closer to the sun than ever before. It's an audacious mission that will test technology – and the nerves of the scientists behind it – to the limit

Interviews by ***Richard Webb****. Photos by* ***Michael Soluri***



Our sun is no serene orb. Every now and then its fiery surface turns explosive, sending matter, energy and magnetism whirling into the surrounding vacuum.

In 1859, a particularly violent solar flare-up coincided with a huge electromagnetic storm in Earth's atmosphere. The interference caused polar auroras that could be seen as far south as the Caribbean and as far north as Auckland, New Zealand, and knocked out telegraphic systems.

That was when we first grasped the power of solar storms on Earth. But what caused them remained unknown. In 1956, ***Eugene Parker****, a young postdoc at the University of Chicago, was investigating cosmic rays arriving at Earth from far off in the galaxy when an idea struck him.*

We knew cosmic rays were correlated with the sun's magnetic activity, but the timing of the cosmic rays on our detectors during one particularly violent solar flare showed that the particles were moving very freely from sun to Earth. Around the same time, astronomers were noting that comet tails always pointed away from the sun, and that, too, was very difficult to explain.

One day in 1958, it occurred to me this was all very simple. The sun's atmosphere, the corona, is not tightly bound. Stuff can escape, and the whole thing acts like one big gaseous outward wind. It starts off very slow, but gets faster and faster, and by the time it's out at Earth, it's supersonic. It sweeps cosmic rays to Earth – and blows the comet tails in the opposite direction.

I came in for a lot of flak for the idea, but no one could find anything wrong with the mathematics. Then, in 1962, they launched Mariner 2 to Venus, the first mission into interplanetary space. What it saw could hardly be denied. The transformation was very quick: people were saying we always knew there was a solar wind. You know how it goes. I never criticised.

Previous page: The Parker Solar Probe being tested at the Goddard Space Flight Center in Maryland

Above: A mock-up of the instrument that will observe how electrons, protons and ions behave in the sun's atmosphere

6.2
million km
The closest the Parker Solar Probe will get to the sun, or about 10 solar radii away

1400°C
The temperature the probe will feel on its sun-facing side at its closest approach

Above: A silver blanket covering the probe will protect its instruments from the sun. One of its two solar panels will attach to the pair of mounts at the bottom of the shot

Fears of a repeat of the 1859 storm – one that might wreak havoc with modern power systems, satellites and communications networks – fuelled a growing desire to take a closer look at the solar wind, says Parker Solar Probe project scientist ***Nicola Fox****.*

The birthplace of the solar wind – the sun's atmosphere or corona – must be super-energised. In fact, it must be 300 times hotter than the sun's surface. That defies the laws of nature: you shouldn't have a heat source that gets hotter as you move away from it. There's some additional energy, some black magic going on in this region, and it's causing the solar wind to say, I'm off.

The solar wind doesn't just break away from the sun, it carries the sun's magnetic field with it somehow. Whatever state the field is in, whatever direction, however strong it is, it is frozen into the solar wind. That's what impacts Earth. When the activity's high, that makes solar storms.

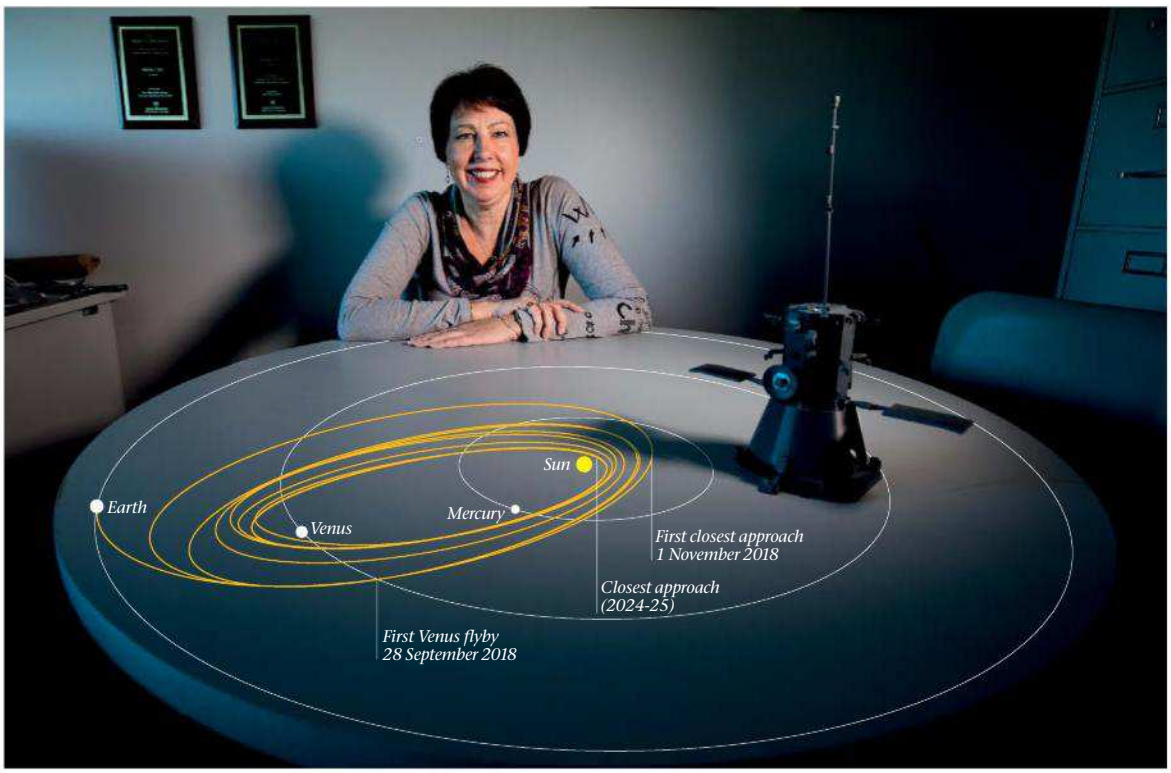
The details of this process remained enigmatic, and various missions were planned to fly into the solar wind to investigate. In 1976, the Helios-B spacecraft made it to within 60 solar radii [or 42 million kilometres] of the sun's surface, inside Mercury's orbit. But there was a fundamental technological barrier to getting any closer: no material existed that was lightweight yet heat-resistant enough to shield the probe's instruments from the sun, says engineer ***Andy Driesman****.*

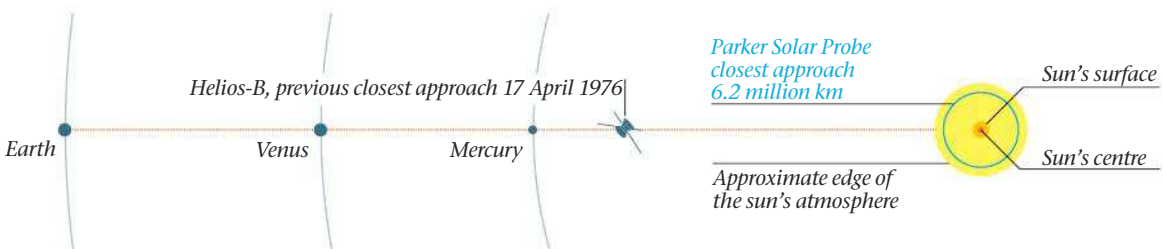
As close to the sun as we wanted to get the probe, there would be almost 3 million watts of heat energy on its front surface, and we had to make sure there would only be 30 watts on the back side. There are some high-temperature metals that could make the protective shield, but they are too heavy to launch.

