

New Scientist

WEEKLY September 30 - October 6, 2017

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This is Axiom, a new film premiering at New Scientist Live, aims to answer the question.

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Thursday 28 September, 13:15–13:55

Followed by a fascinating panel debate on the biggest health issues: Friday 29 September, 10:30–11:10, The Humans Theatre

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Live long, and prosper?

Rejuvenation medicine is a double-edged sword

ON 17 October 1995, a French woman called Jeanne Calment set a new official record for human longevity: 120 years and 238 days. When she died, she was 122 years, 164 days. Her record still stands.

You might conclude from this that research aimed at extending the human lifespan has gone nowhere, and that 120 or so remains a non-negotiable upper limit. If the radical claims of life extension science are true, where are all the supercentenarians?

The answer is: they are still in middle age. Today's oldest person, a Japanese woman called Nabi Tajima, turned 97 the day Calment died – already too old to benefit

from treatments aimed at slowing or reversing ageing. We won't start to see any population-level effects of targeted life extension for another 30 to 40 years, when today's septuagenarians may be entering their 12th decade in increasing numbers.

Whether this will happen is still an open question. Nothing has yet been shown to work in humans, although there are promising avenues, including research on the rejuvenating effects of young blood (see page 39). Most may prove to be dead ends, but the quantity of research effort and money that has been poured into anti-ageing suggests that if it is

possible, it is going to happen.

That is good news for individuals, but a challenge for society. Consider that Tajima was born in the 19th century and reached retirement age more than 57 years ago. Now extrapolate that life trajectory to large numbers of people. Bioethicists have long flagged concerns about the social consequences of life extension, including overpopulation and the prospect of a "care home world" full of decrepit people. These problems are half a lifetime away, and are unlikely to be a deal-breaker. But it is not too soon to start thinking seriously about how we should deal with them. ■

Making the world slightly less wrong

IN THE run-up to New Scientist Live, some chatter on Twitter caught our eye: "It looks amazing," said Neil Gaiman. "A very promising line-up," said Richard Dawkins. "Looking forward to chatting on stage with astronauts Helen Sharman and Al Worden": that was Tim Peake. Duncan Jones, the director of *Source Code* and son of David Bowie, saw the line-up and responded: "Thanks for making

me feel inadequate, @newscientist!"

Even if we say so ourselves, our programme of talks, exhibits and hands-on features is unrivalled. We've got 130 scientists from around the world, ranging over all the subjects we cover in the magazine every week. If you're reading this hot off the press, you still have the chance to see what happens when the magazine comes to life. New

Scientist Live is running right now (28 September to 1 October) at the ExCeL centre in London. If you don't make it, at least you have the next best thing in your hands. We'll leave you with the words of Robin Ince, who is closing the event on Sunday with his science-comedy variety show. After the festival, "we will live in a slightly less wrong world than we did before".

ALVIN BAÑEZ/REUTERS



Less than perfectly stable

Storm after storm

HURRICANE Maria is the latest in a succession of severe tropical storms to have pummelled the Caribbean and southern US.

It follows Hurricane Harvey, which caused vast flooding in

Maria was the 13th named storm of the 2017 hurricane season, with two months still to go

Texas, and Hurricane Irma, which left a trail of devastation in the Caribbean before striking Florida.

The National Oceanic and Atmospheric Administration (NOAA) says the flurry of storms has borne out its warning that 2017 would be the most active hurricane season since 2010. "This is the peak of the season running to 30 November, and our forecast in August is valid and verified," a spokesperson told *New Scientist*.

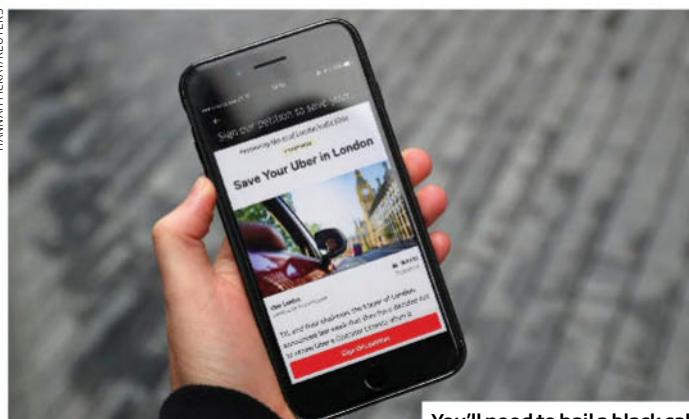
NOAA had warned that from June to November there would be 14 to 19 named storms, including two to five major hurricanes. Maria was the 13th named storm

this season, with two months to go. As *New Scientist* went to press, Hurricane Lee had formed in the Atlantic and was moving west.

It is even possible that storms will occur later on than usual. "Hurricanes have happened outside the window of the season," said the NOAA spokesperson.

Hurricane researchers have previously warned that the number of Atlantic tropical storms and hurricanes will rise. Climate change is creating conditions that help them form and intensify, such as warmer sea surface temperatures.

HANNAH MCKAY/REUTERS



You'll need to hail a black cab

Dam threatens to breach

"STAY away or be swept away." This grim advice was issued on Monday to the people of Puerto Rico by the US National Weather Service, after a dam swamped by rainfall from Hurricane Maria developed a large fissure.

The Guajataca dam lies on the Rio Guajataca in the north-west of the country. The 90-year-old earthen dam holds back almost 40 billion litres of water. But its reservoir is now too full, after Maria dumped 40 centimetres of rain on the area. If the dam fails, it could cause flash floods.

Since the crack formed last Friday, local officials have been warning of the danger, with 70,000 people advised to evacuate. "We don't know how long it's going to hold," Governor Ricardo Rosselló said last Sunday.

"Photographs of the incident show

there's structural damage at the base of the dam's spillway, where overflows appear to be eroding the bottom of the dam," says Tracey Williamson, chair of the British Dam Society. "There's a possibility that erosion could progress to the point where the dam could breach."

There are several ways to stop the dam bursting. One is to reduce the reservoir level by draining water through all other available outlets. This would relieve the water pressure on the dam and slow the flow of water over the spillway.

Another approach is to deploy high-volume pumps to divert the overflow around the damaged area. Finally, relief workers could jam additional material into the existing crack to prevent further erosion.

UK web abortions

HUNDREDS of UK women are seeking illegal abortions online, even though abortion is legal in the UK. Between November 2016 and March this year, more than 500 women approached a charity called Women on Web for mail-order abortion pills, the organisation revealed in a study published last week.

Based in the Netherlands, Women on Web provides the same medications as used in UK clinics for legal abortions, but only sends them to women living in

countries where abortion is illegal. It is illegal for women in the UK to take the drugs outside of approved medical services.

During the study, women were told about services at their nearest health clinic, and asked why they had approached Women on Web.

Of the 180 women who responded, about half said they had difficulty accessing National Health Service abortion services (*Contraception*, doi.org/cdjs). Reasons given included distance and waiting times, as well as being unable to get childcare or time off work.

Goodbye Uber?

RIDE-SHARING firm Uber last week had its licence to operate in London revoked, with regulator Transport for London (TfL) saying it was "not fit and proper to hold a private hire operator licence". TfL cited the company's lax approach to criminal and medical checks for drivers. The company had been criticised for its slow response to allegations of assault by drivers.

"If this decision stands, it will put more than 40,000 licensed

60 SECONDS

drivers out of work," says Tom Elvidge, Uber's general manager in London. "It deprives Londoners of a convenient and affordable form of transport."

Many Londoners seem to agree. As *New Scientist* went to press, over 780,000 had signed a petition to keep Uber on the road.

They may not need to worry. The firm's licence will expire on 30 September, but Uber can continue to operate during the 21 days it has to appeal. Indeed, the company has announced its intention to appeal, and some estimate that this will let the service continue for up to a year.

To Bennu and back

ON 22 September, NASA's OSIRIS-REx spacecraft hurtled around Earth at 8.5 kilometres per second, getting the boost it needs to reach the asteroid Bennu next August.

Since its launch in 2016, OSIRIS-REx has been circling the sun in Earth's orbit, just ahead of the planet. Bennu's orbit is slightly tilted compared with Earth's, so the spacecraft had to slingshot around our planet to adjust its path, allowing it to meet that of the asteroid. Its closest approach to Earth came at about 17,000 kilometres above Antarctica.

OSIRIS-REx will keep cruising for another year, travelling more than 1 billion kilometres before it reaches Bennu. It won't land on the asteroid, but will get close enough to kick up some dust. When it is within a few metres of the surface, it will extend its arm and blow out a puff of nitrogen gas, causing a plume of dust to stream up from Bennu.

If that works out, OSIRIS-REx will return to Earth in 2023. That will mark the first time the US has ever brought back such samples, and only the second time that any dust has been retrieved from an asteroid.

Kidney coupons

THE world's first voucher system for people who donate kidneys has boosted donations in the US.

When somebody needs a new organ, they go on a transplant list, but organs are in short supply, and 12 people die waiting every day. One way to get around this is to have a friend or relative donate a kidney directly to you, but biological incompatibility stops about a third of people being able to accept these organs.

The voucher scheme, created by Jeffrey Veale at the University of California, Los Angeles, and his team, encourages people to donate to a compatible stranger by giving them a voucher they can then give to an incompatible loved one in need of a kidney. This starts a chain of donations, and a voucher-holder gets a place in a chain when a compatible donor turns up.

An analysis of the system suggests it boosts donations. Working with the UCLA team, the US National Kidney Registry has so far issued 21 kidney vouchers across 30 hospitals, stimulating donation chains that led to a total of 68 transplants (*Transplantation*, doi.org/cdjz). "For the first time in history, we could actually start reducing the waiting list," says Veale.

Ad astra, Australia

Australia announced this week that it will establish a space agency. It will join more than 70 other nations that have their own agencies. It isn't yet clear what the Australian space agency's budget will be, but government officials stated that it will be "small" and "not NASA".

Sleepy jellies

Jellyfish enter a sleep-like state at night, and become dozy the next day if their rest is interrupted. This is remarkable for an animal with no centralised brain. The finding implies that sleep is ancient, dating back to the very first animals (*Current Biology*, doi.org/cdjjv).

Middle-aged HIV

People over the age of 50 account for roughly 1 in 6 newly diagnosed cases of HIV in Europe. The rate of new cases in older people has been rising in recent years, and an analysis suggests that those over 50 are more likely than younger people to acquire HIV through heterosexual sex (*The Lancet HIV*, DOI: 10.1016/S2352-3018(17)30155-8).

Super connection

Facebook and Microsoft have added another connection between the US and Europe. The 6500-kilometre, 4.6-million-kilogram undersea cable, known as Marea, boasts the highest capacity of any Atlantic cable to date: it can ferry 160 terabits of data per second, equivalent to streaming 71 million HD videos at the same time. It is due to come online in 2018.

Alligators vs sharks

Who wins in a fight between an alligator and a shark? An overlooked conflict between the two has been going on for centuries at least. A literature review revealed instances of alligators eating lemon, nurse and bonnethead sharks, and an Atlantic stingray. Sharks could be a key food source for alligators (*Southeastern Naturalist*, vol 16, p 383).

UK Lyme disease warning

THE UK National Institute for Health and Care Excellence (NICE) has named areas in southern England and the Scottish Highlands as high-risk regions for Lyme disease. It also warns that many other places in the UK present a risk of infection.

There are thought to be some 2500 cases of the disease in England and Wales every year. In a draft guideline, NICE has called for a large study to flesh out incomplete data.

Lyme disease is spread by ticks, and can lead to conditions like meningitis, facial paralysis or heart failure if untreated. UK areas with a particularly high tick population include Exmoor, the New Forest, the Lake District, the North York Moors and the Scottish Highlands.

Not everyone who gets bitten by a tick will contract the disease, as only a small proportion of the invertebrates carry the bacterium that causes it. However, NICE suggests that the UK incidence of Lyme disease is underestimated because doctors aren't required to report cases they see.

The disease is also hard to diagnose, as symptoms include headache or fever, and people may not realise they have been bitten. "Our draft guidance will give GPs and hospital doctors clear advice on how to diagnose if they think Lyme disease is a possibility," says Saul Faust at the University of Southampton, UK, who helped write the guideline.



You may not even notice its bite

Roused from a vegetative state

Man "wakes" after 15 years unconscious following brain stimulation

Anil Ananthaswamy

FIFTEEN years after a car accident, a man in France has regained some aspects of consciousness, following stimulation of his brain via a nerve in his neck.

The 35-year-old was diagnosed with "unresponsive wakefulness" after a car accident in 2001. People in this state can show involuntary movements, but are thought to have no awareness of self or their environment. Repeated tests showed no improvement in the man's condition.

That was until Angela Sirigu of the French National Centre for Scientific Research in Bron and her team stimulated his vagus nerve. Before treatment, the man's eyes were shut for most of the day. If open, they would stare into empty space, says Sirigu. "You had the feeling he was not looking at you."

"For way too long, doctors have seen unresponsive wakefulness patients as waiting to die"

That changed once her team began stimulating his vagus nerve. Almost immediately, he started opening his eyes more often. About a month after stimulation began, his behavioural improvements started stabilising. "His eyes were moving around as if he wanted to follow me," says Sirigu. He then began to respond to instructions to turn his gaze from one side of the bed to another. When a clinician asked him to smile, he would react by raising his left cheek.

The vagus nerve runs from the brain to several areas of the body. It helps modulate heart rate and lung function, and is connected to brain regions involved in emotion,

memory, arousal and alertness. Sirigu's team hypothesised that stimulating the vagus nerve would increase activity in brain regions that could help the man regain consciousness. "I believe that's what happened," says Sirigu.

For the treatment, the team wrapped thin electrodes around the vagus nerve in the man's neck. He was treated continuously over six months, each treatment involving 30 seconds of stimulation followed by 5 minutes of rest. The team started with an electrical current of 0.25 milliamperes, increasing each week up to 1.5 mA.

His scores on the "coma recovery scale" suggest he could

now be defined as being in a minimally conscious state – in which a person has partial conscious awareness (*Current Biology*, doi.org/cdjp). However, the man is unlikely to ever regain the ability to talk or walk, given the damage to his brain.

Sirigu's team recorded EEG signals from the scalp before stimulation began and at points throughout the trial. They also scanned the man's brain after the electrodes were implanted, and six months later. They saw that changes in brain activity supported the man's behavioural changes. Many areas of the cortex – which is associated with higher functions and

thought – were more active after stimulation. "We observed activity in those areas that were mostly targeted by the vagus nerve," says Sirigu.

Potential treatment

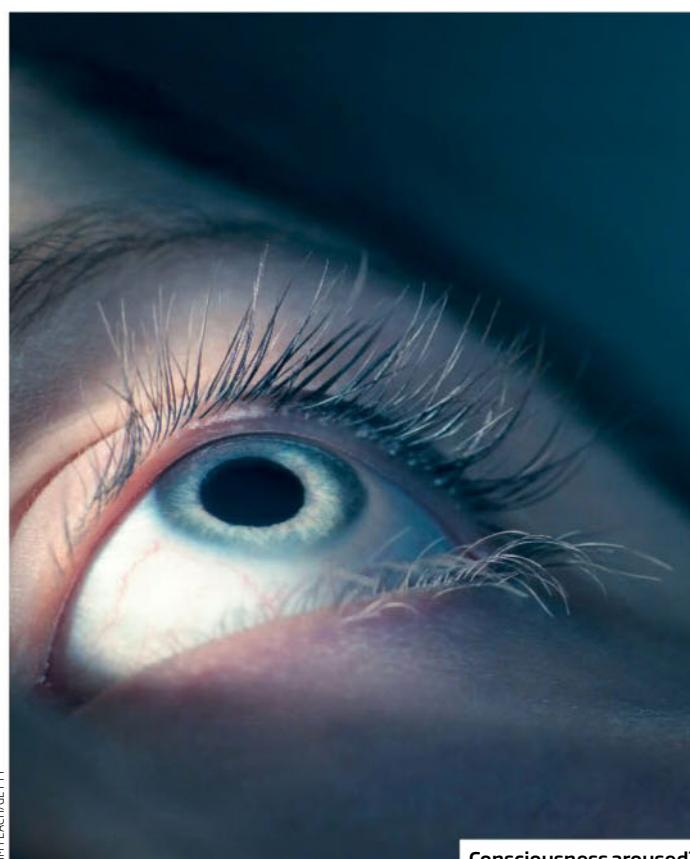
"Clinicians for way too long have considered patients of unresponsive wakefulness as just waiting to die," says Steven Laureys of the University of Liege in Belgium. "I'm convinced that vagus nerve stimulation is a potential new treatment."

But Laureys warns that the technique is unlikely to work in all patients, and says a better baseline should have been established before treatment. The team tested the man three times over two months to establish that he was unresponsively wakeful. Laureys's research has shown that accurate diagnosis requires five assessments within one to two weeks.

Laureys would like to see randomised, controlled trials done at multiple centres. "We shouldn't give false hope," he says. "But we also shouldn't give false despair."

The fate of people in a vegetative state is a controversial subject. Last week, the Court of Protection in England and Wales ruled that families no longer need the court's permission to withdraw life support and to let their loved ones die (see page 25).

But Sirigu is hopeful that their technique will work on others in a similar state. Her team is now studying more patients to see if the results can be replicated. "I'm very thankful to this patient and [his] family," she says. "It was not easy to have surgery without knowing what the result would be. It was a very bold decision for the family." ■



Consciousness aroused?

TIM FLACH/GETTY

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New Zealand's kiwis may be losing eyesight

BLIND kiwis seem able to survive quite happily using other senses. It's possible that the flightless birds are evolving to lose their sight - so vision might actually be a waste of energy for them.

The discovery of the blind birds came when researchers studied a group of 160 endangered Okarito brown kiwis in the Okarito forest on New Zealand's South Island. "We found a very high prevalence of birds with eye lesions," says Alan Tennyson at the Museum of New Zealand Te Papa Tongarewa in Wellington. "A third of them had eye problems."

But the biggest surprise was chancing upon three sightless birds (*BMC Biology*, doi.org/cdgw). "No other birds are known to have a free-living population of blind [individuals]," says Tennyson.

Plenty of other animals, like moles, have evolved to lose their sight, so the discovery could help explain how this "regressive evolution" happens - if the Okarito kiwis survive.

In the case of kiwis, the most likely reason is that they do not need vision because of where and how they live.

"Kiwis are flightless and generally nocturnally active, and have very good senses of smell, hearing and touch," says Tennyson. What's more, their habitat has plenty of food and few predators.