The magic material is carbon. In the 1980s, you began to see carbon technologies in your golf clubs and tennis rackets. In the early 2000s, we took things one step further, making carbon materials light enough and strong enough to withstand the sun's heat, and coating them so they are not so black and absorb less heat.

Carbon is very brittle and fragile, and a lot of work went into making a heat shield that could survive the launch environment. When we finally thought we had a solution, we went back to NASA and NASA said, OK, go forward, you're now a mission.

The Solar Probe Plus mission, approved in 2009, looked very different from previous proposed sorties to the sun. That was down to ›





a shortage of plutonium radioisotope fuel for nuclear-powered spacecraft, which led NASA to favour purely solar-powered missions – and ironically that becomes a particular problem when you want to visit the sun. Mission scientist ***Yanping Guo*** *had to find a way to solve it.*

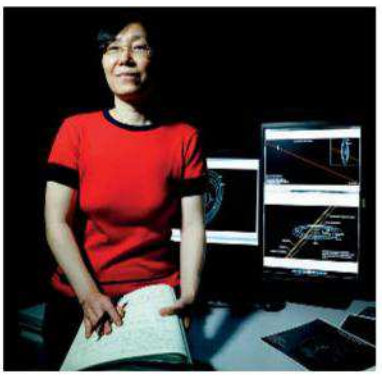
When you launch a spacecraft from Earth, it possesses Earth's orbital velocity, about 30 kilometres a second. To get to the sun, you have to cancel out most of that, slow it down so it can fall in under gravity. That takes a lot of energy. If you want to launch directly from Earth to the sun, you need 55 times more energy than to get to Mars. It's more than twice even what you need to get to Pluto.

For five decades, we had been studying this problem on and off, and had come to the same conclusion: to get to the sun you need a Jupiter gravity assist. Instead of going directly to the sun, you launch out to Jupiter, and use its gravity to reduce the spacecraft's speed so it falls inwards.

But at Jupiter's distance, solar power won't work: you need nuclear. Everyone said the problem was impossible, but I started looking at whether you might use the gravity of the inner planets instead. Venus is much smaller than Jupiter, so its gravity assist is much less. You can

Above: To get within the sun's atmosphere, the probe will have o loop round Venus seven times, using the planet's gravity to slow it down so it can fall into orbit around the sun. The different orbital periods mean the probe has to go round the sun several times between gravity assists, getting closer to its target each time

Photos, clockwise from above: Nicola Fox, project scientist for the probe. Test engineer Annette Dolbow. Yanping Guo, who devised the novel trajectory for the probe. Andy Driesman, engineer



flyby multiple times, each time losing some velocity and falling in closer to the sun, but that means manoeuvring to pass Venus in the right orbit each time, which is tricky and uses up fuel.

Eventually, I found a trajectory with seven Venus assists that passes the sun 26 times, each time closer. The closer the probe falls, the faster it gets. At its fastest, it will be travelling at 200 kilometres a second – the fastest spacecraft ever.

*In May 2017, NASA renamed the probe after **Eugene Parker**. Now 90 years old, he became the first living scientist to be so honoured.*

I was invited to have a look at it. It's quite a monstrosity. When I came out with the theory 60 years ago, I never thought about whether it would be possible to get that close to the sun, because I didn't know what the limits were. But after those years of people being sceptical at the beginning, I feel very good. With instruments right up there in the solar wind, we will be able to measure it directly, and all the speculation will be over.

*The probe is scheduled for launch on 31 July – the tensest time for the mission team, says **Andy Driesman**.*

It's like having a baby. You read the books and you see the kids around you, so you know how it's done and what to expect, but nothing prepares you for that moment. You have built this thing, you have designed it, you have tested the heck out of it and then you launch it. You are in the hands of a fiery beast and you have 60 minutes with no control whatsoever. And then you make first contact after launch and you catch a breath of relief because now you've got control again. You can talk to the thing, you can understand what is going on.

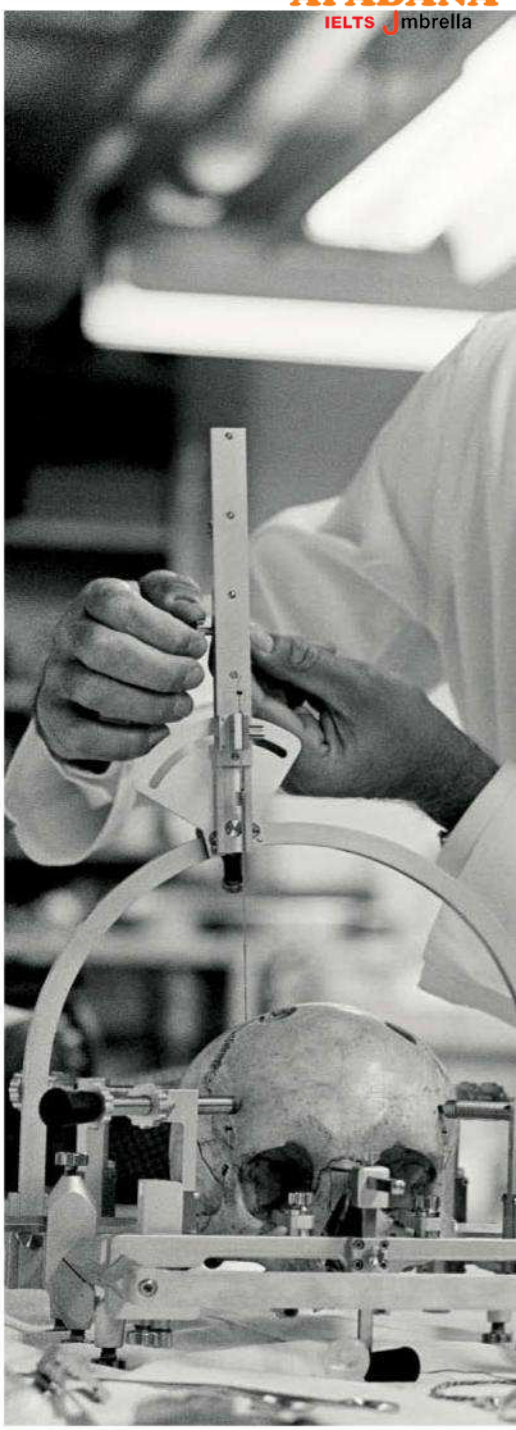
*After it arrives at the sun in November, the probe will fly past it a further 25 times over seven years, getting closer each time. With each pass, its measurements of fluctuating magnetic fields and fast-moving charged particles in the sun's corona will give us further insights into what makes the solar wind. That's when things get interesting, says **Nicola Fox**.*

The most exciting thing will be our first closest approach. Even though it won't be at the ultimate goal of 10 solar radii – it will be out at about 35 solar radii – it is still way closer than anyone has been before. We are going to be in uncharted territory, a "here be dragons" space. Just that is exciting – to be somewhere no one has been before. Even so, the idea of never seeing her again is traumatic. It's a little bit like sending your kids to college – you have brought them up and all you can do now is hope you have brought them up right, and hope they write. ■

Richard Webb is *New Scientist*'s chief features editor. Michael Soluri is a freelance photographer based in New York

Doctor feel good

Psychiatrist Robert Heath wired up his patients' brains to zap their pleasure centres. **Lone Frank** re-evaluates his pioneering, controversial work



IT'S like a scene from a classic horror movie. A man sits with his back to the camera, wires flowing from his scalp to an array of electrical equipment. The only noise is a rumbling, industrial sound. "Listen to this," says another man in a white lab coat, who bears a passing resemblance to movie star Gregory Peck. "It sounds like a plane with its engines misfiring. This is the sound of a sick brain."