Other researchers speculate that a gene called *Sonic hedgehog* might be responsible. It has been implicated in loss of sight in other animals, such as the Mexican blind cavefish. The gene might enhance the functioning of touch and smell sensors in the kiwis' long beaks, at the expense of sight.

"Eye degeneration can be seen as 'collateral damage,'" as the birds adapt to their "nocturnal, lightless niche in which normal, functioning eyes are not necessary", says Stanley Sessions at Hartwick College in Oneonta, New York. "That's our best guess as to what's going on in these birds."

Andy Coghlan ■



Use a different route

Pollution sensor keeps you out of choking air

A PERSONAL pollution guardian has arrived. On Tuesday, the world's first low-cost wearable air quality sensor went on sale, capable of monitoring your exposure to the three most harmful pollutants.

The gadget, called Flow, can be used as a handheld sensor or attached to pushchairs, purses and bags, and will set you back about \$200. "We want to help people take ownership of what they breathe," says Romain Lacombe, the CEO of Plume Labs, the Paris-based firm behind the device.

"It will certainly be the most complete," says Jean-François Doussin at Val-de-Marne University in Paris, who advised Plume. A few similar devices are already on sale, but Flow is the first that can detect the big three pollutants: volatile compounds, airborne particulates and nitrogen oxides. The device tells you whether they exceed

safe levels on the street or in your home.

In much the same way as you can monitor traffic jams on your smartphone, the Flow will work with a mobile app to create pollution maps. These won't just rely on user data, instead drawing on air quality readings, weather

"Giving people precise information about their exposure will let them change their daily routine"

information, temperature and other variables to forecast pollution hotspots.

Giving people precise information about their exposure will let them change their daily routine. For example, the parents of young children might decide to stay at home on high pollution days, joggers could take a different route, and people with asthma could keep the windows open when cooking or using indoor

woodburning stoves.

While pollution has been falling in many cities in Europe and the US thanks to tightening regulations, Frederica Perera at Columbia University in New York says city dwellers should still be concerned. "We have found no convincing evidence of a safe level of exposure to common urban air pollutants," she says.

Until recently, many cities depended on a few fixed monitors to track air quality over vast urban areas. But these offered little insight to the average person because pollution is unevenly distributed, varying from block to block, thanks to trees, traffic patterns and architecture.

Rising concerns about health effects have spawned an explosion of portable monitoring devices. Many of these are no longer on sale, and the few that still remain on the market only monitor one class of pollutants. That is largely due to space and data-processing constraints, says Doussin.

Recent technological developments include nanowire gas sensors built into microchips. This has enabled three pollution sensors to be crammed into the Flow device.

Melissa Lunden of air monitoring company Aclima hopes maps created by new tools and projects will give governments a way to evaluate the impact of schemes such as electrified bus lines, bike lanes and adding green space in congested urban cores.

Doussin says smaller sensors like Flow are less accurate than the equipment scientists use, but they are "more than sufficient to evaluate personal exposure to air pollution".

He hopes this will create pressure on local officials to get serious about cleaning up the air. "The problem that we have with air quality is that it is an invisible problem," he says. "These devices make the invisible visible."

Richard Schiffman ■

Time to digitally prove who you are

Chris Baraniuk

THERE'S a new way to prove you are who you say you are – inspired by the tech underpinning bitcoin. Usually, when you need to verify your identity, the process is archaic, insecure and time-consuming. You get a copy of your birth certificate in the post, put it in an envelope and hope it gets to whoever is asking for it. In the digital era, this should take seconds.

But putting something as sensitive as a birth certificate online risks identity theft in the era of hacks and leaks. Now, the US state of Illinois is experimenting with a secure way of putting control of that data into its citizens' hands, with the help of distributed ledgers, similar to the blockchain used by bitcoin.

Just last month, Illinois announced a pilot project to create "secure 'self-sovereign' identity" for Illinois citizens wishing to access their birth certificate. The idea is to use a blockchain-like distributed ledger that allows online access only to the people owning the ID, and any third parties granted their permission.

Illinois is working with software firm Evernym of Herriman, Utah, to create a record of who should be able to access data from the state's birth register. Once this is done, no central authority should be required, just your say-so.

They're not the only ones. According to a report by Garrick Hileman and Michael Rauchs at the Cambridge Centre for Alternative Finance, UK, governments are increasingly experimenting with it, including the UK and Brazil.

Activists have long called for people to have greater control of their data. Hacks and leaks are making it too risky for authorities to be the central repository of citizens' most vital information.

With distributed ledgers, all participants within a network can have their own identical copy of data like access permissions – so no one can view cryptographically sealed birth certificate data unless they're meant to. Blockchains are a type of distributed ledger that gets the whole network to observe and verify transactions – such as when someone sends a bitcoin to their friend.

Distributed ledgers could be a great way to store critical data. But "the devil is always in the details", says Dave Birch at electronic transactions consultancy Consult Hyperion. Done wrong, distributed ledgers could carve mistakes in stone. "If your midwife fat-fingers the weight of the child or the name then you're going to have a typo in your name from birth forever," he says. "Bullshit in, bullshit forever."

Nonetheless, some think these projects are a step towards a world where all data is managed by the individuals who own it. It could backfire on governments, though. Citizens in Catalonia are gearing up for a referendum on independence from Spain, planned for 1 October. It has been termed "illegal" by authorities in Madrid. But a start-up is studying the possibility of using blockchain technology to let citizens hold their own vote, with no government authority needed. ■



Own your data, gain independence?

Super-Earths pull in asteroids that seed life

PLANETS up to 10 times more massive than Earth, aka super-Earths, might play billiards with planetary systems. If a super-Earth existed in our own solar system, say, between Venus and Earth, far more asteroids would collide with us, new simulations show.

Asteroid hits aren't necessarily a bad thing – if the timing is right. Understanding how massive planets influence others nearby could help

direct the search for exoplanetary life.

Our galaxy is overrun with super-Earths, so Jeremy Smallwood at the University of Nevada and his colleagues set out to discover what their effect might be on neighbouring worlds. They simulated the formation of the inner solar system, shuffling a theoretical super-Earth around, and found that one closer to the sun than we are would increase the number of asteroid impacts on our planet. A super-Earth outside our orbit would do the opposite (arxiv.org/abs/1709.06032).

Why? A super-Earth near our sun would stretch asteroids' orbits,

making a collision with Earth more likely. It may seem that a system with fewer asteroid impacts would be more conducive to life – but many astronomers argue the opposite.

"Asteroid collisions are thought to be destructive for life – that was definitely true for the dinosaurs," says Smallwood's adviser Rebecca Martin. "But they are also essential for life."

An asteroid impact is a double-edged sword. A large one could leave

"Asteroids are thought to destroy life – just ask the dinosaurs – but they are also essential for life"

a planet hostile to life. But the building blocks of life, like water, may actually have come to Earth on asteroids. Their hits on early Earth also stabilised our orbit, and the climate. Some scientists even suggest that life itself could have hitched a lift on early asteroids, jumping from planet to planet.

Still, if astronomers discovered two exoplanetary systems – one with a super-Earth orbiting inside, and the other outside, a rocky planet's orbit – Smallwood would search for life on the first. Sure, the planet might be sterile. But the other might not have received the ingredients for life in the first place. Shannon Hall ■

Transparent brains reveal stroke damage

NOW we can see stroke damage in 3D. A technique that turns mouse brains transparent has given us the most detailed view yet of how stroke cuts off the blood supply in the brain.

Stroke damages the brain's blood vessels, stopping oxygen and nutrients reaching cells. To understand this impact, researchers usually examine thin brain slices under the microscope.

Now Dirk Hermann and Matthias Gunzer at the University of Duisburg-Essen in Germany and their team have developed a way to see all of a brain's blood vessels clearly, without having to slice it up. They injected a fluorescent gel into the hearts of mice, waited for it to be pumped around the body, and then removed the brains and soaked them in chemicals. "You're left with a brain that is clear like glass," says Hermann.

The team looked at each brain under a microscope, lighting up the fluorescent gel using a laser (*Journal of Cerebral Blood Flow and Metabolism*, doi.org/cdg3).

The brains of mice that had experienced a stroke provided the first-ever 3D view of how stroke cuts off the blood supply to parts of the brain. "You could see which capillaries had died and how the surviving ones were reorganising themselves," says Gunzer. Alice Klein ■

MARCIWARD/STOCK TREK IMAGES/GETTY



BAM! Subduction zone

Impacts from space started Earth's tectonics

PLATE tectonics – the process that shapes Earth's surface and causes earthquakes – may have begun at least half a billion years earlier than we thought. And it may have been triggered by violent impacts from space rocks.

Plate tectonics creates landscapes, including mountain ranges, and allows chemicals to flow from Earth's interior, some of which are essential to life. Yet nobody knows how or when it got started.

Nicolas Greber of the University of Geneva, Switzerland, and his colleagues set out to trace the origin of global plate tectonics by determining which rock types were present at different stages of Earth's history.

They focused on two rock types. Mafic rocks like basalt are typically dark, while felsic rocks like granite are lighter.

Felsic rocks only form in the presence of water and heat, found in subduction zones where tectonic plates are forced under each other. So felsic rocks are a sign that subduction zones were active during their formation.

Greber determined how early in Earth's history felsic rocks were present by looking at shales dating back 3.5 billion years. Mafic and felsic rocks carry different mixtures of titanium isotopes, which are preserved in the shales. This revealed that, as far back as 3.5 billion years ago, 55 to 60 per cent of the continental crust was made of felsic rocks (*Science*, doi.org/cdhm).

"Young Earth's interior was probably too hot to drive plate tectonics. That is, unless it had help"

For Greber, that means subduction zones and modern plate tectonics must have been in action at least 3.5 billion years ago.

This runs counter to the prevailing wisdom, which is that global plate tectonics started around half a billion years later.

It could be that tectonics started more than once. When Earth was young, its interior was probably too hot to drive plate tectonics, says Craig O'Neill of Macquarie University in Australia. That is, unless it had help. He has now

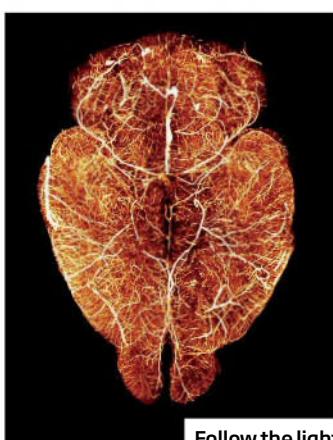
shown that plate tectonics could have got started much earlier, thanks to massive rocks from space smashing into the planet.

O'Neill and his colleagues simulated what would happen to Earth's crust and interior if rocks of different sizes collided with it. They found that a single large impact could trigger a subduction zone that remained active for 10 million years (*Nature Geoscience*, doi.org/cdj2). By itself that is quite a short-lived period of tectonic activity, but young Earth was hit by a lot of space rocks.

The first spate of impacts happened when the planet was still forming and ended around 4.4 billion years ago. Then there was a lull until 4 billion years ago, followed by an intense bombardment that lasted until 3.5 billion years ago, with occasional big impacts until as recently as 2 billion years ago.

Combined with Greber's findings, this suggests that from Earth's birth until 3 billion years ago, there was intermittent subduction driven by impacts, which produced the felsic rocks Greber found. After that, the planet's interior had cooled enough for global plate tectonics to begin in earnest.

Michael Marshall ■



Follow the light



SUPERSTOCK

Modified wheat for gluten-free bread

Michael Le Page

PEOPLE forced to avoid gluten could soon have their bread (and cake) and eat it. Now there are strains of wheat that do not produce the forms of gluten that trigger a dangerous immune reaction in as many as 1 in 100 people.

Because the new strains still contain some kinds of gluten, though, the wheat can still be used to bake bread. "It's regarded as being pretty good, certainly better than anything on the gluten-free shelves," says Jan Chojecki of PBL-Ventures in the UK, who is working with investors in North America to market products made with this wheat.

Gluten is the general term for all the proteins in wheat and related cereals. During baking, these proteins link up to form elastic chains, which is what holds breads and cakes together as they rise.

But some people have an autoimmune condition called coeliac disease. Their immune

systems respond incorrectly to gluten, which damages the gut lining and can lead to diarrhoea, vomiting, malnutrition, brain damage and even gut cancers.

Not all gluten proteins trigger this response, though: the main culprit is a group called gliadins. So Francisco Barro's team at the Institute for Sustainable Agriculture in Cordoba, Spain, set about getting rid of them.

They used a genetic modification technique to remove 90 per cent of the gliadins in wheat. They did this by adding

"It cannot be used for making large sliced loafs, but is good enough for baguettes and rolls"

genes that trigger a process called RNA interference, which stops specific proteins being made. But because the gliadin genes themselves remain intact, in theory, there is a risk that the wheat could start making the crucial proteins again.

So Barro's team next tried using

Daily bread: if gluten's not for you

CRISPR gene-editing to get rid of the genes entirely. This is a huge task because there are no fewer than 45 copies of the gene for the main gliadin protein that causes problems. Nevertheless, Barro's team report that they have already managed to knock out 35 of the 45 genes (*Plant Biotechnology Journal*, doi.org/cdfd).

More genes need to be disabled before the CRISPR strain is ready for testing, but it should be worth all the effort: the team have already shown that the GM wheat strain makes an acceptable bread. It cannot be used for making large sliced loafs, but is good enough for baguettes and rolls, says Chojecki.

"Some people will be very happy with this," says Sarah Sleet, head of patients' group Coeliac UK, not least because sticking to a gluten-free diet is difficult.

However, others may not want to eat genetically modified foods, or to take the risk that some immune-triggering components remain in the wheat, Sleet says.

Small trials of the GM wheat involving 10 and 20 people with coeliac disease are already being carried out in Mexico and Spain. "All I can say is that the results are very encouraging," says Chojecki. ■

Fingers are slow to get to grips with glass

YOUR fingers take time to engage in full contact with a touchscreen. In some cases, even 30 seconds or more after placing a dry finger on the glass, your skin is still adjusting. This can lead to problems using fingerprints to access phones and getting screens to respond to your touch.

Michael Adams and Brygida Dzidek at the University of Birmingham, UK, and their team had two volunteers press a washed and dried index finger against a glass surface with increasing force. After 2 seconds, very little of the fingerprint was actually in direct contact with the glass (*PNAS*, 10.1073/pnas.1706233114). After a while, more of the fingerprint made contact. In most cases, the entire fingerprint was visible on the glass after about 30 seconds.

The keratin in the outer layer of our skin is inflexible when dry. This means that when you first push a finger against the screen of a smartphone, only the high points of your fingerprint come into contact with it. But fingertips start to sweat quickly. The skin absorbs the moisture, making the keratin more flexible, allowing your finger to make full contact. "Most of us have ignored the effect of time when doing our own research on fingerprints," says Roland Ennos at the University of Hull, UK.

Next-generation touchscreens are already being designed to use ultrasonic vibrations that give the illusion that smooth glass has texture. The screen can be made to feel smoother or rougher by varying the frequency of vibration when you touch particular parts of it. The vibrations decrease the friction between skin and screen for a smoother glide, but they also mean a finger has only an intermittent contact with the glass.

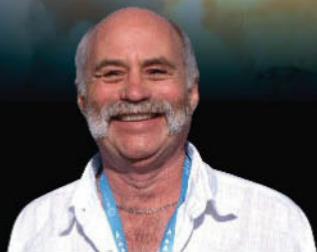
This could lead to responsiveness problems, so Adams says developers may have to take his findings into account and make allowances for finger friction changes. Colin Barras ■

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FIELD NOTES Queensland, Australia

Saving the Great Barrier Reef

Alice Klein

THE sky above is grey and drizzly, but the wetlands are still beautiful to behold. Flocks of magpie geese settle on the glassy water, honking and nibbling at bright green tufts of sedge.

I'm at Mungalla Station, a cattle property on the north-eastern Queensland coast. Here, a large-scale conservation project is under way. Its aim: to help save the Great Barrier Reef 20 kilometres out at sea.

The reef is a World Heritage Site in trouble. The obvious threats are climate change and coral bleaching, both of which could kill coral. But agricultural run-off is also a problem. About 10 million tonnes of sludge from farms wash onto the reef each year, smothering the coral, says Mungalla's director Jacob Cassady.

He is a member of the local Nywaigi people, who took over Mungalla when it was returned by the Indigenous Land Corporation in 1999. At that time, the property had been damaged by more than a century of cattle farming. Overgrazing had caused soil erosion, native vegetation had been cleared and the wetlands along the coast were choked with invasive weeds.

This presented a threat to the reef. Sediments, pesticides and fertilisers were leaking into the wetlands and out to sea, poisoning and smothering reef organisms like coral and turtles.

To restore Mungalla, the Nywaigi owners kept one section for cattle farming and allowed the rest to grow wild. Much of the area is now thickly forested and full of squawking birdlife.

Since 2013, the owners have focused on restoring the wetlands. They call them the "kidneys" of the reef, because they filter out silt and chemicals before they reach the sea.

First, they targeted alien weeds like marsh grass and water hyacinth that blanketed the wetlands and squeezed out native aquatic plants. There was an easy fix: they knocked down an earth wall, built in the 1940s to stop the tide from coming in. The weeds couldn't handle the saltiness of the incoming seawater and withered.

Now, only a few small patches of these weeds remain. In their place, native sedges such as the grass-like bulkuru have sprung up, attracting geese and other birds to feed on them.

Water quality is also better. Before, microbes feeding on rotting weeds sucked oxygen from the water, making



Watch out for sludge

it uninhabitable for wildlife. Now, Cassady says, the wetlands are filling up with fish and crocodiles. I back away quickly from the water's edge.

The thriving wetlands will provide a buffer for the Great Barrier Reef, says Niall Connolly of Greening Australia, a conservation group helping with the restoration efforts. Farm chemicals and silt stick to the bulkuru and are buried via their root system, he says.

Greening Australia is now working with other landowners in the area to restore 200 hectares of coastal

wetlands. Its modelling suggests such measures could cut sediment pollution by 75 per cent in key areas. This would go a long way towards meeting the Australian government's target of halving sediment load in the Great Barrier Reef by 2025.

As we stare at the geese flapping around the bulkuru, Cassady says the results have been better than he expected. "I am elated," he says. "You can feel the country healing itself." ■

Greening Australia flew Alice to Mungalla Station

Three-body problem gets 1000 solutions

FOR 300 years or so, mathematicians have puzzled over the "three-body problem" – the question of how three objects orbit one another. Now, there are 1223 new solutions to the conundrum, more than doubling the existing number of possibilities.

No single equation can predict how three bodies will move in relation to one another and whether their orbits

will repeat or devolve into chaos.

The new solutions were found when researchers at Shanghai Jiaotong University in China tested 16 million different orbits using a supercomputer (arxiv.org/abs/1709.04775). All the fresh orbits found are periodic. This means that objects, whether planet or proton, end up where they first began the orbit, with their paths forming three intertwined loops.

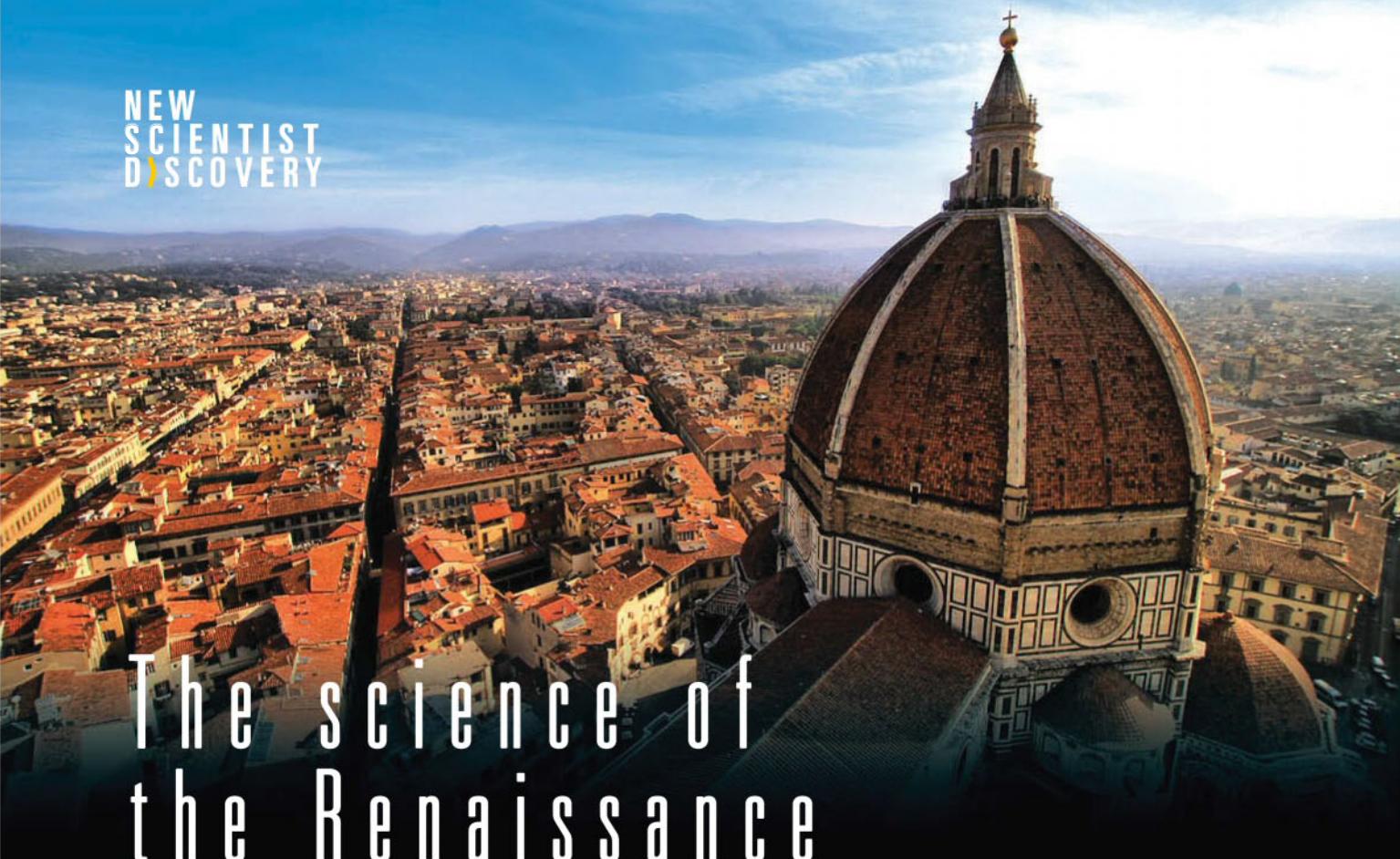
"It is impressive that they've made the list a lot longer," says Robert Vanderbei at Princeton University. Perhaps the most important

application of the three-body problem is in astronomy, as it helps researchers figure out how any set of three celestial objects can maintain a stable orbit. But these new orbits rely on conditions that are somewhere between unlikely and impossible for a real system to satisfy. In all of them, for example, two of the three bodies have exactly the same mass and they all remain in the same plane.

"These new orbits don't reflect real astronomy, but solving these equations is beautiful"

In addition, the researchers did not test the orbits' stability. It is possible that the tiniest disturbance in space or a rounding error in the equations could rip the objects away from one another. "These orbits have nothing to do with astronomy, but you're solving these equations and you're getting something beautiful," says Vanderbei.

As well as giving us 1000 pretty pictures of knot-like orbital paths, the solutions mark a starting point for finding even more orbits. And we may eventually figure out the whole range of paths three objects can follow around one another. Leah Crane ■



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STEVEN SAFFI

Energetic cosmic rays cross galaxies

Anil Ananthaswamy

A LONG-STANDING mystery about the origin of the highest energy particles arriving from outer space has been solved. Ten years of readings from the world's largest cosmic ray observatory show that these ultra-high-energy particles come from outside our galaxy.

Cosmic rays are charged particles, mainly atomic nuclei of hydrogen, helium and some other heavier elements, that constantly bombard Earth. Particles with energies above about 8 billion billion electronvolts were first detected about 50 years ago, but the sources of such ultra-high-energy cosmic rays (UHECRs) have been a mystery.

That is because as cosmic rays become ever more energetic, their numbers plummet. On average, only a single UHECR falls on one square kilometre of Earth's surface per year. At that rate, telescopes couldn't collect enough of them to reveal their origins.

That changed with the Pierre Auger Observatory, which is

spread across 3000 square kilometres of Argentinian grassland. Over a decade, it detected 30,000 UHECRs.

Some thought that the high-energy particles could have been produced at the centre of the Milky Way, which is known to harbour celestial objects that can accelerate particles to at least a million billion electronvolts.

But the Pierre Auger analysis shows that the UHECRs are coming from outside our galaxy

The particles are travelling about 326 million light years from a region that has starburst galaxies

(*Science*, doi.org/cdf4). After accounting for the deflection of the cosmic rays by the Milky Way's magnetic field, the team found that the particles are travelling about 326 million light years from a region of extragalactic space containing several potential sources, such as active galactic nuclei and starburst galaxies.

"We can conclude that these are

truly extragalactic sources, and it's the basis of ongoing studies looking for the sources," says Karl-Heinz Kampert, a spokesperson for the Pierre Auger Observatory.

To identify the precise sources, the observatory's telescopes will now try to measure the exact atomic weights of the rays so their precise deflection by the Milky Way's magnetic field can be worked out. For example, helium nuclei will be deflected twice as much as hydrogen nuclei of the same energy. This can then be used to retrace each cosmic ray's path back to its source.

Other telescopes have also been looking at the extreme universe of high-energy particles by hunting for highly energetic neutrinos and gamma rays. "The energy density in the extreme universe observed in cosmic rays, in neutrinos and gamma rays turns out to be the same," says Francis Halzen at the University of Wisconsin-Madison and the principal investigator of the IceCube Neutrino Observatory. "This may point at common sources and not be an accident."

Neutrinos don't get deflected by the Milky Way's magnetic field, so if it can be established that they come from the same sources as the cosmic rays, the neutrinos can be used to better locate their shared origins. ■

AI investigates electricity theft and bill errors

AN ALGORITHM tested on several million Brazilian households could help cut electricity theft and ensure your bills are accurate.

Electricity theft is a problem in Brazil, but it isn't limited to that country: some nations see as much as 40 per cent of their supply siphoned off, largely by users who have tampered with meters. "Mostly it's fraud," says Patrick Glauner at the University of Luxembourg. But big data may soon blow the thieves' cover.

Glauner and his team looked at records of the energy used by 3.6 million Brazilian households over five years. Based on this, they developed an algorithm that could recognise when energy use at a property was suspiciously low. Because the researchers also had data on past inspections against which to check the AI's conclusions, they could verify that their tool was correctly highlighting potential cases of fraud or faulty metering.

The system identified problem cases just over 65 per cent of the time, which the team believes outperforms similar tools (arxiv.org/abs/1709.03008). Smart energy firm Choice Technologies plans to deploy the tool in Latin America.

AI could help better target physical inspections of properties in developed countries too. "It's interesting that this software can, in theory at least, tell that a building using 10 per cent of what others are using is stealing electricity," says Paul Ruyseveldt at University College London's Energy Institute. However, he points out that it's normal for adjacent buildings to use different amounts of energy, which could lead to false positives.

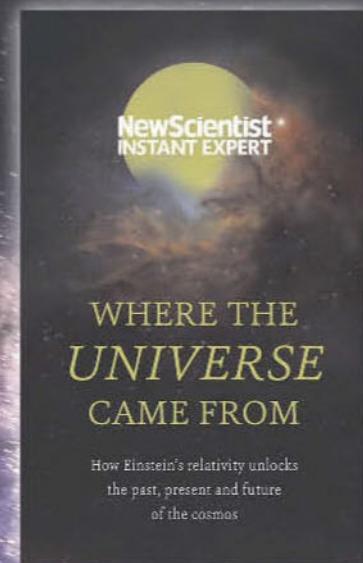
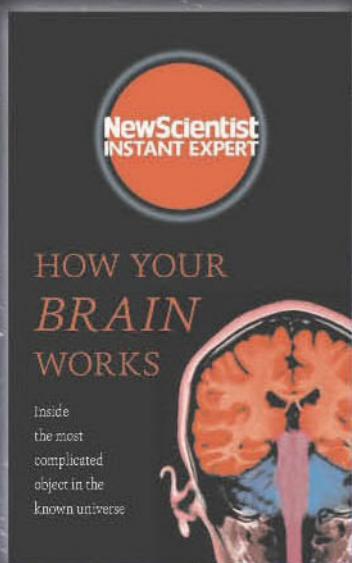
Similar false positives may be leading to erroneous billing by energy companies. "Meters break, or there could be billing errors," says Glauner. An algorithmic approach to meter readings could lead to a better deal for both suppliers and consumers.

Chris Baraniuk ■

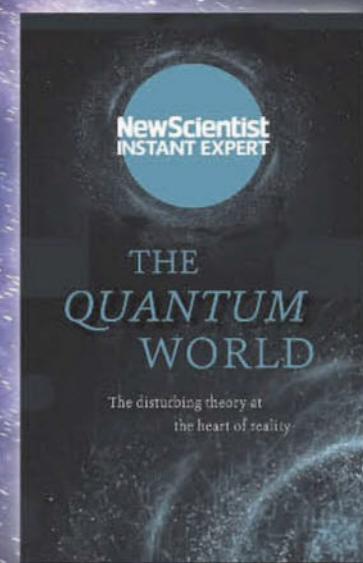
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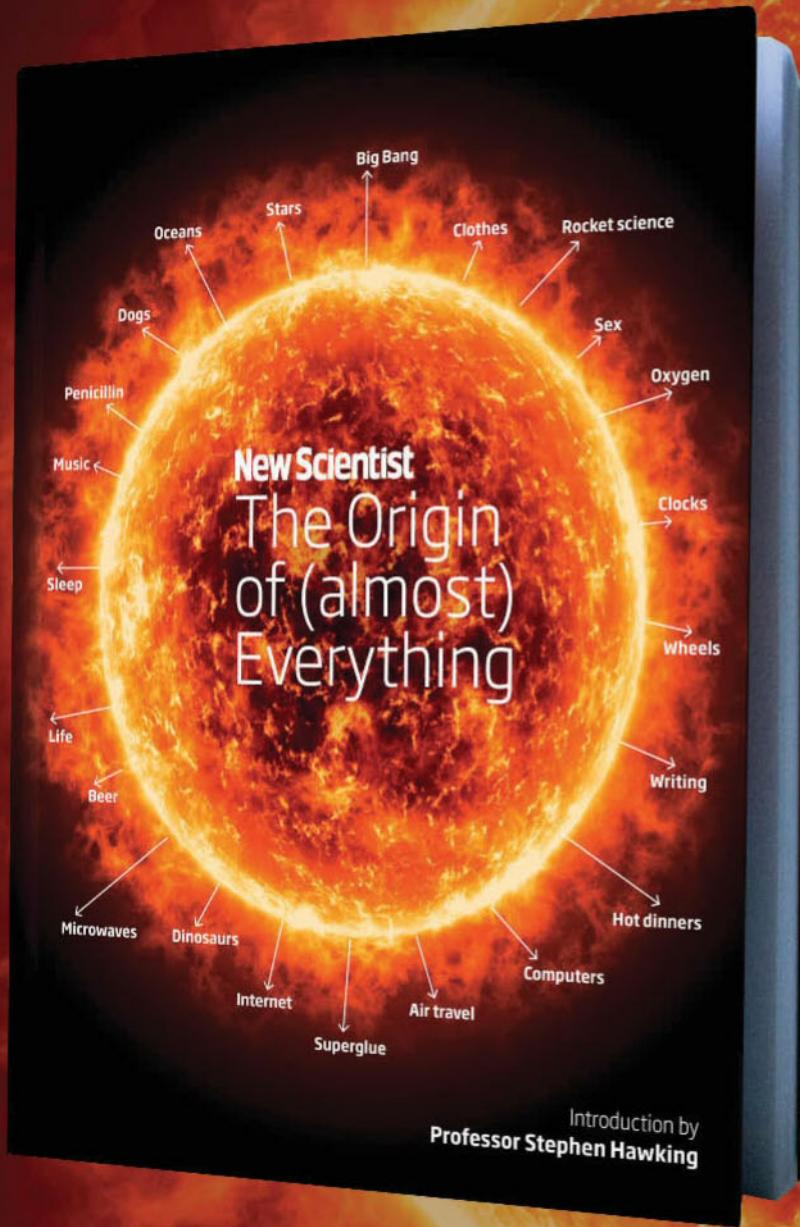
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Introduction by **Professor Stephen Hawking**

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Pixels that change colour under light may fight forgery

THIS will have you seeing double. Two different images have been printed in the same space using nanomaterials.

To create the image, Alasdair Clark at the University of Glasgow, UK, and his team used what they call nanopixels. Instead of being a dot of dye or light, a nanopixel is made of a hole less than a micrometre across in a thin sheet of aluminium.

The punctures are shaped like crosses, with a long arm and a short one. The length of each arm corresponds to the wavelength of one colour of light, for example one nanopixel could encode red in one arm and blue in the

other. When white light is shone from behind the sheet, each hole can only let through one colour at a time.

The colour seen at each pixel depends on how the light coming through the pinhole is polarised – that is, whether the waves of light all oscillate in the same plane vertically, horizontally, or at some angle in between – and so whether it lines up with the long or short arm.

With the right pattern of crosses, two different pictures can be stored on the same surface at the same time, each visible under a different type of polarised light (*Advanced Functional Materials*, doi.org/cdd8).

Unlike regular inks and paints, these pixels won't become washed out from exposure to light, heat or humidity. That makes them ideal for anti-counterfeit measures, since they would be tricky to forge.

Star eats its own planets

A SUN-LIKE star seems to have devoured some of its offspring, prompting researchers to nickname it after a titan from Greek mythology.

The star HD 240430 is part of a binary system, and the two have now been nicknamed Kronos and Krios. They both seem to be about 4 billion years old, suggesting they were born from the same interstellar cloud, and initially

had the same chemical make-up.

But an analysis by Semyeong Oh at Princeton University and her team found that Kronos has far higher concentrations of elements like lithium, iron and magnesium in its atmosphere than its companion (arxiv.org/abs/1709.05344). In fact, the stars are more chemically different than any pair yet discovered.

This could be because they

hooked up later in life, rather than being born together. Or perhaps the cloud they came from gave them different concentrations of elements.

But Oh and her team argue that the difference could be explained if Kronos devoured several orbiting rocky planets. They calculate that it would take 15 Earth masses crushed up and scattered throughout Kronos's roiling atmosphere to explain the star's blend of excess elements.

'Veggie' dinosaurs munched shellfish

PLANT-EATING dinosaurs may not have been as strict vegetarians as we thought. Some seem to have occasionally dined on shellfish.

Karen Chin at the University of Colorado Boulder studied 15 coprolites – fossilised excrement – from dinosaur-era Utah.

The dinosaurs mostly ate rotten wood, but in 10 of the samples, Chin found shell fragments. She consulted Rodney Feldmann at Kent State University in Ohio and they realised the shells were the remains of ancient crustaceans (*Scientific Reports*, doi.org/cdd7).

The shells had clearly been eaten, says Chin, because they had been disintegrated. She says it is most likely that "duck-billed" dinosaurs called hadrosaurs ate crabs or crab-like creatures.

Nobody knows why. Perhaps females ate crustaceans as a source of protein and calcium to make eggs, or dinosaurs resorted to them when food was scarce.

Alloys could let planes fly longer

A NEW process for 3D printing could pave the way for lighter, faster aircraft that may fly further on the same amount of fuel.

The lightweight but strong aluminium alloys used for today's aeroplane frames have a problem: when heated for welding or 3D printing, they weaken and fracture. Instead, parts are held in place using rivets, which adds weight.

But by coating the metal particles used to 3D print components with zirconium nanoparticles, researchers at HRL Laboratories in California have found a way to create a crystalline framework for the molten alloy to follow as it cools (*Nature*, doi.org/cdhp). This lets the part retain its physical strength once cooled – possibly spelling the end of rivets.

Older dads pass on more mutations

OLDER fathers pass on more genetic mutations to their children than older mothers do. The team behind the discovery hopes to understand how such mutations put children at risk of rare diseases.

New mutations are genetic alterations that appear for the first time in embryos rather than being carried for generations. "A large percentage of rare diseases in children are rooted in mutations that are not found in their parents," says Kári Stefánsson of deCODE genetics, based in Iceland.

To find out where these mutations are coming from, Stefánsson and his team sequenced the genomes of 14,688 Icelanders, including parents and their children.