It is 1958 and TV network CBS has descended on Tulane University in New Orleans to broadcast about an experimental treatment for mental illness. Robert Heath, the man in the white coat, is the university's chief of neurology and psychiatry, and he is explaining how he treats schizophrenia by implanting electrodes deep in people's brains. He uses these to stimulate regions that display abnormal electrical activity – at the same time, inducing therapeutic pleasure.

This is Heath at the top of his game. He has no idea that 15 years later he will become a scientific pariah accused of conducting exploitative "Nazi experiments"; nor that, today, when deep-brain stimulation (DBS) for treating mental conditions is a hot research area, his contribution will have been swept under the rug. Unfairly, in my view.

After combing through archive documents and footage, and interviewing former colleagues and a patient of Heath's, I realised that this pioneer of DBS deserves to be remembered as both ahead of his time and a flawed product of it.

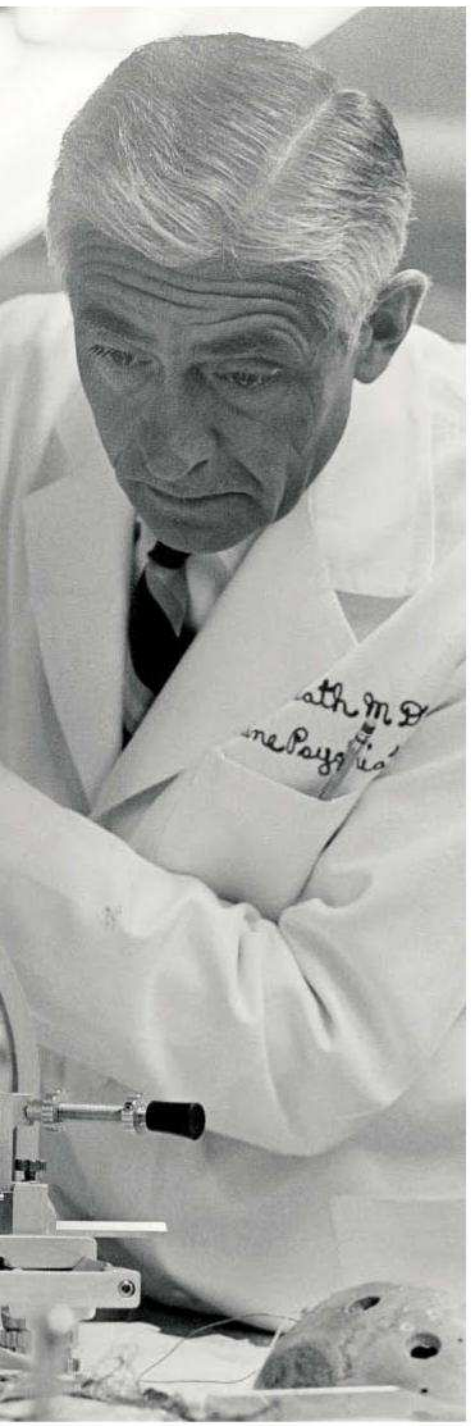
Heath's ascension began in 1949. Tulane University was recruiting visionary scientists in an attempt to become "the Harvard of the South". Psychiatrist Heath, 34 at the time, fit the bill. His passion was schizophrenia – "that most devastating disease in all of medicine" – and he wanted to try a radical approach.

If putting electrodes in people's brains sounds excessively radical, bear in mind that this was before drugs to treat schizophrenia became available. Alternatives included institutionalisation, and infection with malaria as a "fever treatment", which could prove fatal. It was also the heyday of lobotomy. Heath had evaluated people who had been lobotomised as a treatment for schizophrenia, and concluded that this process of destroying connections in the brain's frontal cortex did precious little to help, and often caused debilitating, irreversible side effects.

Schizophrenia's core issue, he thought, was anhedonia – the inability to experience pleasure and positive emotion – which would mean that the structures deep in the brain that give rise to emotions were central to the disease. His idea was to induce pleasure by electrically stimulating these structures, lifting patients from their mental isolation and making them amenable to therapy.

Heath's target was the septum, thought at the time to be part of the brain's pleasure system. He was onto something: the septum encompasses what is now known as the nucleus accumbens, a key node in our reward circuitry.

After experiments in cats, Heath's Tulane team moved to trials in people with schizophrenia who, along with their families, were willing to consider bold alternatives to the standard options. The team put septal



AP/REX/SHUTTERSTOCK

Robert Heath demonstrates electrode placement
Right: One of his patients

electrodes in 20 people. They had 1-hour treatment sessions every week in the lab, some for months, and according to Heath's 1954 monograph *Studies in Schizophrenia*, nearly half saw improved symptoms in the year-long follow-up. But the surgery to place the electrodes proved risky: three patients had seizures. Worse, there were two cases of infection and one patient died as a result.

Heath would ultimately conclude that the stimulation had no permanent benefit in people with schizophrenia. But by then, with a new, safer and more precise technique for electrode placement, he had reliably observed that stimulating the septum produced a pleasurable feeling. So he widened his experiments to include people with other diagnoses, including clinical depression.

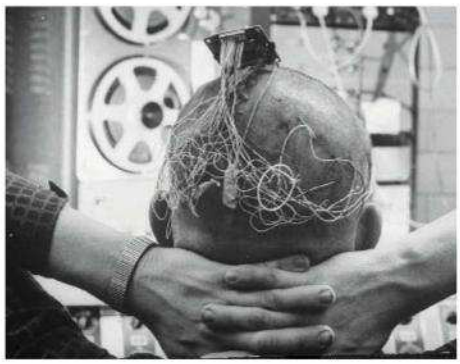
While treating patients, his team began to map the brain circuits thought at the time to underlie their conditions. Heath stimulated the brain structures under scrutiny and the patient related the experience: pleasure, discomfort, anxiety, sudden recollections.

Archive footage of patient A-10 illustrates the collaborative tone of these sessions. Discharged from the army with paranoid schizophrenia, he had problems with uncontrollable rage. Asked by Heath to recall an episode, irregular activity was picked up by electrodes placed in his hippocampus. Then electrode stimulation of the same spot made the calm man immediately fly into a rage, shouting: "I feel fierce! I'll kill you, doctor!" As hard as such a moment is to watch, it stands in contrast to the calm conversation that follows, in which A-10 explains his stimulation experience to Heath, and compares the feelings to previous incidents.

At this time, psychoanalysis was in its prime and many of Heath's contemporaries – often not inclined towards a biological approach to mental illness – baulked at such frontier work. But it was quite a different experiment that sparked Heath's downfall. In his 1972 paper "Septal stimulation for the initiation of heterosexual behavior in a homosexual male", Heath describes an attempt to use pleasure-conditioning to "convert" a homosexual man, dubbed B-19, who complained of "alterations to his ability to experience pleasure" and was reportedly suicidal due to "his lack of masculinity".

> "B-19 stimulated himself to almost overwhelming euphoria and elation"

With electrodes implanted in his septum, this 24-year-old was given a self-stimulator button to press while he watched heterosexual porn movies in the lab. Heath reported that "B-19 stimulated himself to… almost overwhelming euphoria and elation, and had to be disconnected, despite his vigorous protests". After several sessions, B-19 reportedly "expressed desire to attempt heterosexual activity". A lab-based meeting with a female prostitute – approved by a state court – was arranged. The encounter went to plan. B-19 would later report having a long-time girlfriend, but also further sex with men. While this is a fascinating case study, its scientific value is difficult to spot.



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At the time, homosexuality was a psychiatric diagnosis, but the times were rapidly changing. After spotting Heath's publication, a New Orleans magazine wrote of "Nazi experiments" and soon after, Heath was picketed at a psychiatry conference in the city. His funding started to dwindle and his career entered a nosedive.

Heath's rise and fall shows how so much of science is down to personalities, and how timing is everything. Neurologist Helen Mayberg of Emory University in Georgia, who introduced modern DBS treatment for depression in 2005, summed up Heath's career this way: "You're a hero, until you're not."

Today, the oft-repeated creation story of DBS is that it was invented in the 1980s to treat Parkinson's disease and only recently became an experimental possibility for people with treatment-resistant forms of depression, anorexia, Tourette's syndrome and obsessive-compulsive disorder. A favoured target for several conditions is the nucleus accumbens – Heath's septum. Indeed, it is one of two targets used last year in a Spanish pilot study of DBS aiming to alleviate anhedonia in treatment-resistant schizophrenia.

If Heath's work is remembered at all, it is often shorn of the context of his era and he is judged by modern standards. He was controversial, undoubtedly, and in some ways a poor scientist. Nevertheless, I would argue that this sincere pioneer's approach didn't differ that much from those of modern DBS researchers, albeit with more basic technology.

Few contemporary practitioners know of Heath, but his echo is everywhere. ■

Lone Frank is a science journalist in Copenhagen. Her new book is *The Pleasure Shock: The rise of deep brain stimulation and its forgotten inventor* (Dutton)

Real colour of money

The idea that profits and green credentials can be aligned dominates new thinking and writing. But **Fred Pearce** finds angry pushback

ROBERT WALLIS/PANOS

Saving the planet Dubai-style with real snow and a ski run

Will Big Business Destroy our Planet? by Peter Dauvergne, Polity Books

Earth at Risk: Natural capital and the quest for sustainability by Claude Henry and Laurence Tubiana, Columbia University Press

GREENWASH is everywhere. In 2018, almost anything, it seems, can be painted "sustainable".

Take snow-covered ski slopes in the deserts of the Persian Gulf. You might think they were a hard sell as a contribution to the greening of the planet. Just ask Ibrahim Al-Zu'bi, head of sustainability at Dubai-based shopping mall and leisure company Majid Al Futtaim, who delivered the keynote address at a conference on green development goals in Spain last month. He had to argue that the masterminds behind a ski run and 22,500 square-metre area of real snow, built in a country with one of the largest per-capita carbon footprints in the world, were helping to save the planet.

To be fair, Al-Zu'bi assured students at the conference, organised by IESE Business School in Barcelona, that the company intends to make its activities "net positive for carbon and water" by 2040. Even so, those slopes might not be such a good example of the conference's theme: that the juggernauts of 21st-century global business are part of the environmental solution.

For sure, corporations need to be encouraged to go green – and the less green they are the greater the need to encourage them. But this looks like a case of the tail wagging the dog. It certainly is at one with Peter Dauvergne's caustic and highly readable critique of ethical corporate behaviour in *Will Big Business Destroy our Planet?*

A professor of international relations at the University of British Columbia, Canada, Dauvergne concedes there is a case to be made for ethical business, in that it is less bad than unethical business. Yes, some of these titans of commerce are improving the efficiency with which they use and recycle resources; yes, they sometimes take the lead on renewable energy where politicians refuse to tread; and, yes, sometimes they even show some awareness of the social fallout of their activities.

"We have no choice, reasons Dauvergne, but to challenge the paradigm of unending growth"

But that still doesn't make them part of the solution. Too often they are "wasting less to produce more", he writes, finding efficiency savings "to invest in more factories and stores, and to sell more product". We have no choice, he reasons, but to challenge the paradigm of unending growth.

Even genuinely green-minded consumer giants like Unilever are slave to it. Although the company promises that this decade it will have helped a billion people improve their health and well-being, while halving the environmental impact of its products, it also promises to double turnover while doing so.

Dauvergne's book is especially strong on how corporations are taking over debates on the environment and sustainability, writing the rules and bending the targets to suit their commercial aims. Their grand plan, he says, is to create "a regulatory setting amenable to maximising production, profits and sales".

Thus targets for delivering clean drinking water are turned into targets for laying pipes and sinking wells. A global demand to end deforestation morphs into a target for ending "net deforestation" – code for "you can keep chopping as long as you plant, too". No need to guess who will do both the chopping and the planting, profiting all the way.

Likewise, corporate pressure has helped ensure that big carbon dioxide emitters such as the aviation industry can keep polluting, so long as they offset those emissions by planting trees to soak up CO_2.

Viewed this way, green certification systems such as the forest and marine stewardship councils turn into something altogether different. They become a method of grabbing competitive advantage, not least by squeezing out small suppliers who simply can't afford to pay consultants' fees to demonstrate their green credentials.

Many environmental groups have been persuaded to buy into a vision of big business policing itself through such bodies. They now seek out partnerships with corporations, rather than challenging their wealth, power and greenwash. The World Wildlife Fund and Unilever were behind both the forest and marine stewardship councils.

UN agencies are also taking the corporate shilling. The Barcelona

conference heard from Marcos Neto, director of the UN's Istanbul International Center for Private Sector in Development: "There is a lot of money to be made by the Sustainable Development Goals [SDGs]," he told his student audience. "This is about making profits. Profits are good. It's not about charity."

It sounded callous, but he was right in the sense that, "we need the private sector. It is the engine of the world. If we don't have business, we don't have SDGs. Get used to it." If you want to change the world, he advised students, "don't come and work for the UN. Go to [investment managers] BlackRock".

The meeting was studded with corporations telling stories of how well profit-making could be aligned with their preferred environmental targets. The world's largest brewer AB InBev (think Stella, Corona and the American version of Budweiser) boasted of having halved the water needed to brew a litre of beer, while glossing over the far bigger water footprint in the fields of barley feeding the fermentation tanks.

Power and money

Pepsi proudly outlined how 27 per cent of its turnover is now in "nutritious" food and beverages that are helping meet the SDGs. "In sub-Saharan Africa, we provide nutritious food to undernourished people," said a spokesperson. That left the rather uncomfortable impression that 73 per cent of its products, sold in Africa and elsewhere, are not nutritious.

The great thing about Dauvergne's 120-page polemic is that it recognises where the power and money are in the world today. The turnover of corporate giants now dwarfs that of many national governments, he notes. "Of the world's top 100 revenue generators in 2015, 69 were companies and 31 were states."

It is a breath of fresh air compared with the earnest and well-informed but ultimately ill-conceived *Earth at Risk*, by Claude Henry and Laurence Tubiana. From their vantage point in the world of sustainability think tanks, they show how the abstruse idea of sustainable development rose up the political agenda, culminating in the Paris climate change agreement and the UN SDGs, both signed off in 2015.

It is a story worth telling. But the elephant in the room – big business and the consumption it feeds – is barely mentioned. A section on "unlocking private finance" to find "the new financial ecosystem needed to deploy the SDGs and sound climate policies" gets less than two pages.