They discovered that 80 per cent of new mutations come from the father, and that the number of mutations increases with the age of the parents (*Nature*, doi.org/cdd9).

This makes sense: women are born with all the eggs they will ever have. These cells aren't thought to divide. Men, on the other hand, are continually making sperm – and every cell division carries the risk of creating a new genetic mutation.

Research shows that older fathers are more likely to have children with schizophrenia and autism, but the team doesn't know if the mutations they observed are linked to either condition.

SUPERSTOCK



Robotic sucker could hitch a ride on sharks

UNDERWATER robots could soon hitch-hike on sharks and whales thanks to a fish-inspired suction cup that clamps on to sharkskin and other surfaces. "Scientists could record data by attaching this robot to animals without hurting them," says Li Wen at Beihang University in China, whose team developed the sucker.

The design is inspired by the slender sharksucker – a fish that latches on to sharks, rays and turtles using a suction disc on its head. It then eats their faeces and the crustaceans that live on them.

Hitch-hiking like this on sharks and whales could offer an improved way of tracking and tagging these animals.

Saving energy while swimming is a big deal for robots too. None of the few existing swimming robots are particularly fast. Their top speeds approach 6 centimetres per second, slower than even tiny fish. Attaching robots to fish could provide a real speed boost.

The sucker's gripping abilities are largely down to its fish-inspired design, which combines a large suction pad with around

1000 tiny carbon fibre spinules that help the sucker stay attached.

Even on a smooth surface, the sucker has serious sticking power too, notwithstanding forces trying to rip it off equivalent to more than 340 times its own weight (*Science Robotics*, doi.org/cdff). In the lab, it has been attached to sharkskin, glass, a carton of orange juice and an iPhone.

The next step will be to fix a hitch-hiking robot to swimming sharks or dolphins, and see how well it can hang on in the real world.

Household chores extend your life

TIME to get moving – and cleaning. One in 12 early deaths could be prevented with 30 minutes of physical activity, five days a week. But you don't need to be sweating in a gym – walking to work and household chores also count. That's the conclusion from the world's largest study of physical activity, which analysed data from more than 130,000 people in 17 countries.

Participants provided information about their typical weekly exercise regime and their medical history and lifestyle. They were followed-up at least twice over the next seven years to record information about cardiovascular disease and death.

Over the period studied, Scott Lear at McMaster University in Hamilton, Canada, and his colleagues found that 150 minutes of activity per week reduced the risk of early death by 28 per cent and rates of heart disease by a fifth.

If the world's population met these goals, 8 per cent of early deaths over seven years would be prevented (*The Lancet*, doi.org/cdfc). "Exercise truly is the best medicine for reducing the odds of an early death," says James Rudd at the University of Cambridge.



REUTERS/GINNETTE RIQUELME

No way to spot big earthquakes

ALL earthquakes look the same when they start, so it is unlikely that we could predict which will prove most devastating from early observations.

Early warning systems rely on seismometers picking up tremors before major shaking starts. Even a few seconds' warning can make a lot of difference, says Daniel Trugman at the Scripps Institution of Oceanography in La Jolla, California.

Mexico got a 10 to 15-second alert before last week's quake, says Men-Andrin Meier at the California Institute of Technology in Pasadena.

But such warning systems must

estimate the size of an earthquake from the earliest tremors. Meier had hoped to show that small and large earthquakes start differently, revealing the really big ones right away. "Our results show that such hopes are not realistic," he says.

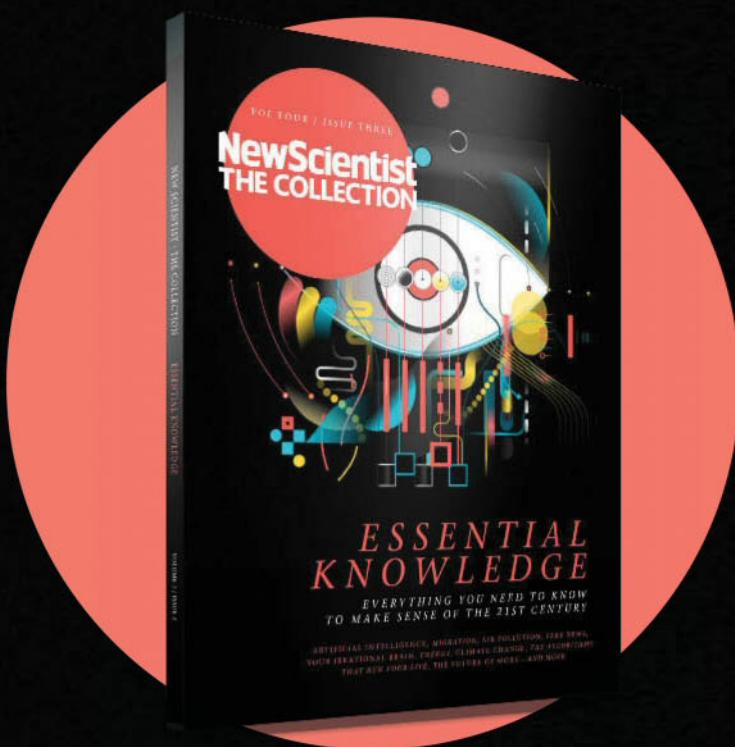
Earthquakes grow until they hit a peak and then decay. When Meier and his colleagues analysed 116 large earthquakes from the past three decades, they found they all grew at steady rates. Different-sized earthquakes were statistically indistinguishable until they reached their peak (*Science*, doi.org/cdd6).



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Exploring the digital future

Share and share alike?

Estonia wants to introduce the free movement of data as a fundamental principle of the European Union. **Douglas Heaven** asks if a digital super-state is a good idea

BREXIT is having many unexpected consequences. One of them could be the start of a digital super-state. With the UK no longer in a position to take on its scheduled presidency of the European Union this year, Estonia, one of the most digitally advanced countries in the world, has stepped up for the first time, and plans to remake the EU in its own image.

Estonia's government bureaucracy is paperless, its public services are online, and data is shared freely between state bodies, making life easier for citizens and businesses. This week, the nation will host a meeting of EU heads of

state to discuss the technological future of the union.

The key to it all is data. Estonia wants the EU to adopt data as a "fifth freedom" – alongside goods, services, capital and people – promoting its free movement across EU borders. But is pooling half a billion people into a single digital nation a good idea? Can you apply a system that works for a small country of 1.3 million across the 27 member states remaining once the UK has left, each with different infrastructure, security policies and public attitudes to data?

This digital version of the "ever

closer union" is the kind of EU initiative that Leave voters want to get away from, but what Estonia's plans mean for a post-Brexit UK is not yet clear. They are unlikely to take effect before the UK leaves the EU. But what role the UK will play once outside the club remains to be seen (see "Data haven", right).

For the remaining EU members, there are clear benefits to sharing data. At the moment, a lot of data lives in silos. Most nations require

"Estonia, one of the most digital countries in the world, plans to remake the EU in its own image"

that servers holding certain information must be physically located within their borders. This makes sense for data pertaining to national security, for example. But in many cases, such restrictions are out of date.

Take laws that require a company to keep its financial records in the country in which it is based. This made sense in an age of paper records, when a company could file records overseas to dodge tax audits. But with digital records, it doesn't matter where they are stored, as long as they are accessible.

When Estonia published a

paper explaining its digital vision in July, it gave the example of an Estonian start-up selling software to universities. The system is used by 150 institutions across Europe, but the company is struggling, as many states require student data to be kept in the same country as their university, forcing the company to navigate local laws.

This regulatory overhead is bad for business. If the existing four freedoms that underpin the EU's single market are to continue, the data attached to them will need to flow as freely, argues Estonia.

"Free movement of data is the digital equivalent of the highways and roads that make the freedom of goods work," says Luukas Ilves, part of Estonia's diplomatic mission to the EU.

Reduced bureaucracy

According to consulting firm McKinsey, global cross-border data flow, mostly from the likes of internet giants such as Amazon or Ebay, generated \$2.8 trillion in GDP in 2014 – more than the value of global trade in goods. Estonia wants the EU to grab a larger share of that pie.

Sharing data between countries is good for citizens too, says George Theodorakopoulos at Cardiff University, UK. As an EU citizen who has worked overseas, he has experienced the downsides of data duplication. "I've had to go to government agencies in different countries giving them the same information over and over again," he says. It would be much easier to submit that information once and simply authorise each agency to access it when they need to, he says.

He's not the only one experiencing this hassle. There are 8 million journeys between Estonia and Finland every year, says Ilves. To get health insurance, some people end up printing out a form, carrying it across on the ferry and handing it over on the other side – where it gets digitised again. "It's a waste of people's

time," says Ilves, which is why the two countries are planning a pilot to share medical information across borders.

Other countries could set up similar agreements, but, with hundreds of thousands of people moving around the EU each year, it would be better to set up common standards, says Ilves. The digital infrastructure needed to implement this EU-wide "once only" principle is being explored in a larger pilot involving joining up government IT systems across 21 countries. The know-how is nearly there, says Ilves.

But there are major hurdles. For a start, sharing data between 27 countries is a security nightmare. It's easy to legislate that every member state should have adequate security for data stored within its borders, but achieving that will be hard.

The Estonians talk up their secure domestic networks, pointing out that they have never been hacked. But this digitally advanced country was still heavily hit in a large-scale cyberattack that took out its internet in 2007, known as Web War 1. And data breaches, such as the recent theft of 143 million customer records from US firm Equifax, are a regular occurrence around the world. "It's a fundamental truth

of computer security that nothing is completely secure," says Theodorakopoulos.

The problems with Estonia's vision are similar to those with care.data, the UK government's now defunct proposal for digitising NHS England patient data, he says. "Making personal data easily accessible, transferable and shareable is a disaster waiting to happen."

There are ways to reduce the risk. Kaspar Kala, one of the authors of Estonia's vision paper, admits that storing data in multiple places increases the risk of attack. That's why Estonia

"It's a fundamental truth of computer security that nothing is completely secure"

doesn't duplicate data across different computers. Instead, each government department holds only part of the data and requests the rest from other agencies.

"If one registry gets attacked, the amount of data you can get from that registry is limited," says Kala. "There isn't a single database that is a single point of failure."

Still, hackers are just one concern. Should we also worry about legitimate data-hoarders? Kala and his colleagues say that

free movement of data will give machine-learning algorithms more to feed on – and more data should mean smarter artificial intelligence. But in a cross-border free-for-all, how much data should we allow governments and companies to hold on us – and for how long? And should we expect AI trained on public data to also be publicly held, rather than locked up by private firms?

Such questions are at the heart of the EU's General Data Protection Regulation, which comes into force next year and offers far-reaching protections to EU citizens, like the right to ask social media companies to delete their data. It also lets people opt in to data-sharing arrangements, rather than having to navigate opaque terms to opt out.

These strict privacy policies are at odds with Estonia's plan, says Theodorakopoulos. How do you square the right to control your own data with its free flow across borders? Asking each person to give permission every time an organisation wants to access their data is impractical, he says. Kala agrees – too much admin and legalese will mean people just click to consent without reading what they sign up to.

Ultimately, the vision of data as a "fifth freedom" stands or falls on trust. Many people don't trust their own government with their data. Estonia is asking EU citizens to trust governments of other countries. The fact that Germany and France, for example, have a more cynical outlook on data sharing and privacy than Estonia makes this an uphill struggle.

Rather than dropping restrictions in one go, Theodorakopoulos thinks the best way to get data flowing is to open doors one by one. "Let's start with specific scenarios where we see a clear benefit and where the risk of sharing is low," he says.

After all, the last thing the EU needs right now is another backlash against its growing power, and the risk of more exits. ■

DATA HAVEN

When the UK leaves the European Union, it could find itself sandwiched between two very different data regimes. Last year, the EU adopted the General Data Protection Regulation, which restricts the sharing of data with non-EU countries. The UK is drawing up its own set of regulations, although these are expected to be less stringent than the EU counterpart.

Some speculate that this could turn the UK into a "data haven" – a halfway house between relatively lax US laws and those of the EU. Data-hungry internet companies might find this an attractive place to do business.

On the flip-side, if the EU relaxes restrictions on sharing data between

member states (see main story), then UK firms could find themselves on the wrong side of a digital wall.

But that may not be bad news to everyone. Inge Graef at Tilburg University in the Netherlands points out that many organisations might not like operating in a more open culture. "Sharing data in the short term could lead to more innovations," she says. "But in the long run we could see less innovation if companies are less willing to invest in things they will have to share."

Companies might even set up in the UK specifically to avoid sharing data. As with nearly everything related to Brexit, the future is uncertain.

Last of the lost

Should we leave uncontacted peoples alone or force them into the modern world to help protect them, asks **Curtis Abraham**

WHILE gathering food in a remote stretch of Brazil's Amazon region, members of an uncontacted tribe are reported to have run into gold prospectors. The prospectors allegedly killed 10 of them and, after drinking in a bar, bragged about the gory details.

International outrage followed, and an investigation has begun. As well as anger, the incident inevitably rekindles the question of whether uncontacted tribes should be left alone or ushered into the modern world to help protect them.

Although it is hard to know exactly how many such groups are at risk, there are thought to be more than 100 left, mostly in forests in Central Africa, South America and New Guinea.

Such peoples still have a strong relationship to the land they live on. But pressure is growing. Outsiders often want to exploit



that land for timber, mining, dams, road-building, ranching and settlement.

Resulting contact often leads to violence. In 2014, the Sapanawa Indians of Brazil came out of the forest after outsiders, possibly illegal loggers, massacred many of their older members. And violence isn't the only threat: common diseases such as influenza and measles, to which the uncontacted have little or no immunity, often prove fatal.

Some think these peoples should be actively sought out and brought into the modern world to safeguard them. Proponents say this would allow them to benefit from modern medicine and other protections.

It sounds tempting, but it isn't the best answer. The reality is that groups who make contact often end up on the lowest rung of the ladder, sometimes as beggars or

Give them a medal

Drone pilots deserve military honours despite the lack of physical risk, says **David Hambling**

MILITARY drone pilots should get medals for controlling aircraft over battlefields thousands of kilometres away, says UK defence secretary Michael Fallon. His comments will spark a heated debate rooted in age-old worries about technology in warfare.

The US has already battened this around. Three years ago, its

defence secretary pulled the plug on the Distinguished Warfare Medal, which would have gone to uncrewed aircraft and cyberwarfare operatives. Veterans' bodies complained that the medal demeaned holders of existing combat awards.

Behind such objections lies the ancient idea that warfare is about

physical valour and skill at close quarters. Killing with lance and sword was considered chivalric, while doing so from a distance was ignoble and cowardly.

The argument against honouring drone crews is similar. Operators in cubicles in the US or UK don't face the same physical risks as colleagues in the battle zone. They do, however, suffer disproportionately from post-traumatic stress disorder. Unlike jet pilots, drone operators see the

"Drone crews suffer PTSD disproportionately. They see the results of their missile strikes in close-up"

bloody results of their missile strikes in close-up. Psychological damage is real. On that basis, Fallon's suggestion is justified.

The UK military has two kinds of awards: campaign medals for serving in a particular conflict and those for valour. The drone medal would be of the first type.

Stealth may be Fallon's best approach. In the US, the Pentagon quietly introduced 12 awards earlier this year. These are variants of existing medals, some with an "R" prefix to indicate Remote roles. Drone operators earn less than aviation crews and have less chance of promotion. The new awards will provide some

prostitutes. History shows that these groups end up in a far worse state after contact. Many succumb to addiction to alcohol or drugs.

That is why the choice of making contact and the speed at which a culture adapts to modernity must be left entirely in the hands of these groups, many of which are well aware of the existence of wider society.

This is ultimately about self-determination. The only way to enable that is to ramp up protection of indigenous land, to properly fund that effort, and to meet the spirit of the 2007 UN declaration on indigenous rights, which makes it clear that the areas uncontacted peoples occupy should be safeguarded.

There is another upside to this approach. These groups have a lot to teach us about different ways of living and thinking. They can be prime conservers of their land, and indigenous areas are said to be the best barrier to deforestation.

The outside world should help protect without interfering in such unique ways of life. If uncontacted peoples choose to make contact with wider society, they will find a way. But the choice must always be theirs. ■

Curtis Abraham is a writer based in Kampala, Uganda

measure of recognition and encouragement at a time when there is a shortage of drone recruits.

In the longer run, this debate could become even more divisive. Is it possible that AI will one day display what we now consider courage, carrying out actions that would win a human pilot a medal? Will new types of award be created to motivate autonomous systems to carry out acts of valour? If so, expect new battle lines to be drawn in the debate over military honours. ■

David Hambling is a science and technology writer based in London

INSIGHT Vegetative state



Court ruling on ending life support is right

Clare Wilson

SHOULD someone in a vegetative state, with no awareness of themselves or what is going on around them, be kept alive with a feeding tube for years after all hope of recovery has gone? It's a question not many want to think about, but some families have to.

Now, a judgment from the Court of Protection of England and Wales may make it easier for the families of people in such conditions to stop artificial feeding and let their loved one die without having to go through a lengthy and distressing legal process.

It might seem like this could allow significant decisions to be made too easily, or even that the court is legalising a form of euthanasia. In fact, this change is long overdue, and is in line with other Western countries, such as the US and Australia.

The ruling concerns people who are left in a permanent vegetative or minimally conscious state, usually after they have received a brain injury and emerged from a coma into a state where they can breathe unaided but have almost no sign of awareness. They would die without a feeding tube

providing nutrients and fluid.

Once it is clear that someone's condition is permanent, many families agree with doctors that their relative shouldn't be given any medical treatments that could prolong their life. These might include antibiotics, or resuscitation if their heart stops. Often the patients die after a few years from pneumonia or other infections, but some can live for decades.

Until now, though, a judge's approval was needed to remove someone's feeding tube – even if the family and doctors agreed it was in the patient's best interests. Most families are put

"Until now, a judge's approval was needed to remove the feeding tube of people with this condition"

off by that prospect, as the legal process can take many months or even years, cost them tens of thousands of pounds, and the environment can make them feel like they are doing something hostile to their loved one.

There are thought to have been only about 100 such court cases in the UK over the past two decades, says

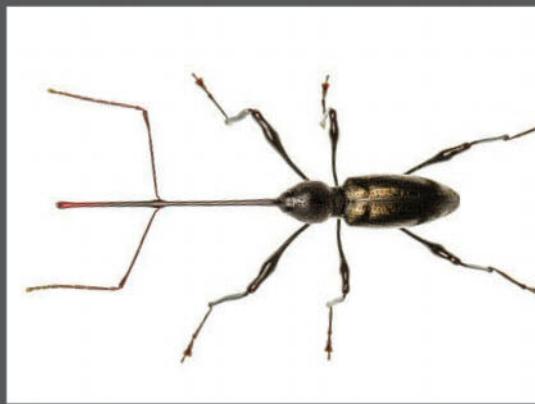
Celia Kitzinger at the Cardiff-York Coma and Disorders of Consciousness Research Centre, though no central records are kept. In comparison, up to 16,000 people are estimated to be in a permanent vegetative state in the UK, plus about three times that number in a minimally conscious state.

We are better than ever at saving the lives of people with devastating brain injuries, but if recovery is incomplete, this leaves more people and their families in the most horrible kind of limbo. Doctors in places like the Netherlands, where there are only a few tens of people in a permanent vegetative state, regard what goes on in the UK with horror, says Kitzinger.

When a feeding tube is removed, the patient can take around two weeks to die from organ failure caused by dehydration, during which time they are given pain relief and heavy sedation. It's no worse than letting someone die from pneumonia, says Kitzinger, which can be distressing for the family as the patient's breathing becomes laboured and choking.

The previous legal guidance in England and Wales – that, for these patients, feeding tubes are unique as a medical treatment that can only be removed by court order – has long been criticised. The new ruling could be appealed, but if it stands, we can welcome the fact that doctors and families will be able to make this hard decision without referring to the courts. ■

APERTURE



Celebrity beasts

THIS is how to give the bugs, birds and bees in your backyard a celebrity makeover. With glamorous photo shoots on brilliantly lit but plain white backdrops, the Meet Your Neighbours project plucks these beasts from obscurity and gives them the star treatment.

This selection of A-listers was shot by local photographers in field studios all round the world. Clockwise from top left, the first to step onto the white carpet is a cicada nymph from Panama that mimics leafcutter ants. Next up, the heavy-set dude with the prominent eyes is a mole cricket from the Netherlands, and its flamboyant neighbour is a flag-footed bug, also from Panama.

Below it, resplendent in a green, fluffy number, is a pale tussock caterpillar, alongside a cheerful-looking forest dung beetle - both from France. A hieroglyph-like long-snout weevil from the Amazon basin in Ecuador takes centre stage just above.

In the far corner, and sporting the latest protective headgear, is an armoured cricket from Cameroon. And the final celebrity to take to the stage is a fetching Spanish festoon butterfly from Germany.

Niall Benvie and Clay Bolt, who founded the project in 2009, hope the photos help excite interest in otherwise overlooked wildlife. They invite more photographers to contribute, either through the Nature Picture Library in Bristol, UK, or through local conservation NGOs. Andy Coghlan

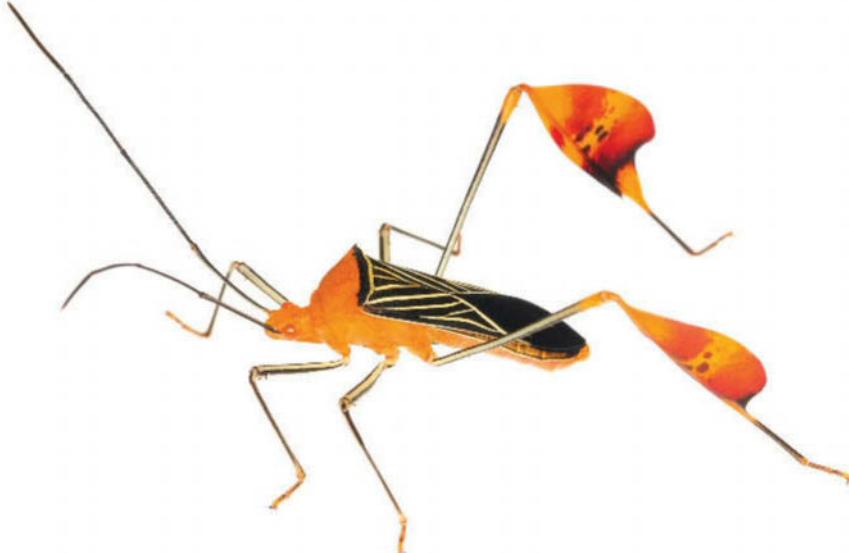
Photographers

Clay Bolt, Dirk Funhoff, J.P. Lawrence,

Marc Pihet, Paul van Hoof, Gil Wizen

meetyourneighbours.net

Nature Photo Library



Throwing shapes

To discover how the brain works, we need to look to higher dimensions.
Anil Ananthaswamy reports

EDWIN ABBOTT, in his 1884 book *Flatland*, created a fictional 2D landscape full of lines, triangles, squares and circles that have no notion of up or down. One day, a 3D Sphere visits Flatland and whisk away a Square to a higher dimensional world. Square learns that Flatlanders are mere 2D projections of 3D beings. He then has the audacity to suggest that Sphere may be a shadow too – of a shape in four dimensions. “The very idea of it is utterly inconceivable,” says the appalled Sphere.

Henry Markram thinks we might be suffering from a similarly blinkered perspective when considering the workings of our own brains. “We look at the brain, we see its immense complexity, but if it’s a shadow projection from a higher dimension, we’ll never understand it,” Markram says. Those aren’t idle words: he and his colleagues of the Blue Brain Project at the Swiss Federal Institute of Technology in Lausanne (EPFL) have been using algebraic topology, a field of mathematics used to characterise higher-dimensional shapes, to explore the workings of the brain.

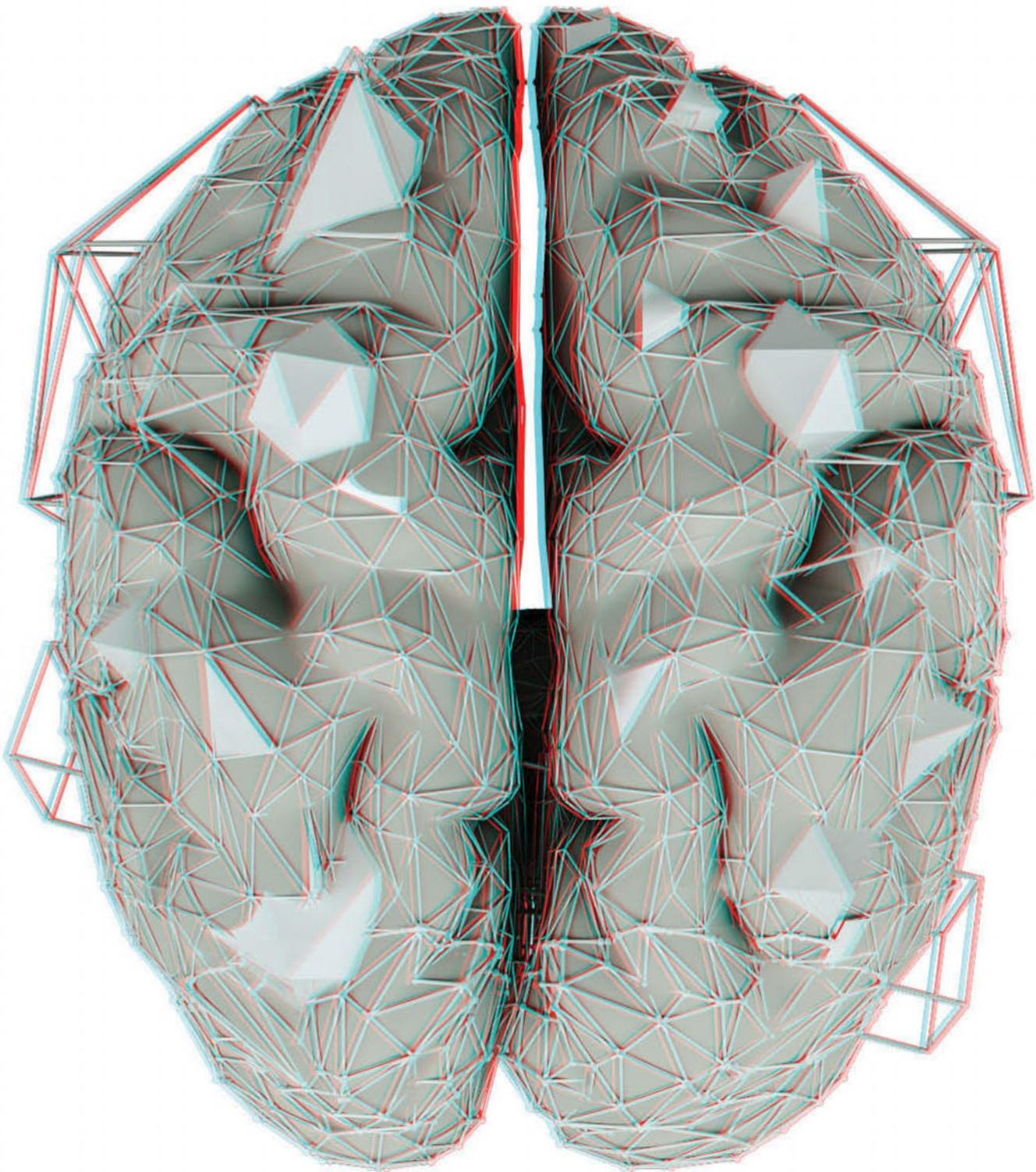
What they have found beggars belief. As our brains think, learn and remember, they create elaborate but ephemeral structures in at least seven mathematical dimensions, and possibly many more. What’s more, these transient structures, which appear and disappear like sandcastles on a beach, could help us understand how the brain creates our thoughts and feelings. They might even unravel the greatest mystery of them all: consciousness. “Algebraic

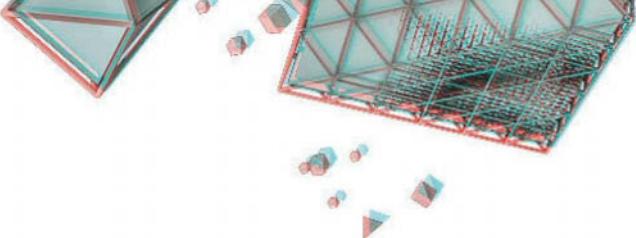
topology is the mathematics to take neuroscience out of Flatland,” says Markram.

The Blue Brain Project was launched in 2005, with the aim of simulating the entire human brain inside a computer. That’s an ambitious goal and far from fruition. In late 2015, however, the team announced it had recreated a sliver of the rat brain that is involved in sensing touch. The real brain tissue is only 0.5 millimetres wide and 2 millimetres long, but its digital analogue consists of 31,000 neurons of more than 200 different types, with some 8 million connections between them (see “How to build a brain”, page 32).

This is the most detailed digital reconstruction of part of a brain ever created. Not everyone thinks it’s possible to understand a biologically complex organ like the brain by simply recreating it inside a computer, but for Markram, the project director, such simulations let you see how neurons work together at a level of detail unobtainable with an actual slice of brain tissue, let alone the whole brain. But he admits there’s a problem: making sense of the data the simulations provide. That’s where algebraic topology comes in.

Topologists study shapes as they undergo continuous deformations – things like pushing, pulling and stretching, but not breaking and reattaching. It’s not always obvious if two shapes are similar. Push your finger into a ring doughnut made of clay and create an indentation, for example, and you can slowly deform this doughnut into a coffee cup. The indentation becomes the inside of ➤





the cup and the doughnut's central hole becomes the handle. The key is that both shapes have just one hole – the topology's invariant property. "People call topology rubber geometry," says Kathryn Hess, an algebraic topologist who also works on the Blue Brain Project. "Things can be deformed as if they are made of rubber or silly putty." The algebraic part refers to the use of algebra to represent and manipulate the properties of such objects.

Markram's fascination with the subject began in 1994, when he was neuroscientist at the University of Heidelberg in Germany. There he met algebraic topologist Ron Levi, and the two began discussing how this branch of mathematics might be used to understand the brain. Levi introduced Markram to Hess, and the three have spent years speculating

"How does a gigantic mass of identical cells produce such beautiful complexity?"

about the topological shapes that might form in a working network of neurons, and what these shapes might have to do with brain function. "The algebraic topologists are very pure mathematicians, they live in these high-dimensional spaces, and they don't really care about the realities of life," says Markram. "So we had very, very abstract discussions." The Blue Brain simulation provided an opportunity to test those abstractions on real data.

They were looking in particular for the appearance of structures called cliques. A network of neurons can be depicted as a graph, the mathematical name for a diagram like the map of the London underground. The neurons are like the stations on the map and the lines represent the connections between them. A clique is a dense type of graph in which every neuron is connected to every other neuron. They correspond to geometrical shapes: three neurons in a clique form a 2D triangle; four will form a 3D shape, a pyramid with triangular faces known as a tetrahedron. But if the cliques have more than four neurons, the geometric structures they represent exist in mathematical dimensions higher than we can visualise – four dimensions for five neurons, and so on (see "The multidimensional shapes of thought", below).

Other researchers had seen such cliques in real brains. For example, Chad Giusti at the University of Delaware in Newark and his

HOW TO BUILD A BRAIN

The goal is to recreate a human brain in a computer. There's still a long way to go, but the Blue Brain Project at the Swiss Federal Institute of Technology in Lausanne has made a start.

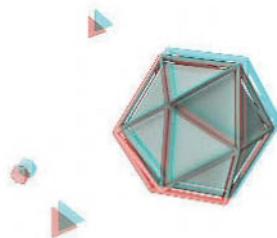
In 2015, the team published a digital simulation of a tiny slice of a rat's brain – the somatosensory cortex, which processes touch. Even this took years of painstaking work. More than 20,000 experiments on rat brains were used to meticulously model the shape of neurons, together with their properties such as electrical signalling and molecular mechanisms. Then, using anatomical details from five rat brains – factors such as the thickness of layers and the density of neurons in each – the neurons were assembled into a detailed digital model.

The next challenge was to figure out how these neurons would be connected. "No amount of experiments, even in the next 100 years, is going to give you all the data on all the connections that are inside a piece of brain the size of a pinhead," says Henry Markram, director of the Blue Brain project. Instead, the team had to rely on biological principles. For example,

neurons must be within 3 millimetres of each other to connect.

But if all the neurons within shouting distance got interlinked, the network would be far more densely connected than it actually is in the brain. So the team applied algorithms to prune connections, to get the level of connectivity seen in real neural tissue.

Finally, they tested their simulation to see whether it responded to sensory inputs in the same way as the real thing. "The digital piece of tissue behaved very similarly to what we see in the brain," says Markram. "We see the same patterns of firing, with the same delay."



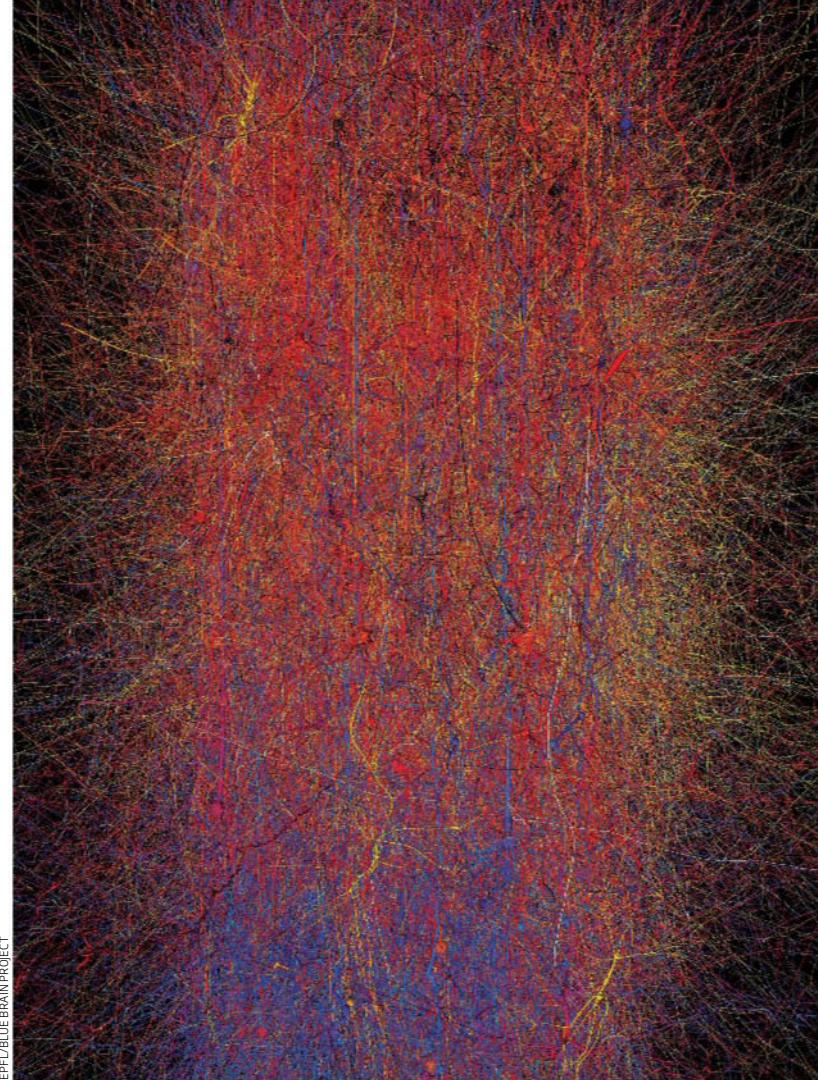
colleagues found them when looking at the electrical activity of neurons in the hippocampus as a rat ran around its environment. But they were unable to discern the direction of information flow from one neuron to another within these cliques, which is crucial to understanding how they work.

This is a general problem when working with a real, functioning brain. "Directionality of information flow is very difficult to ascertain," says neuroscientist Olaf Sporns of Indiana University in Bloomington, who coined the term "connectome" for the brain's connectivity diagram. But it's not a problem when you're working with a digital brain.

Hess, Levi and their colleagues looked for "directed" cliques in the Blue Brain data, in which information enters via one neuron, passes through each of the other neurons and

then exits via the last. So, for example, in a clique of three neurons, A, B and C, the information must flow from A to B to C, even though they are all connected to each other. You can tell whether this is the case by looking at the synapses connecting each pair of neurons, because information flows only one way across them.