Dauvergne picks up where Henry and Tubiana leave off. Ultimately, he does not say who is to blame, whether it is big business or us, the consumers. But he skewers the idea that big business is an innocent player simply doing consumers' bidding. And his conclusion is surely right that "unless states and civil societies do far more to rein in the rising power of big business over world politics and consumer cultures," then our planet will soon become a much less green, fertile and hospitable place.

"Of the world's top 100 revenue generators in 2015, 69 were companies and 31 were states"

Ethical big business is pitching to have it all ways. The guys with all the money want to buy that most elusive thing, a sense of virtue. As Al-Zu'bi put it, without a hint of irony, the greatest thing he could do for his bosses in Dubai was to "make them feel good".

Maybe that is how we save the world in the 21st century. But when the money in the global economy slushes around in milliseconds according to algorithms of profitability, and when the vast "remuneration packages" of corporate CEOs are dependent on quarterly returns, it is hard to see where big business gets the traction for genuine change.

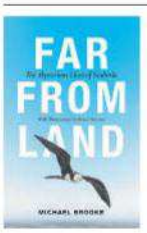
Anyone for skiing? ■

Fred Pearce is a consultant for *New Scientist*. He attended the Doing Good and Doing Well conference at the invitation of the IESE Business School

Secret lives at sea

Knowing more about seabirds could save species, finds **Adrian Barnett**

Far from Land: The mysterious lives of seabirds by Michael Brooke, Princeton University Press



ALONG with the featherballs that visit back gardens and parks, seabirds include some of the world's most familiar avian species. Gulls, terns and cormorants, puffins, pelicans and penguins, gannets, fulmars and auks are all part of this 350 species-strong group, made up of mostly ancient families.

Some, such as the penguin family, do virtually nothing but go to sea, while others, like certain ducks, seem to toy with the idea, with a handful of species, such as king eider and velvet scoter, actually getting their webbed feet salty wet.

Seabirds come in a range of sizes, from the royal albatross, soaring above the ocean on 3.5-metre wings, to the sparrow-sized storm petrel that dances across wave tops. They are also ecologically diverse: terns and puffins catch shallow-water sand eels, while prion petrels skim surface plankton, and guillemots dive deep for fish and squid.

Yet for the longest time, almost all we knew about them came from ringing and from observations at breeding colonies. This yielded information on everything from diet, breeding cycles and longevity, to the considerable distances travelled by some species, even in those frantic months when there were clamouring beaks to be filled.

All of this research was worthwhile, but, as Michael Brooke explains in his new book, *Far from Land*, it omitted crucial and extensive detail of the biology of many species: what they actually did in the open sea, and where and when they did it, especially when not breeding on wave-thrashed rocks.

The problem, Brooke points out, is that cliff-based observations can tell you pretty much all you need to know about seabirds that do all their living close to shore, such as gannets, gulls and terns. But many others simply disappear into the sea mist once they have reproduced, which both frustrates biologists and worries conservationists. The annual vanishing act led to some really odd knowledge gaps. For example, no one knew where puffins went in the winter (the open waters of the north Atlantic), and important details about the diet and feeding patterns of the albatross were uncertain. One solution emerged only recently with the microelectronics that enable us to track seabirds with satellites and reveal their secrets.

"Albatrosses have an energy-saving mechanism that locks their wings in place while they soar"

Brooke is the ideal narrator for the tale of this transition. He is a zoologist at the University of Cambridge, with a 40-year research career that began on the UK's Fair Isle (part of Shetland) and has taken him to some of the ocean's most remote and craggy islands.

He shares his encyclopedic knowledge with dry wit and fine attention to detail in this absorbing book. I was fascinated to learn that albatrosses have an energy-saving mechanism that locks their wings in place while they soar, and that while puffins look cute, they are hell to handle because of their big, strong beak and sharp claws.

There is, clearly, much still to learn. One new species, the Pincoya storm petrel, was described as recently as 2011, and the nesting site of Hornby's storm petrel was discovered only in April 2017 – some 70 kilometres into Chile's Atacama desert.

Brooke is a man who adores his subject (seabird biologists are, apparently, "people who love nothing more than the smell of guano"). His enthusiasm is so infectious that *Far from Land* is bound to hatch some much-needed new devotees. Seabirds, it turns out, need all the help they can get: designed for long lives, low mortality and slow reproduction, many have been decimated by long-line fishing and marine pollution. If we are not more vigilant, the satellite-tracking revolution Brooke reveals may, for many species, merely provide a tragically accurate record of their demise. ■

Cute but hell to handle: puffins have strong beaks and sharp claws

MICHAEL KRABS/IMAGEBROKER/FLPA

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

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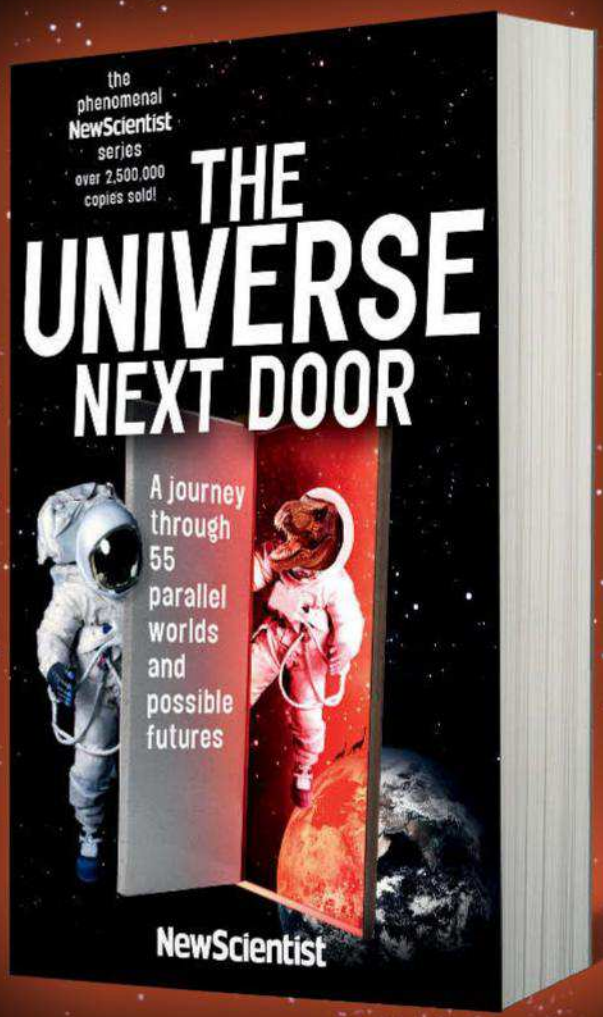

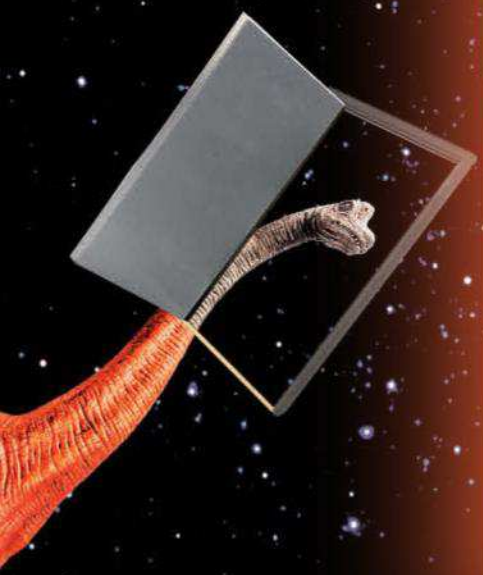

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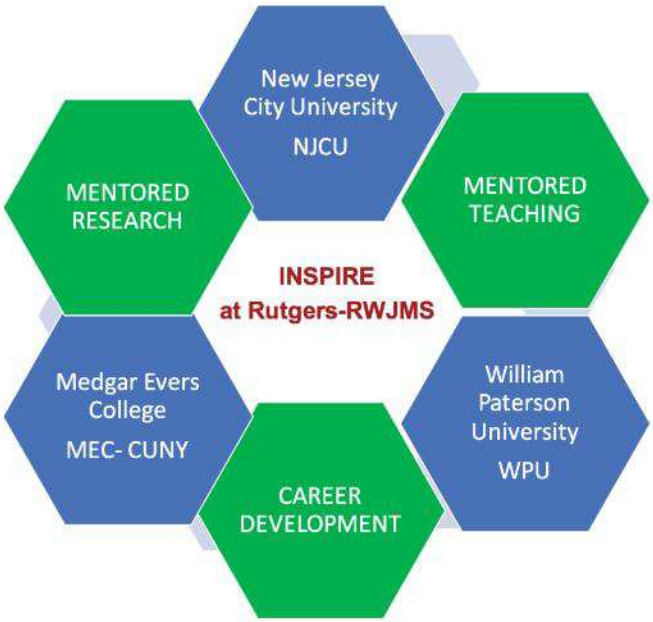

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EDITOR'S PICK

Survival of the tamest

From Guy Dauncey, Ladysmith, British Columbia, Canada

Colin Barras compares the loss of wild traits in our species to that seen in domesticated animals (24 February, p 28) and discusses what led to domestication of humans.

A hypothesis that fits with some of the ideas suggested is that of primatologist Christopher Boehm in his book *Hierarchy in the Forest: The evolution of egalitarian behavior*, in which he explores the process by which our ancestors rejected despotic alpha-male behaviour characteristic of chimps and gorillas.

By successfully overthrowing the alpha males, and establishing a highly egalitarian ethos that has been observed in hunter-gatherer groups around the world, with strong sanctions against those who try to dominate, they would have deprived the alpha males of their breeding monopoly, and given everyone a chance to breed.

In this way, the more aggressive genes of the alpha males were displaced by tamer genes, and, as a result, we engineered our own domestication.

Trying to find some beauty in the uglyverse

From Ken Goddard, Musbury, Devon, UK

Your discussion of inelegance in fundamental physics (3 March, p 30) once again deals with those in retreat from the idea that the laws of nature should be sublime rather than arbitrary – known as "naturalness" – as they dance warily around alternatives. They seem unwilling to grant the anthropic principle and the multiverse hypothesis credibility.

But what's the problem? What if all but one of the uncountable incipient universes generated at the big bang collapsed within the first millisecond of expansion because for each, their random mix of fundamental constants rendered them not fit for purpose?

What if the only one that continued to develop was the one whose mix was "just right" and that is the one we have evolved to live in and apparently to almost comprehend? The reason we don't quite yet – and why our current models generate values for some fundamental constants that don't seem right – is because we don't understand what process made that successful mix "just right".

But I'm fairly sure we will eventually. Even if we don't, the point is that there is nothing wrong with the concept of the anthropic principle when in harness with the concept of uncountable multiverses collapsing almost instantly, except for one – this one.

From Andy Bebington, Croydon, UK

I was struck by one suggestion in your look at resistance to "ugly" cosmological physics: that the surprisingly small mass of the

"Finally! I can look like Ashton Kutcher!"

@meisteringeniur celebrates the news that faking faces using artificial intelligence is going to change our world (17 March, p24)

Higgs boson is the net result of a large positive number (its "interaction" mass) and a slightly smaller negative number (its "inherent" mass).

This seems parallel to another cosmological oddity – the large amount of normal matter and the slightly smaller amount of antimatter thought to have been created in the big bang. With mutual annihilation converting most of the former and all of the latter into energy, we are left with the matter you and I (and the rest of the universe) are made of. Of course, "parallel to" doesn't imply cause and effect… or does it?

From Philip Stewart, Oxford, UK

If only chemistry coveted beauty as much as fundamental physics. In 1952, starting chemistry at school, I was repelled by the lop-sided conventional periodic table, which helped to turn me away from science. The fact this version persists when more elegant ones are available suggests that chemists do not want beauty.

Interruptions – more tips for the resistance

From Bryn Glover, Kirkby Malzeard, North Yorkshire, UK

May I report a highly effective way to counter interruptions while talking, to add to those offered in your article (10 March, p 34).

In the 1980s, I sat on the council of the Association of Scientific, Technical and Managerial Staffs trade union. Meetings were always attended by the extrovert and voluble general secretary Clive Jenkins. He would frequently interrupt speakers during what were otherwise disciplined and strictly non-interrupted meetings in order, as he put it, "to be helpful and progress business".

One member, who seemed to be interrupted more than others, developed the technique of instantly stopping speaking and waiting in silence until Clive, with his usual sweet smile of acknowledgement, had finished.

She would then immediately continue speaking at precisely the same point in the sentence she had been delivering as when interrupted. There was never any loss of sense, grammar or syntax. It was as if the interruption had never occurred. This was so effective that it eventually cured Jenkins of his habit.

It is a very difficult trick to carry off, but it can be devastating.

From Philip Welsby, Edinburgh, UK

When I taught medical students I passed on several tips when it comes to interruption. I told them it is grossly impolite to do so mid-sentence. If you must interrupt, do so while the speaker is taking a breath at the end of a sentence. That is why politicians are trained to take breaths mid-sentence – Margaret Thatcher used this a lot and was hardly ever interrupted.

From Alan Coady, Edinburgh, UK

What particularly infuriates me – and was missing from your examples of interruptions – is people butting in to counter a point I haven't even made.

Wash your way to the Anthropocene

From Bruce Boyd North Gower, Ontario, Canada

Having read your article on the pollution linked to making and washing clothing (24 February, p 36), I feel good knowing that ›

the microfibres from my laundry are being flushed through my septic tank and out into a weeping bed. There they are added to the sediment 60 centimetres below the surface. With time – 10 million years should do it – those fibres will be part of the sedimentary rock and their ions may even migrate to form new, hopefully inert, minerals.

Even with less muscle we are endurance champs

From Malcolm Knight, Rheda Park, Cumbria, UK
Colin Barras reports a study suggesting primates, which includes us, sacrificed slow-twitch muscle to provide energy for bigger brains (10 March, p 10).

However, this clashes with the idea that early humans were nomadic hunter-gatherers, a way of life for which slow-twitch muscle is essential. With the advent of farming, humans would again rely on slow-twitch muscle when spending all day in the fields tending livestock or ploughing, sowing and so on.

As a personal trainer, I know that humans have an outstanding capacity for endurance. What we lack is the strength and explosive power that results from fast-twitch muscle.

Turks had the scoop on dice that were fair

From David Arthur, Hook, Hampshire, UK
Following on from your article on fairer dice emerging in northern Europe about 600 years ago (27 January, p 14), I have a pair of antique dice from Turkey, of the variety with opposite sides that always add up to seven. I find that the number 1 face has a scoop with a diameter of 3.6 millimetres whereas the number 6 has six scoops with a diameter of 2 millimetres each.

I find that the sum of the volumes of the scoops on any face is equal on all sides of the dice. A modern dice has equal-sized scoops and therefore the side with six scoops will be lighter than the opposite face with one scoop. In this case, has anyone found that the six is more likely to be facing up?