The team was in for a surprise. The biologically inspired network had many times more directed cliques than a randomly constructed network would. "And, there were more of the higher dimensional ones," says Hess. They found directed cliques with up to eight all-to-all connected neurons, forming 7D cliques – a number Hess thinks will increase as the Blue Brain simulation grows in size. "I expect we'll find cliques with up to 15 neurons or 20 neurons," she says. But the



Neurons firing in the brain create tangled webs of connections

complexity doesn't end there. The team saw that cliques come together into structures called cavities. For example, several 4D cliques can bound the surface of a 3D cavity. "This doesn't happen by chance," says Hess.

So far, so abstract. What do these structures have to do with brain function? Well, in a real brain, neurons that fire together wire together: the more two neurons work together, the stronger their connection becomes. And when the researchers let their simulated brain buzz with spontaneous activity, they found that pairs of neurons connected as part of a directed clique were more likely to fire together than pairs simply connected, but not part of a clique. What's more, the bigger the clique a pair of neurons belonged to, the more likely they were to fire together. "This was already an 'aha!'" says

Hess. "Being connected is not enough. You have to be connected and be a part of a bigger structure. That was the first indication that we were on the track of something interesting."

The clincher would be to see how the digital brain would respond to the sort of stimuli that occur in a real brain. To find out, the Blue Brain team first recorded various neural signals that reach a real rat's somatosensory cortex – the part of the brain that processes touch – when its whiskers are tickled. Then they fed nine different sets of such signals to the digital simulation to see what would happen. They found that simple 1D and 2D cliques formed first, and then quickly grew into higher-dimensional cliques, sometimes reaching all the way to 7D. The stronger the tickling stimulus was and the more synchronised the input received by the neurons, the more

dimensions the cliques formed. Once the peak was reached, the structures collapsed. "There's a culminating point, and poof, everything collapses," says Hess. Typically, the process would last a few tens of milliseconds.

The topological perspective shows how individual neurons work together to process information. "It's only when you put on these glasses that suddenly you see this incredible sandcastle, a multidimensional structure," says Markram. Neuroscientists have for decades been looking at the electrical activity in different neural networks and wondering what they all have in common. The cliques and cavities could be it. "When anything happens, the brain builds the most complex structure that it can. It climbs as high as it possibly can go, and then it collapses. All stimuli evoke the same stereotypical, multidimensional sandcastle building and collapsing," says Markram.

Worm map

But could all this simply be an artefact of the digital model? To check this, the team applied algebraic topology to a real nervous system – that of the nematode worm *Caenorhabditis elegans*. The worm has only 302 neurons, and their connectivity has been completely mapped, allowing the team to look for directed cliques. What they found confirmed their simulation. "It's far, far more complex than randomly connecting those few hundred neurons," says Markram. "Even a worm has multidimensional structures, allowing those very few neurons to do incredibly sophisticated tasks. That's why we think this is a universal principle of neuronal organisation." If animals as diverse as rats and worms exhibit complex multidimensional cliques, then "it's pretty likely that this is a highly general phenomenon across brains", says Markram.

If they are right, this study is a big deal, providing a way of analysing the transient connections that determine what an active brain is doing. So what do others think of it? Sporns says he is impressed that the research considers the direction of flow of information within the brain, which has been missing from connectome studies.

Karl Friston, a computational neuroscientist at University College London, agrees, but he also sees a problem with the approach. Trying to explain brain function by understanding its structure is circular reasoning, he says. "This overlooks the small fact that neural network structure emerges from function." In other words, the cliques and other networks that

form are determined by how the neurons have previously fired, and so become wired.

Nevertheless, Giusti thinks structures unearthed using algebraic topology will lead to a greater understanding of function – although it is early days. “The mathematics involved is technical enough that it’s not widely known,” he says, and the mathematical tools are still being developed. But they can potentially do amazing things, he says. For example, they could allow us to compare different people’s brains and different cognitive states. “I think we are at the beginning of a very exciting story,” says algebraic topologist Jacek Brodzki of the University of Southampton, UK.

Already, topological analysis is helping to solve some long-standing puzzles. For example, it is thought that the brain’s power

“Consciousness may itself be a shadow of a higher-dimensional structure”

comes from its “neural plasticity”, its ability to rewire itself as needed. This is a crucial ingredient for learning and forming memories. In theory, a brain is most plastic when there is a 50 per cent chance that one neuron will connect to another in its proximity. Yet in biological brains there is only about a 1 per cent chance that such connections occur, says Markram.

On the face of it this makes no sense, but the topological structures provide a rationale: higher-dimensional cliques and cavities form only when the brain is sparsely connected. If these structures are a reflection of the brain’s ability to process information, then having a lower chance of making connections is better, not worse. “To form complex structures, you have to lose connections,” says Markram. “You have to try to find the lower bound of connections, which is completely radical thinking in neuroscience.”

Another puzzle that the topological lens addresses is how the brain, which looks so homogenous, nevertheless functions as though it were compartmentalised. “You see this tension: on the one hand, you have this gigantic mass of identical cells; and on the other hand, this beautifully complex array of ability of the various regions of the brain,” says Brodzki. Perhaps the cliques and cavities are the missing, emergent structures that influence function. “It’s a great result,” he says.

There are implications for artificial

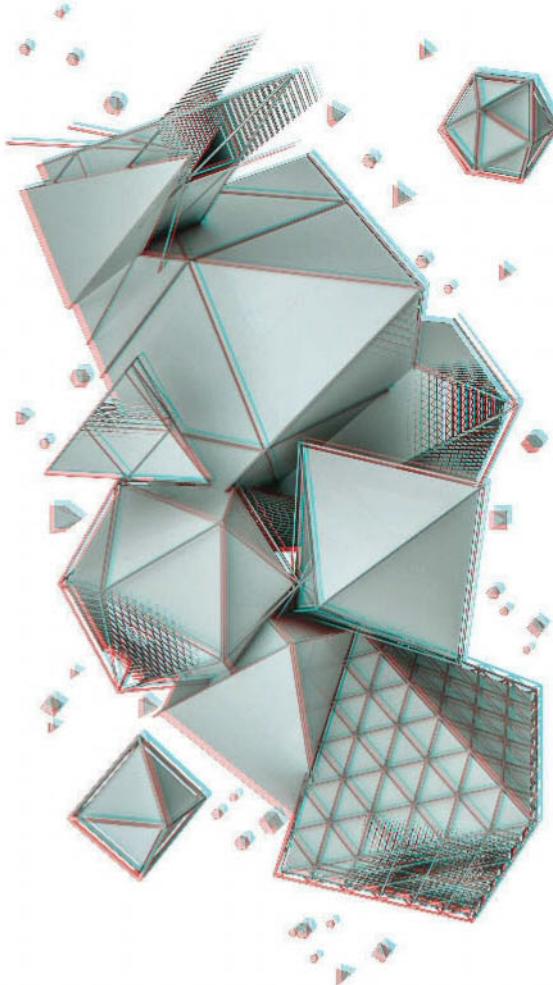
intelligence, too. Richard Granger, head of the brain engineering lab at Dartmouth College in New Hampshire, thinks the Blue Brain Project is addressing a crucial gap in our knowledge about how the brain works. We know the anatomy and physiology at the level of single neurons and at the level of millions of neurons. But what if the intermediate scale is what matters when it comes to information processing? If that’s the case, digitally simulating the brain and trying to find these mid-scale structures could help reveal the brain’s powerful algorithms, which in turn could lead to powerful artificial intelligence.

“These are exciting and potentially groundbreaking studies,” says Granger. “The scientific aim of understanding our brains and the engineering aim of duplicating them rely on our cracking the codes that make brains the best thinking machines we know of.”

For Markram, the next step is to tie the ephemeral structures his team has discovered to learning and memory formation. For decades, neuroscientists have been looking at how synapses change when brains learn or

store information, but they still have little idea what such changes mean. Maybe we have been doing Flatland mathematics all along. “If the changes that occur in the brain only make sense if you map them to a higher dimensional structure, then that’s what you are going to have to do,” he says. “Memory may be hiding in high-dimensional structures.”

As the Blue Brain team continues its effort to create a larger and more accurate digital brain, Markram thinks that one day the topological approach could even help crack that hardest problem of all – consciousness. “When we see a phenomenon that looks mysterious and difficult and intractable, there is a scientific possibility that what we are seeing and experiencing is a shadow projection from higher-dimensional representations,” he says. “We need mathematics to climb up into those higher dimensions. Then we’ll understand how those shadows emerge. Consciousness may be a shadow.” ■



Genuine article?

From alcohol to airbags,
we have a way to root
out dangerous fakes
every time, says
Ida Emilie Steinmark



DETECTIVES from the City of London Police had been investigating the activities of Robert Czernik for a year. In February, they finally picked him up and charged him with "selling goods liable to be mistaken for a registered trademark". That might not sound like a heinous offence, but the goods in question were counterfeit car airbags that would not have worked properly in a collision. Police have alerted 680 people they think bought the airbags on eBay, and Czernik is due to be tried in the coming weeks.

It's a reminder that all manner of goods are subject to fakery. People have tried to counter the problem for hundreds of years using devices intended to prove authenticity. In the Middle Ages, elaborate wax seals were the method of choice in Europe. Today, holograms and watermarks are ubiquitous. But the principle has remained the same all along: ➤

tag goods with an object that is extremely difficult to copy. Trouble is, “extremely difficult” isn’t always good enough – we need tags that are impossible to copy.

That is not beyond our wits. The basic recipe for unfakeable tags has been around for 15 years, but it was always too complicated, costly and impractical. But make it work – as one man now claims he has – and fakery could be a thing of the past.

Criminals do a roaring trade in forging consumer products from cigarettes and alcohol to condoms. They aren’t shy of opportunism: knock-off solar observing glasses led to permanent eye damage for one man watching August’s US eclipse.

Perhaps the most troubling area of counterfeiting is pharmaceuticals. In 2015, Interpol’s Operation Pangea

18%

UK adults that say they have bought counterfeit alcohol

SOURCE: PRICEWATERHOUSECOOPERS, 2013

seized fake medicines worth \$81 million. Sometimes the drugs are merely diluted; other times, active ingredients are replaced with chalk or worse. The problem is most acute in developing countries, but the West gets its share too, with up to half of drugs bought online being fakes.

To see our best anti-counterfeiting efforts, you only need reach into your pockets: banknotes are full of colour-changing prints, watermarks and luminescent inks. Yet cloning each of these features is possible if you have time and resources. In 2007, the forger “hologram Tam” (real name Thomas McAnea) was apprehended in Glasgow, UK, while printing half a million highly sophisticated copies of £20 notes.

In most situations, however, forgeries don’t need to be perfect because the point is not to fool experts but ordinary people. What we really need, then, is a security tag that is both impossible to fake and easy for anyone to verify. Cue the idea of one Ravi Pappu.

In 2001, Pappu was beginning a PhD project at the Massachusetts Institute

of Technology that involved developing machines to scan 3D objects – anything from fingerprints to brains – in fine detail. However, a lot of his colleagues were working on security tags, and an inspiration from the digital world made him think he might be able to help.

Pappu knew that digital cryptography is based on a series of fundamental algorithms called primitives. One of these primitives is called the one-way function, so named because it is easy to compute in one direction but practically impossible backwards. Imagine, for example, multiplying two extremely large prime numbers. That’s easy for a computer, but the reverse – factorising to find the original primes – is so time-consuming as to be unfeasible. Such primitives can be combined like building blocks to do things like generate secure email signatures.

Pappu thought it might be possible to make a physical version of these one-way functions. “The moment I said those words – ‘physical one-way functions’ – in my head, the way to demonstrate it became very clear,” says Pappu, who now works for In-Q-Tel, a non-profit organisation that invests in security technology.

In essence, he needed to create a physical tag that produced some sort of readout, like a string of numbers or a bar code. Getting the readout from the tag should be easy, but working backwards from the readout to make a tag to match should be impossible. If he could pull that off, then products could be labelled with tags that would be easily verifiable via their readout – and entirely unclonable.

In his PhD thesis, Pappu demonstrated how to do just that. First, he stirred microparticles into a gel so they ended up in random positions. Once the gel had set, he could shine a laser at it to create a readout: a speckled pattern of light and shadow.

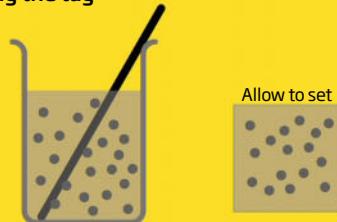
In principle, a manufacturer would be able to create such a tag, measure the pattern of light and shadow and upload the details to a public database. Then anyone buying an object with that tag could measure the pattern themselves and access the database to check the entry matched their purchase.

The ultimate in security

The idea of the unclonable security tag surfaced in 2001, but it wasn’t practical. Taking things to the atomic scale could make it work

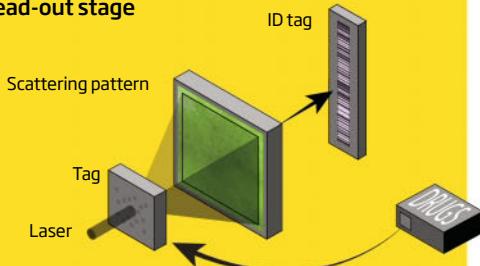
Original method

Forming the tag



Stir microparticles into a gel to distribute them randomly. Pour them into a mould to create a tag

Read-out stage



Consumers would have to use a laser to generate a scattering pattern, and convert this mathematically into an ID code. Then check this against what the manufacturer says it should be

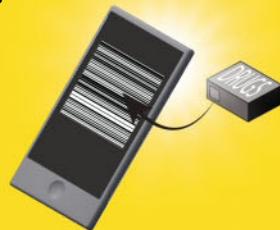
New method

Forming the tag



Sheets of 2D materials like graphene oxide all contain random, unique defects. One of these can be fashioned into an unclonable security tag

Read-out stage



A smartphone camera flash makes the sheets luminesce, and captures the pattern. This can be compared with a manufacturer’s database automatically



Edible security tags could be printed on individual pills

Yes, counterfeiters would be able to see that pattern too. But to clone the tag, they would need to work out the exact positions of the microparticles from the scattering pattern. That would be like looking at a shadow cast by three people standing in front of each other and trying to figure out what they look like. Even if the counterfeiter managed that, they would still need to arrange the microparticles with unattainable precision to get the same readout.

Other researchers embraced Pappu's idea and renamed it the physical unclonable function (PUF). But some wrinkles still had to be ironed out. For one thing, you needed a perfectly positioned laser to read the pattern. More important, though, were the limitations of the readout. The laser beam produced a strictly black-and-white pattern, which would give pixels corresponding to a 0 or 1, when digitised. That generates a lot of possibilities but, ideally, we would want so many that we could never run out of unique tags – enough to label each and every object we might conceivably want to sell.

Over the past decade, researchers have explored PUF designs that would generate higher numbers of unique tags. One idea was to have a coloured pattern. To that end, some researchers

2410

Number of websites selling fake medicines that were shut down by Interpol's operation Pangaea in 2015

SOURCE: INTERPOL

tried using chemical dyes in place of Pappu's microparticles, though that wasn't straightforward because they tended to fade over time.

A way round this hurdle emerged in work by Riikka Arppe, a biotechnologist at the University of Copenhagen in Denmark. Arppe was experimenting with random arrays of lanthanide compounds that luminesce in luscious shades of pink, blue and green. Then she stumbled across Pappu's work and realised she'd inadvertently created a coloured PUF, one that was far more stable than any of the dye-based devices. Even so, "there hasn't been a perfect PUF system yet," she says. Scanning the readout of most of them, Arppe's included, still requires specialist equipment and expertise.

At last, however, that could be changing, thanks to Robert Young, a physicist at Lancaster University, UK. Like Pappu and Arppe, Young never planned to start fighting counterfeiting.

He works on the properties of materials that are one atom thick, like graphene.

A couple of years ago, it struck him that these 2D materials still hadn't found a killer application. The trouble is, they have random defects like impurities and holes in their atomic structure. That makes it "very difficult to make two devices that behave in exactly the same way", says Young. Discussing the problem in a hallway with a colleague one day, he suddenly had a thought: the defects could actually be useful – in PUFs.

Young's idea was to make security tags using flakes of 2D materials like graphene oxide or tungsten disulphide, which luminesce colourfully like Arppe's lanthanides. Under a beam of light, the imperfections in each tag create a random and complex luminescent glow. A smartphone's flash is enough to excite the luminescence and the camera can capture it: no other equipment required (see diagram, left).

Young's PUF is probably the most secure yet. Because the luminescence is dependent on each atomic defect, cloning the tag would involve manipulating each atom in the sheet. With current technology, that would take about the age of the universe. "Nobody is ever going to come up with a security solution that is more unique than the atomic scale," says Young.

Best of all, Young's work can potentially help tackle the scourge of fake drugs. The tags are, he says, safe for human consumption. Once they have passed government food safety tests, they could be printed directly on to pills, ensuring that each comes from a trustworthy source.

We don't yet know whether pharmaceutical firms will adopt that idea. But in other areas the transition to things that cannot be faked could be swift. Young's spin-off company, Quantum Base, recently struck a deal with OpSec, one of the world's largest makers of holograms. The firm will start incorporating atomic scale PUFs into their holograms next year. The first products to get the treatment? Car parts... airbags included. ■

Ida Emilie Steinmark is a science writer based in London

The ultimate origin story

Whatever you think of **Lee Berger** and his methods, you can't deny his extraordinary success in finding human fossils. Colin Barras reports

I'M PORTRAYED as a maverick, as a cowboy scientist," says Lee Berger. "What's so funny is that I'm the one following the rules."

Even if you haven't heard of Berger, there's a good chance you are aware of his work. He is the palaeoanthropologist behind the recent discoveries of not one but two new species of human ancestor. The finds were so remarkable that, by some accounts, they are rewriting the story of human evolution, and Berger, his team and his methods are at the centre of it.

In 2010, Berger made headlines after he (or, more accurately, his then 9-year-old son) found a trove of hominin bones belonging to what we now know as *Australopithecus sediba* in the hills north of Johannesburg, South Africa. It was the sort of once-in-a-lifetime find that most people in his line of work only dream of. If Berger had taken the conventional approach, he might have built the rest of his career on analysing it.