Medical care means more survive modern wars

From Peter Jacobsen, Davis, California, US
One factor may be missed when comparing war severity between 1823 and 2003 using fatalities, as in the study questioning if we are in a new era of peace (3 March, p 15). Recent wars have had fewer fatalities, but perhaps not because they were less severe. Weapons are increasingly potent but trauma care has improved a lot, and hence the lethality of war has decreased over time. A similar bias can be seen with the murder rate.

Saving our secrets will be a monumental task

From Daniel Dresner, Manchester, UK
What an exemplary article on cryptography Michael Brooks presented to us (3 March, p 40). As we seek algorithms to ensure security against code-cracking quantum computers, surely we ought to be considering how such security will be rolled out across the myriad of devices that will no-doubt be in use for years to come and made vulnerable by quantum code cracking?

We are already challenged by people putting themselves, data and systems at risk, for example by not installing upgrades from software developers in time to counteract a careless click. So, how we take on the wide-scale upgrade to root and branch security in a quantum computing era is a problem that will need technologists, psychologists, management scientists et al. to solve.

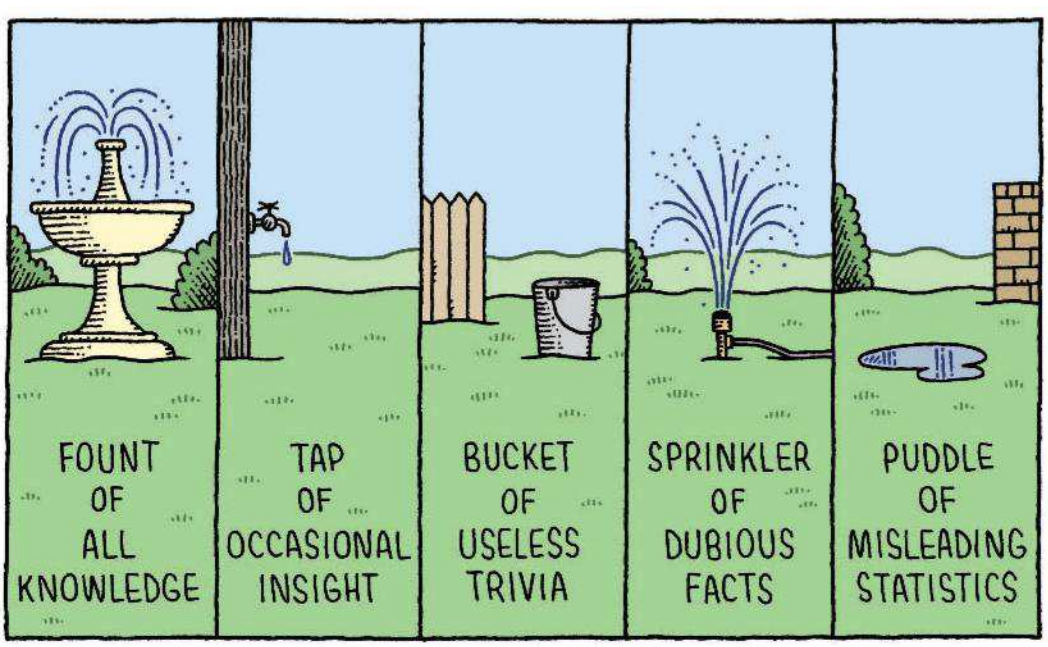
Game theory could also fight superbugs

From David Feldman, London, UK
An algorithm that guides the sparing use of treatments to prevent the evolution of drug resistance in prostate cancer is interesting (10 March, p 4). It struck me that it might be possible to use the same strategy to prevent the evolution of microbes that survive the use of antibiotics.

How did we ever manage to live together?

From Lothar Voigt, Rose Bay, New South Wales, Australia
I had a good laugh when reading that a common trait in those who support authoritarian leaders is a hatred of bad body odours (10 March, p 17). Seriously though, getting sniffy about out-groups must have been a problem older than our species. One wonders how we ever managed to conglomerate into large societies at all.

TOM GAULD



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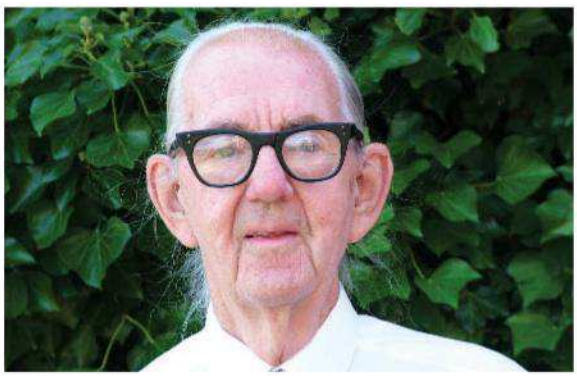
OLD SCIENTIST

Bob Walker



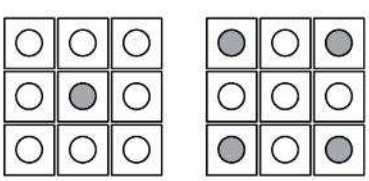
LONG-STANDING readers will recall the Enigma puzzles, which were published in *New Scientist* each week until the end of 2013. The 1780th and last was entitled "Pure hedronism", and was written by compiler Bob Walker. Sadly, Bob died in February, aged 91.

For him, puzzles and problems were a lifelong passion. Inspired by everyday objects, games and a sound understanding of logic and mathematics, he was one of Enigma's most prolific compilers.

Bob studied mechanical, electrical and electronics engineering, as well as mathematics and physics. He became an electronic engineer in the British Fleet Air Arm, which led to many other interests such as computer programming, stereographs and Mandelbrot fractals.

As a tribute to Bob, here is one of his puzzles, chosen by his family. It first appeared in *New Scientist* in our 9 October 2010 issue.

One good turn



Joe's 3-by-3 grid can be made to represent any of the six faces of a die by placing nine counters, coloured on one side and white on the other. Joe placed the nine counters with just the one in the centre coloured side up. Penny's task this week is to increase the number represented to 4 by turning over counters. But, of course, there is a catch. Every time Penny decides which counter to turn over, she has to remember to turn over all counters in squares that are immediately adjacent, horizontally and vertically. Not only that, she has to record how many counters she turns over each time, and the total has to be the minimum possible. What is that minimum?

Answer: Penny turned over a counter 33 times.

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

PAUL MCDEVITT

NOMINATIVE determinism has been posited exhaustively on these pages, to the point that on more than one occasion we have declared the subject forbidden, off-limits, no more.

Yet Feedback is powerless to ignore the news that one in eight employees at the UK's Royal Horticultural Society (RHS) have a name associated with green fingers.

An announcement preceding this year's National Gardening Week, 30 April to 6 May, reveals that the organisation's 900 staff include "four Heathers, three Berrys and another three called Moss". Visitors to RHS gardens may be served by a Gardiner, Marsh or Shears, a Garlick, Greenfield, Moore, Shaw or Goodacre among others.

Whether nature-themed monikers are significantly more common at the RHS than among the general UK population is still an open question. Yet Feedback feels that one groundskeeper working at Garden Hyde Hall in Essex deserves a special mention: step forward, Heather Cutmore.

PREVIOUSLY, Feedback heard from Richard Machin on the topic of "*puros*" in Colombia: the distance covered on horseback in the time it takes to smoke one *puro*, a cigar (10 March). "When I was climbing in the Andes in Peru in 1962, the distance up the access valley, 17 kilometres, was said to be seven '*cocadas*'," says Charles Sawyer.