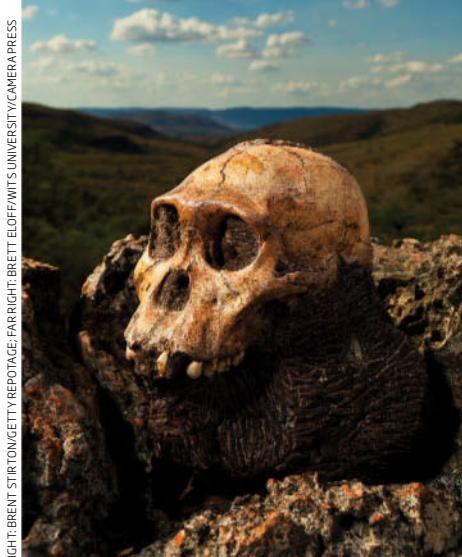
But following convention was not what Berger, an American who made South Africa his home 27 years ago, had in mind. He was convinced that even greater discoveries were waiting, particularly in the ancient caves that riddle the limestone-rich countryside.

He enlisted local help to search them, and hit the jackpot in 2013: two chambers deep inside the Rising Star cave system contained hundreds of bones from another unknown species, which his team dubbed *Homo naledi*. This time, the story went stratospheric, not just for the scale of the find but for its drama. One of the chambers is at the bottom of a 12-metre vertical passage just 20 centimetres across at some points and Berger recruited a team of very slim, palaeoanthropologist cavers to excavate the site. The fact that all of them

were women only heightened the publicity.

Publicity is something Berger has never shied from, indeed he courts it. It's just one of the reasons why, over the years, he has managed to upset and dismay an impressive number of his peers, including some of the most respected senior figures in the field.

The Rising Star excavations (see picture, page 38) are a case in point. Donald Johanson – one of the discoverers of the 3.2-million-year-old Lucy skeleton – has claimed the excavation should have taken months, not the 21 days Berger and his colleagues set aside. Berger responds that this was essentially a pilot



The skull of a juvenile male *Australopithecus sediba*, dubbed MH1, was found largely intact

PROFILE

Lee Berger is a palaeoanthropologist at the University of the Witwatersrand in Johannesburg, South Africa

excavation, although within months his team submitted several papers to *Nature* based on analysis of the fossils. They weren't accepted.

In person, Berger is chatty, warm and likeable. He is clearly passionate about his subject. He is also open about his motives. In the late 1980s, Berger got his first opportunity to join a dig, in east Africa. Right from the start, he saw himself as an explorer. "I wanted to find fossils, to make discoveries," he says, "That's why I went into the field."

But opportunities in east Africa were limited. Many senior scientists had already staked claims there, he says. South Africa, on the other hand, was relatively unexplored, although hominin fossils had been found there since the 1920s. He was accepted to study for a PhD at the University of the Witwatersrand, Johannesburg, in 1990.

He never left. Berger reasoned that being able to hunt for fossils all year round would boost his chances of discovery. He says the main strategy at the time was to look for baboon fossils, since hominins were often found with them. But he wanted to look underground, not least because hominin fossils had already been found in caves. Ancient people would have made extensive use of the vast subterranean networks, he thinks. "This dolomitic landscape is one of most stable in the world," Berger says. "In a sense we're standing on their land."

So far, his team has found the remains of at least 18 *H. naledi* skeletons, of all ages. It's a ➤



"I wanted to find fossils, to make discoveries. It's why I went into the field"

huge hoard, particularly because many hominin species exist only as a handful of bones. "There was a real perception that these fossils are rare," he says – and those who found them became reluctant to share access to such precious objects. "I've watched scientists become possessive," he says. "I vowed early on not to do that if my opportunity arose."

His critics see things differently. They argue that they work on the fossils behind closed doors not out of a sense of ownership but to make sure their published conclusions are solid. Tim White – a co-discoverer of the 4.4-million-year-old "Ardi" skeleton – has insisted that good research can't be rushed.

Yet scientists in other fields collaborate, Berger says. "It's what NASA or the Large Hadron Collider team does: they put as many of the best minds in the world towards a solution." Just months after the first Rising Star excavation, Berger did the same, inviting researchers – particularly young scientists – to a month-long workshop to make sense of the *H. naledi* material. This is what Berger means when he says he is following the rules.

This month, Berger's team is back at Rising Star. They camp at the site even though it is just a 45-minute drive from Johannesburg: it's about maximising time in the field, he says. A typical day begins at 5.30 am with breakfast. By 6.30 they are discussing the day's

Berger directs excavations in the Rising Star caves, where *Homo naledi* was discovered



UNIVERSITY OF THE WITWATERSRAND/BARCROFT

objectives, and shortly afterwards the cavers begin to inch their way into the chambers.

This time, they are looking for evidence that *H. naledi* deliberately disposed of its dead, particularly signs of the fire they would have needed to navigate the deep, dark caves. It's a controversial idea, because the most striking feature of *H. naledi* is that its brain was only marginally larger than a chimpanzee's – much too small, according to conventional thinking, to allow for such advanced behaviour.

Strikingly weird

But the human evolution story is changing in other ways that are making this possibility seem less remote. *A. sediba* existed around 2 million years ago, and we learned this year that *H. naledi* may have lived just 235,000 years ago, yet both have a mix of what were previously considered to be primitive and modern features. This might hint that early hominin history involved a lot of evolutionary experimentation, with an array of unusual looking species forming a family tree with many branches.

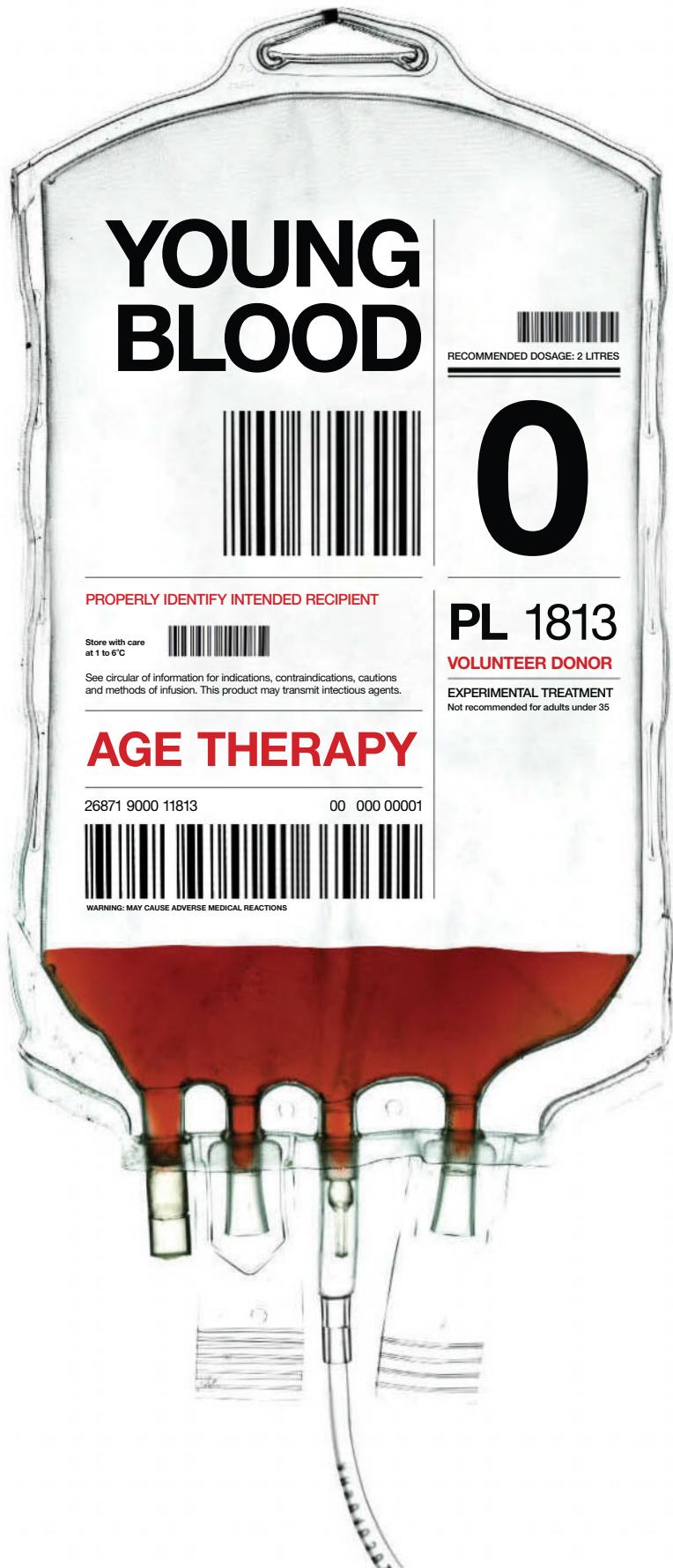
Berger says palaeoanthropologists have often assumed a simpler, linear story. This is partly because many ancient hominins are known only from fossil fragments that might fail to reveal just how strikingly weird complete skeletons can be.

This is a theme that Berger may develop. It's an open secret that his team has made yet another ancient hominin find, unconnected to *A. sediba* or *H. naledi*. Berger is not prepared to share details yet, but he is clearly relishing the prospect.

Berger's enthusiasm is infectious. He is a great storyteller, drawing listeners in and leaving them itching for the next chapter. It's easy to imagine how this might get him in trouble: he does like to push the boundaries of what can be learned from the evidence to hand.

But there is so much more evidence waiting to be found, he says. "These hominin fossils are just not as rare as we once thought. We were looking in the wrong places." When I ask about the scientific legacy he might leave, Berger's answer picks up on this idea. "In 50 years, this might be looked on as the moment when we grew into an evidence-based science," he says. "I hope that this snowball we've pushed off the hill is going to lead to more and more fossils."

In other words, he says, he would like his research to inspire so many others to make spectacular discoveries that *A. sediba* and *H. naledi* no longer stand out as exceptional. "That would be my dream." ■



When **Sally Adee** heard about a clinic offering to reverse ageing, she wanted in. This is what she found

DISCOVER the French bistro tucked into a strip mall that wraps around a parking lot it shares with a hardware shop and a barber. The man I am meeting has asked to come here instead of the clinic because he doesn't want to do an interview while being transfused.

I am led to a booth where I find him drinking a glass of wine, wearing the blazer-and-T-shirt uniform common among venture capitalists. His youthful looks have an enhanced, slightly uncanny cast, but I am still shocked when he tells me he is 65. To protect his privacy, he chooses to be identified for this article as JR.

JR is a minor celebrity in these parts. It is the fifth time this year that he has flown in from Atlanta to have the treatment. Monterey doesn't get a lot of traffic from people like him.

You might think of the Californian coast as a homogeneous stretch of sun-drenched sand and rich people. But things change around the middle of the state. Driving there from San Francisco, you quickly lose the sun behind a permanent blanket of fog. The central coast is long and flat, with glimpses of iron grey choppy waves behind squat buildings.

So it's a bit odd that this is the epicentre of a phenomenon rocking Silicon Valley: young blood treatments. JR is one of about 100 people who have each paid \$8000 to join a controversial trial, offering them infusions of blood plasma from donors aged between 16 and 25 in a bid to turn back the clock. Participants have come from much further afield, including Russia and Australia.

It's not hard to see why. After a spate of recent trials showed astonishing rejuvenation in old mice, the notion of filling your veins with the blood of the young has gone from creaky vampire myth to the latest tool in Silicon Valley's quest to "disrupt death".

Now start-ups, universities and pharmaceutical companies are clambering to commercialise the potential of young blood. Venture capitalists and high-level hospital executives are rumoured to be partaking behind the scenes. The idea's popularity is sparking fears of red markets and a dystopian future in which the old steal youth from the young, and no longer just metaphorically. ➤



Scratch beneath the hype, however, and we may have been looking at young blood the wrong way round. Within a few years, new insights could usher in a safer, more effective way for blood to stop the inevitable declines of ageing.

Mystery ingredients

Vampire tales aside, we have suspected since the mid-19th century that young blood has rejuvenating powers, thanks to a grim surgical technique known as parabiosis. Scientists would stitch together two animals, usually rats – like twins conjoined only at the skin – and wait a week for capillaries to form and fuse their blood supplies. The new plumbing seemed to change the old rats, making them physically and cognitively resemble their younger partners. By 1972, research began to suggest that after being conjoined, old rats even lived longer.

In the early 2000s, researchers at Stanford University in California revisited the technique, this time with a view to reversing specific ailments of ageing. They damaged the livers and muscles of old mice before connecting each one up to an undamaged mouse. Those with young partners healed well. Those with old partners did not. Similar results emerged with regard to heart health, then age-related cognitive declines.

What was it in blood that was having these rejuvenating effects? The prime suspect seems to be plasma, the yellow liquid that gets separated out after donation. Components like red blood cells are used for medical transfusions, but the plasma often goes spare.

Plasma is rich in all sorts of proteins and other compounds, which could hold the key to what makes young people young and old people old. Not that we know what all these components are. But we do know that their amounts and ratios change as we age. For example, old blood has higher levels of inflammatory compounds that damage tissues they reach. Inflammation has been linked to cancer, heart disease and depression. Younger blood, by contrast, is characterised by a higher concentration of stimulating and restorative factors.

An amazing discovery, but to be medically relevant, we must deliver young blood without having to stitch pensioners to 20-year-olds. So in 2014, a team led by Tony Wyss-Coray, a neuroscientist at Stanford University, injected middle-aged mice with plasma from young mice. Sure enough, after three weeks they had anatomical improvements in the brain and a

cognitive boost, compared with mice given a placebo. Every other system they tested fared similarly.

The plasma didn't even need to come from the same species – old mice became just as sprightly when the injection came from young humans. "We saw these astounding effects," Wyss-Coray told *New Scientist* in 2014. "The human blood had beneficial effects on every organ we've studied so far."

Wyss-Coray had the proof he needed to start a human trial. In October 2014, his start-up, Alkahest, began recruiting participants for a trial at Stanford School of Medicine, using young blood in people with late stage Alzheimer's disease. The following year, Bundang CHA General Hospital in South Korea launched a gold-standard trial to compare the anti-ageing effects of cord blood, young plasma and placebo on markers of frailty in ageing. Both trials were met with enthusiasm. Wyss-Coray was invited to give lectures, including at the World Economic Forum and a TED talk.

Then there's the Ambrosia trial, which JR is taking part in. Ambrosia is a start-up headquartered in Washington DC. The trial didn't need regulatory approval because plasma is already a standard treatment to replace missing proteins in people with rare genetic diseases. And there's no placebo arm to it. All you need to join is a date of birth that

ROOTS OF BAD BLOOD

Young blood has been shown to rejuvenate older animals, and potentially humans too. But many researchers now think that rather than containing some ingredient of youth, young blood just dilutes the inflammatory and other factors that accumulate in old blood (see main story).

If that's true, an even better approach would be to get rid of this bad stuff at source. But where does it come from? Judith Campisi, one of the scientific founders at Unity Biotech in California, suspects that senescent cells are the culprit.

If a cell becomes damaged, one possible response is to undergo apoptosis – cell death. Alternatively, it can enter a "senescent" phase, in which it stops dividing. Why? One theory is that senescent cells send out chemical signals that let their neighbours know there is a problem.

That means these senescent cells sit in your body for decades and have a helpful function when you are young. But the longer they stay there, the more of these products they secrete. Eventually, these lead to inflammation and end up damaging organs.

Campisi has recently completed as-yet-unpublished mouse studies firming up the causal link between senescent cells and age-accelerating substances which they secrete into the bloodstream.

She and others are now working on drugs that convince old senescent cells to turn apoptotic. "If we let the senescent cells die off, then we'll be able to stop these proteins at the source," she says.

This would have far-reaching medical effects, for instance removing the underlying cause of age-related diseases like diabetes and blood pressure without individual medicines.



makes you over 35 – and a spare \$8000.

For your money, you are infused with 2 litres of plasma left over from young people who have donated to blood centres (see “Blood myths”, page 42). Unlike the trials looking at young blood’s effects on specific diseases, Ambrosia has a softer target: the general malaise of being old. In addition to measuring changes in about 100 biomarkers in blood, the firm is also “looking for general improvements”, says Jesse Karmazin, who runs the start-up.

The methodology falls short of the normal standards of scientific rigour, so it’s unsurprising that scientists and ethicists have accused Karmazin’s team of taking advantage of public excitement around the idea. “I don’t think the Ambrosia trial can be called a trial at all, since they treat healthy people and they have no clear read-outs,” Wyss-Coray says.

This makes any findings virtually unpublishable, which may explain why Karmazin announced his first results to a room full of technologists at the Silicon Valley Code Conference in May instead of at a medical conference or in a journal. The numbers were as unverifiable as they were impressive: one month after treatment, 70 participants saw reductions in blood factors associated with risk of cancer, Alzheimer’s disease and heart disease, and reductions in cholesterol were on par with those from statin therapy.

Karmazin says this could explain his observations during the trial: a woman with chronic fatigue syndrome is now able to get out of bed and live normally; another participant, who had early stage Alzheimer’s when he enrolled, no longer meets the clinical criteria for having the disease.

“Whatever is in young blood is causing changes that appear to make the ageing process reverse,” Karmazin told me. Even healthy participants “just have more energy”.

JR agrees. “I do feel it a bit,” he says. “I am starting to run again now.” However, although Karmazin says that the effects in the blood are identical regardless of participant age, JR says his 39-year-old girlfriend feels no different after two treatments. As for his youthful looks, JR says he tries out many of the therapies his company invests in.

Not that any of this should be taken at face value. Many of Ambrosia’s claimed improvements could be down to the placebo effect. Even so, the numbers are proof enough for Karmazin. He originally aimed to recruit 600 participants. However, the results have made him so optimistic that he is expanding

the business. When I travelled to Monterey in June, Karmazin had just opened his third clinic, and thanks to recent infusions of investor cash, he is planning a total of six in the US in 2018.

I ended up in Monterey because, for the past year, I’ve been preparing myself to enrol in the trial too.

As it did with much of the public, the idea of the glittering Silicon Valley “blood spa” captured my imagination. The reality of this clinic is somewhat different, though. The one-storey building shares an intersection with a flaking self-storage facility and a pockmarked parking lot.

“Whatever is in young blood is causing changes that appear to reverse ageing”

The interior is also modest; patients pass through a wood-panelled kitchen on their way to the reception. In the main room, a row of armchairs, each with an IV drip stand, faces a window overlooking washed-out scenery that culminates with the Pacific Ocean, barely discernible under the fog. Most of the elderly clients occupying those chairs are not getting plasma, but IV fluids.

When I visit, the trial is being run by Craig Wright, Karmazin’s erstwhile partner. Karmazin has a medical degree but not a licence to practise, so he teamed up with Wright, an immunologist formerly at Walter Reed Army Medical Center in Washington DC, who is licensed to run one of the West Coast’s few non-hospital affiliated infusion clinics.