"A *cocada* was a wad of coca leaves and lime placed between the back teeth and chewed, causing all fatigue and exhaustion to vanish. When this no longer happened, it was time for a new *cocada*."

As the trail climbed some 1250 metres into the mountains, progress in the upward direction was "not quite one *cocada* per hour". But he says, since the *cocada* was based on human effort rather than absolute distance, the downhill return was half the *cocadas* of the uphill trek.

Village markets along the way kept barrels of coca leaves for weary travellers, although Charles doesn't mention if he stopped in for this particular local delicacy.

MEANWHILE, Gloucester resident Keith Waldon is reminded of an encounter with a Canadian while on holiday in Mexico. The man described himself as being from just outside Toronto, "about five beers away". This, Keith learned, equated to a distance of a few hundred kilometres. "When he asked where I was from, I replied 'just outside Paris'".

FINALLY, Noel Cramer reports that in the early 1930s, his father was chief engineer for the construction of the transit road linking the Turkish Black Sea town of Trebizond to the Eastern Anatolian town of Erzurum.

"While reconnoitring the land, my father had sometimes to ask local people for the way and distance to given villages," says Noel. The answer was always a gesture in the direction with an outstretched arm, accompanied by *Taeeeee*..., "the length of which gave the distance."

Somehow, Noel's father was able to make use of this information, although Noel says "I no longer recollect how the relation between that utterance and distance was calibrated."

MORE theories out of the mouths of babes: Tony Green writes "As a young child, I noticed that my parents were taller than I was. I also noticed that my gran was shorter than my parents. I came to the obvious conclusion: people start out small, grow, then later in life they start shrinking again. It all made perfect sense!" Perhaps then a daily spell on the rack could increase one's, er, lifespan?

ALSO pondering the big questions was a young Paul Hargreaves, who writes: "One night when I was a young boy, I was riding in the family car down a rural road. Leaning out of the open window and watching the canopy of stars overhead, I exclaimed to my parents 'So that's how it works'."

Apparently used to these gnostic outbursts, his family readied themselves to receive young Paul's latest wisdom. "When it rains," he told them, "the water must fall through all those little holes in the sky."

BOOKING a place at the upcoming Royal College of Psychiatrists Congress, Adrian Leathart notes a banner on their website proclaiming "50% of 0 users rate our live chat as 'fantastic'". Adrian says "I'm not sure if they are exaggerating or being too modest."

BRYN GLOVER writes: "I have just returned from my local Morrisons supermarket, where they now sell edible gold leaf. This gold is described as 23 carat, and the packet has helpful instructions on how to lay it on one's food."

So far, so nouvelle cuisine.

Yet one detail has Bryn scratching his head – the packet also carries a best-before date, recommending he use up his gold leaf before November 2019.

"I think it is absolutely fantastic how they have managed to catch this batch of gold, manufactured perhaps 10 billion years ago in an early universe supernova, just a few months before its usability expires," says Bryn. "How do they manage that?"

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 antimicrobial lining in Ian Moseley's new shoes promises to keep them "clean and tidy". Sadly he reports that the shoes "remain wherever I have kicked them off"

Ol' blue eyes

I'm told that blue-eyed people find coping with dazzling sun more difficult than brown-eyed people do. Why? Or if it's untrue, what difference, if any, does eye colour make?

■ The colour of our eyes is determined by the amount of melanin in the iris – the coloured structure visible through the transparent front of the eye.

"The bluer the eyes, the more light is likely to bypass the pupil and enter the eye through the iris"

The function of the melanin is to make the iris opaque and prevent light entering it anywhere except through the pupil. The back surface of the iris contains the most melanin, although this pigment is also found just below its anterior surface and throughout the fibres at its front, called the stroma.

It is the amount of melanin in the stroma and anterior surface that determines eye colour.

Brown eyes contain a lot of melanin and so absorb most light, especially long wavelength (red) light. Blue eyes contain less, so they absorb less and scatter some of the light, especially shorter (blue) wavelengths. It is light scattered back to an observer that mainly determines an object's colour.

The bluer the eyes, the more light is likely to bypass the pupil and enter the eye through the iris. This may cause light scatter within the eye, which would lead to glare and reduced image contrast. So it is likely that those with blue eyes will be troubled more by bright sunlight than those with brown eyes. Certainly, I have blue eyes and I find it very difficult to see much in bright sunshine. I always have to wear sunglasses. My wife, however, with her lovely hazel brown eyes, rarely has to bother with such eye protection.

She may have other reasons to feel smug: some studies suggest those with blue eyes may be more prone to diseases such as age-related macular degeneration.

Interestingly, the colour of your eyes also affects the drugs used to dilate pupils. Such antimuscarinics bind to melanin, so clinicians may use a 1 per cent concentration of tropicamide or cyclopentolate to dilate the pupil of people with brown eyes, whereas 0.5 per cent may be enough for someone with blue eyes. A colleague informs me that when they punch holes in the iris with a laser to relieve glaucoma, the colour of the iris may have an effect on the success of the treatment.

Ron Douglas
Professor of Visual Science
City, University of London, UK

■ My biology master taught me that my grey irises allowed more light through than the brown variety, which meant that I would find the sun's light more dazzling. Indeed, I have to wear dark brown tinted spectacles for driving in sunlight most of the year. They give life to the phrase "rose tinted spectacles" because they allow more red light through. Flowers and trees are magnificent, and the cloudscapes fantastic.

Steve Swift
Alton, Hampshire, UK

Turning over a new leaf

I'm puzzled by beech trees. They are deciduous and their leaves turn bronze in the autumn, but they don't fall off the tree. Instead, they hang on until spring when other plants are putting out their new leaves. How do these trees benefit from this different approach to deciduousness?

■ This approach does benefit a beech's ecosystem. Leaf litter is a resource to the forest and any leaves shed by beech trees in spring will extend the litter period until autumn when the other species, usually maples, drop their leaves. One noticeable beneficiary is beechdrops, a flowering plant devoid of chlorophyll that is a symbiont of beech. It blooms in late summer.

In winter, the retained beech leaves are noticeable and act as flags to alert deer and turkeys to the presence of beechnuts. After ingesting the nuts, these animals distribute surviving seeds in their faeces. Also, predators, such as foxes, coyotes and weasels recognise beech groves as harbours for their rodent prey.

Interactions between multiple species create and maintain vibrant ecosystems. Member species must benefit their ecosystems, or they may not have a place in which to survive.

Donald Windsor
Norwich, New York, US

One reader disputes the claim - Ed

■ Brought up in a beech wood, I dispute the assertion that the trees retain their leaves over winter. Mature trees do not – this is a characteristic of young beech saplings, most noticeable in hedges. Flexing saplings, unlike stiff trees, are not likely to be uprooted by gales, nor shattered by heavy sticky snowfall, so retaining leaves is less dangerous.

I have seen similar, if less noticeable, retention in seedlings of other trees, such as cherry-plum – although in this instance,

"Predators, such as foxes, coyotes and weasels recognise beech groves as harbours for rodent prey"

photosynthesis may continue into winter. I fancy oak seedlings may also retain brown leaves, if to a lesser degree than beech.

Peter Urben
Kenilworth, Warwickshire, UK

This week's question

IT'S A GAS
Why are farts funny?
Zoe Freeman-Corner (age 10)
London, UK

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