Although at 67 he could be retired, Wright maintains the clinic to look after his patients. “Healthcare in this country doesn’t give a crap about old people,” he says. One of his clients has dementia that used to regularly put him into the emergency room for dehydration. Another, after several rounds battling lymphoma, had a compromised immune system that left her struggling with recurring infections.

Eventually Wright enrolled her in the Ambrosia trial. Her infections went away.

But by the time I get to the clinic, I am rethinking whether I want to go through with this. Wright and I go into his office so he can give me the consent form. I tell him I’m starting to reconsider, and I am surprised to find he doesn’t try to talk me round. “You need to think long and hard before you do this,” he says. For some of his older, sicker patients, plasma has proved beneficial. For younger ➤

BLOOD MYTHS

Receiving young blood means being attached to a blood boy like in the TV series *Silicon Valley* (pictured below)
No. It's not whole blood that's going into your veins. It's plasma, the pineapple-yellow part that contains all the proteins.

The blood supply will be endangered because young people will choose to sell their blood instead of donate

Probably not. In the US, the average donor is a college-educated white male, between the ages of 30 and 50 – so too old for donations of young blood.

It's as safe as any blood transfusion

Not so. The procedure being used in the few existing young blood clinics is done so infrequently that we just don't have the data on complications. But according to some, the complication rate is 1 or 2 per cent. Others go as high as 57 per cent. By contrast, we do know that blood transfusions have a 1 in 3400 complication rate.

The procedure will lead to dangerous unregulated blood markets

Probably not. Plasma is more difficult to obtain than simple blood donations (and is paid for). Plasma is usually highly refined and processed before use, in case donations come from people with a disease they have not disclosed. People are unlikely to want to risk unscreened "donor plasma" and the diseases it could carry, so if young blood becomes a market it will be regulated.

You should bank your blood before you turn 25

Maybe. We won't know for a long time. Hospitals throw away excess frozen plasma after two years, and there's not yet a lot of research to show whether the relevant proteins survive after that.

We should fear old blood

Experiments suggest that old blood can age a young body. So do we need to take more care with transfusions – for instance avoiding giving children blood from middle-aged donors? No. What's in old blood is there as a by-product of cellular mechanisms. Anything problematic would soon get replaced in a young recipient with normally functioning cells.

would-be participants like me, however, he lists a litany of potential side effects.

Risks commonly associated with plasma transfusion include transfusion-related acute lung injury, which is fatal; transfusion-associated circulatory overload; and allergic reactions. Rare complications include catching an infectious disease: blood products carry a greater than 1 in a million chance of HIV transmission. That's too risky for JR, who tells me that before every treatment he takes a dose of the HIV prophylactic PrEP.

Karmazin had previously assured me that none of the risks associated with plasma transfusion exceed 1 or 2 per cent, a statistic borne out in the trial: in his Code presentation, he told the room that "none" of his participants had reported any negative effects. "Not one."

Complications

But when I meet up with JR and Wright on the second day of my visit, both are visibly shaken. A participant had arrived earlier that day from Moscow to get the infusion. As he started on his second unit of plasma, the man had an anaphylactic reaction. His face and tongue swelled up, and he developed a rash all over his body. "Even the whites of his eyes turned red. He was in a lot of trouble," says JR.

Wright administered emergency treatment to stabilise him and sent him back to his hotel.

I am astonished that my visit has coincided with the first complication of the treatment. There's an uncomfortable silence as JR and Wright exchange glances. "It's not the first one," says Wright. When I press him for more information, he demurs. "You'll have to talk to Jesse."

When I call Karmazin, he clarifies that there was also an eyelid rash and a case of pneumonia that was probably already in place before the patient got the treatment. But in



later conversations with Wright, he tells me of worse cases. Without published data, it's impossible to get to the bottom of it.

Either way, those are the known knowns. There are also known unknowns associated with injecting material from someone who is genetically different to yourself, says Irina Conboy, a co-author on the early Stanford work that put young blood on the map, and now at the University of California, Berkeley.

There could be risks of developing autoimmune disorders. And some fear that pumping stimulating proteins into people for years could lead to cancer. "If you keep infusing blood, the risk of reactions goes up," says Dobri Kiprov, an immunologist at California Pacific Medical Center in San Francisco. "Many of these people are just eager to get younger – they don't have a particular disease, so it's not justified."

It's easy to criticise Ambrosia for charging people to receive an unproven procedure (see "Why does it cost \$8000?", opposite), but there is also no evidence yet that the other trials are yielding anything more promising. Alkahest began recruiting volunteers for its Alzheimer's trial in 2014, but there have been no publications yet. Wyss-Coray plans to announce results in November.

Because there's so much uncertainty hanging over both risk and reward, others are looking for a shortcut. Identify one or more "silver bullets" in plasma to reverse the effects of ageing, and it might be possible to develop a safe, convenient pill.

For a while, the chief candidate was GDF11, a rejuvenating protein that decreases in abundance as we age. In 2013, Amy Wagers of Harvard University reported that daily shots of GDF11 restored the muscle size, endurance



HBO

The idea of young blood transfusions made it to the TV show *Silicon Valley*



BERND GEHRE/GETTY

Foggy Monterey is the unlikely hub for a potential rejuvenation therapy

and grip strength of old mice to levels seen in a much younger individual.

Then there's the protein osteopontin, which seems to keep blood cells young and provide an immune boost. And now a protein called TIMP2 from umbilical cord plasma has been shown to improve the performance of old mice in cognitive tests.

Attractive as this option is, it needs a reality check. "There's a lot of hype around single protein factors," says Hanadie Yousef, who also works on plasma at Stanford. "But one plus one is not always two in biology. We don't know which constituents are working together, or how."

Indeed, there was an initial flurry of enthusiasm over GDF11, but multiple labs have failed to replicate Wagers's result.

Besides, it could be that the curative powers of young plasma were a red herring all along. Many conclusions have been drawn about the power of young blood, but most of these come from parabiosis.

The problem is, parabiosis isn't just about blood. There are other reasons the older mice might have benefited from the deal. "These old mice suddenly had access to much more than just young blood," says Conboy: a young liver to filter toxins, a young heart to pump harder, young lungs and all the rest. Not to mention the environmental enrichment. "They were now getting dragged around by the young mice instead of sitting in a corner all day," she says.

So Conboy set out to tease out the effects of blood from those of being joined to another mouse. Funded by Google's life-extension

biotech arm Calico, among others, she developed an experiment in which a pump ferried half the blood from one individual into another. "We were transplanting half the blood supply into the old mouse, not just a bit of plasma," she says. "If you tried this in a human, it would be fatal."

The young blood didn't do much for the old mice, certainly less than had been found in parabiosis. But what surprised Conboy was the extent of damage to the young mice. "After a single exchange, the mice got dumber," she says, and markers of inflammation increased.

What did this mean? For one thing, it suggested that anything good in young blood is swiftly overwhelmed by the bad in old blood.

It also suggests that young blood didn't cause any rejuvenating effects in the trials – if anything, it just diluted the bad stuff. This makes its benefits temporary at best. It would also help explain Karmazin's observations that customers will need to come back for regular top-ups.

To see real benefits from a young person's blood, then, you'd probably need to stitch yourself to the poor soul for a few weeks – a red market perhaps, but not a convenient one.

That's not to say the whole endeavour should be scrapped. We just need to turn the thinking about young blood on its head, says Conboy: instead of trying to isolate what's good about young blood and add it, we could isolate what's so damaging about old blood, and get it out.

Conboy is now working on a different approach with the anti-ageing start-up Unity Biotechnology, which is backed by Amazon founder Jeff Bezos's investment company. They are developing a blood-exchange device, a kind of dialysis machine for old age, which cycles your blood through a filter that washes a laundry list of harmful compounds out of the plasma before returning it to you. This would carry no immune effects or disease risks, because it's your own blood.

WHY DOES IT COST \$8000?

The biggest cost in the young blood treatment is the plasma itself, at \$2500, says Jess Karmazin, whose firm Ambrosia offers the therapy. There are also lab costs and physicians' time to consider. But the cost is likely to fall. Sourcing plasma from different hospitals could help, and Karmazin is also considering offering shorter treatments for \$500 (see main story).

No regulatory approval is needed, because dialysis filters that remove proteins from plasma are already in use, for example to remove cholesterol in people with certain hereditary diseases.

They are also developing sensors to notify you when levels of bad biomarkers are getting too high – a decrepitude meter to tell you when it's time for a decrepitude wash.

The filters have already been tested in mouse blood *in vitro*, and Unity says it is about to publish the data. The firm hopes that human trials will start in 5 years.

Even so, this isn't a procedure you would take lightly. "It's not a pleasant experience to have your blood filtered," says Douglas Kiel at Harvard's Institute for Aging Research. "Just talk to dialysis patients."

Still, Conboy and Yousef think that if we can crack the problem of old blood, a brave new world awaits. They even envisage a time when,

New clinics will offer 30-minute treatments for \$500 a pop"

rather than removing the bad stuff in blood, you could treat it at source (see "Roots of bad blood," page 40). They have evidence that the blood components responsible for ageing could be released by senescent cells. Tackle this, and you might be able to restore a 75-year-old body to functioning like a 35-year-old, they say. "Our age is not set in stone," says Conboy.

Until we see whether the blood-purifying-filter route stands up to scrutiny, what about plasma? Karmazin plans to streamline his services. His new clinics will no longer charge \$8000 or infuse 2 litres over two days: instead, he tells me, he is already trialling a procedure that takes just a few hours. His aim is to eventually offer smaller amounts of plasma over 30 minutes, for \$500 a pop.

Ultimately, it was these plans that drove a wedge between Karmazin and Wright, who developed the original protocol and deemed the new, quicker treatments too risky. He stopped working for Ambrosia in July, a month after my visit.

And even without the risks, any effects – placebo or not – are modest, acknowledges JR. "This isn't a silver bullet. You feel a little better. You sleep better. But you don't come away feeling like your life has changed." Still, he says plaintively, "if I can just get 10 more healthy years of living..." ■

Sally Adee is an editor and reporter at *New Scientist*

Creature comforts

We stroke, cuddle and eat them. **Pat Shipman** finds a fascinating, flawed account of human entanglement with other species

The Animals Among Us: The new science of anthrozoology by John Bradshaw, Allen Lane



THE interaction between human and non-human animals fascinates everyone from anthropologists to the average pet owner. It even has a name – anthrozoology – as biologist John Bradshaw reminds us in the subtitle of his new book, *The Animals Among Us*.

As Bradshaw points out, for humans to consistently live with and nurture animals is a most unusual trait in nature. So a strong, fact-based discussion of how and why we do this and its effects should be eye-opening, engaging and thought-provoking.

Animals ticks some of those boxes, but by no means all. Bradshaw knows how to produce a well-written and accessible tome. A veteran of popular books about the lives and habits of cats and dogs, he focuses most on the ubiquity of people keeping animals, today and over the past few hundred years, and specifically on pets.

As he rightly observes, the practice of taking in and raising young animals is widespread among humans, little influenced by geography or culture. Oddly, though, he seems shocked that this intimacy can extend to the breast-feeding of young animals, domestic or wild. This isn't rare in many modern cultures and probably wasn't in the past. Calling groups who engage in the

behaviour "surviving Palaeolithic peoples", as he does, is inaccurate and culturally insensitive.

Bradshaw suggests that the inclusion of animals as intimate members of the family probably explains the long-term connection behind the genetic and behavioural alterations we now see in domestic species.

Even so, domestication is a less common outcome of keeping animals than we might expect, given that even the most generous list would only include 20 or so

"It's worth asking why so many species that have lived with us have never been domesticated"

domesticated species. Many more have spent at least some time in captivity, so it is well worth asking why so many species that have lived intimately with us haven't been domesticated.

For Bradshaw, the answer lies

partly in the kinds of societies that kept animals. He reasons that in egalitarian, hunter-gatherer societies, animals could be brought into the family and kept temporarily before being eaten or sacrificed, or perhaps kept more permanently. As these societies gave way to stratified, agricultural societies, the animals that were kept depended on their benefit to the household at that time.

During this period, keeping domesticated animals became a status symbol – leading to the rise of pets. Part of their appeal, says Bradshaw (on little evidence), is an atavistic liking of stroking and grooming the fur of another, which he believes played a role in our ancestral, furry past (we lost most of it some 1.6 million years ago) as it does now among non-human primates.

But do we really keep pets so we can stroke them? Stroking a pet has been shown to raise



circulating levels of the "feel-good" hormone oxytocin in both participants. Why don't we keep pets that stroke us back?

Bradshaw's main interest seems to lie in the period between medieval times and the 20th century, which makes this part of the book especially lively and informative. The Victorian era saw the rise of keeping pets and the display of animals with particular colours or shapes to confer status. This was also the time that breed societies and animal shows were founded, and there was a general growth of desirable "types" among all kinds of domestic species, particularly in the UK.

Bradshaw discusses this period at length, dwelling on the transformation of pets from working animals to "members of the family" as the attributes of domesticated species became a



CONSTANTINE MANOS/MAGNUM PHOTOS



RIP HOPKINS/AGENCE VU/CAMERA PRESS

reflection of social standing. And in agricultural Britain, having good livestock or animals was of tremendous importance to their owners' success.

Modern life generally is now very different, more industrialised and urban, but the animals we live with continue to carry great social and symbolic weight. According to Bradshaw, Westerners have reached the third phase of living with animals, where the practice is so common that it is universally accepted.

In fact, pets are increasingly seen as offering us tangible benefits – as therapy animals, assistants to people who are blind or disabled, and companions to those who are socially isolated. Pets are often said to provide distinct health benefits to those with mental, social or physical problems, though Bradshaw points out that the evidence isn't

Is stroking fur part of the reason we love to keep pets?

as strong as the claims for it.

In one of the best and most thought-provoking parts of his book, Bradshaw dissects the practice of anthropomorphism as a typically human attempt to understand the animals with which we live so intimately. He raises important questions about the greater significance of keeping pets and their benefits. For example, is assigning human characteristics to another species really key to the close emotional and family-type relationships many humans form with their pets? Does anthropomorphism balance out the energetic and economic costs of pets in the modern world?

I take a very different view: anthropomorphism is as much a barrier to domestication and

close relationships with animals as it is a boon. My view of domestication is that humans and the species that find it worthwhile negotiate a common language – a world view that is neither human nor animal.

Even very clever dogs can't understand more than a few hundred words, and they don't share our framework for perception. Simply put, we perceive very little of what a dog does: for example, we are nearly scent-blind. Equally, dogs don't perceive as we do nor think about things the way we do. For true cooperation and communication, dogs and humans must each alter their "language" so they understand each other. This process is active, a choice as well as an evolutionary adaptation. Casting a dog's actions in human terms is tempting for a human, but doesn't further the exchange of ideas by much.

At the end of the book, Bradshaw brings it all together by proposing four explanations of the human propensity for keeping pets. First, he reminds us of the idea that the loss of most of our body hair left us with a liking for stroking and grooming.

His second concerns the evolution of the human brain in a way that resulted in us being able to analyse animal behaviour and develop the capacity for anthropomorphism, leading to better animal-keeping.

"Does anthropomorphism balance out the energetic and economic costs of pets in the modern world?"

His third explanation is that young women who were good at caring for animals may have been assumed to become better mothers, making them preferred as brides. This could cause a spread of genes that would make many people good with animals.

And last, he hypothesises that the rise of taboos against eating and killing personal (owned)

animals enabled long-term pet-keeping, which is necessary for domestication. I am sceptical about this scenario since, again, little hard evidence supports it or links each stage to the next.

I wish Bradshaw had included more evidence on the much-researched origin of dogs. Surely the first instance of domestication in the world, of wolves into dogs, should play a crucial role in our understanding of the phenomenon of living with and domesticating animals?

But Bradshaw doesn't dwell on the ongoing and exciting work investigating the genetic, morphological and behavioural differences among wolves and some dogs, including ancient fossil specimens. He neglects research on basal or genetically ancestral breeds, such as basenjis, dingoes and the recently rediscovered New Guinea mountain dogs. These species should tell us a lot about the sort of canid that was originally domesticated.

Bradshaw also gives short shrift to work by leading scholars, such as Mietje Germonpré at the Royal Belgian Institute of Natural Sciences and Melinda Zeder at the Smithsonian Institution in Washington DC. And he often supports his arguments with out-of-date contributions to the field or articles in popular magazines or newspapers rather than peer-reviewed journals.

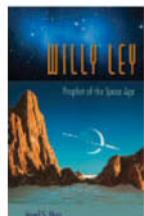
This means that he gives too much credence to ideas that haven't been rigorously tested or that have been overturned by later studies. While there are many good things in his book, understanding and interpreting our tendency to live with animals and its impact is an important and vibrant field that deserves a fuller presentation than Bradshaw offers here. ■

Pat Shipman is adjunct professor of anthropology at Pennsylvania State University. She wrote *The Animal Connection* and *The Invaders*

A rocket man

Rocketry owes a lot to the unsung Willy Ley, finds **Michael Doser**

Willy Ley: Prophet of the space age
by Jared S. Buss, University of Florida Press



ROMANTICS have long dreamed of flying to the moon, but few lobbied as relentlessly for the technological advances that would allow us to reach outer space as Willy Ley.

He was a largely self-educated, technically savvy polymath, a great communicator and writer of successful pulp science fiction. From the start, his vision was of a fully fledged space age, but after fleeing Nazi Germany for the US, he drifted at the fringes of real technical work.

He was also a visionary, garnering popular support through aspirational narratives that bridged the chasm between the cold equations of space flight and its romantic possibilities. Over time, Ley has been eclipsed by better-known actors such as Wernher von Braun (whom he knew well) and Isaac Asimov. Now a fascinating new biography by Jared Buss restores him as a central figure in the history of rocketry and its popularisation.

Ley's role was complex, and his life took an intriguing and meandering path through many of the 20th century's key events: the rise of airborne technology after the first world war; rocketry's beginnings; the Nazis' ascent; the cold war; the popularisation of the idea of space travel; and, finally, as apotheosis, the first moon landing, which occurred

mere weeks after his death.

Ley's prodigious output reflected the two sides of his character. As a public speaker and a writer for magazines such as *Popular Mechanics* and *Amazing Stories*, he romanticised the natural world, and gloried in the idea of brave explorers setting off into an unknown that awed and fascinated him. At the same time, his expertise and attachment to hard facts when discussing, for example, the technical details of weapons, revealed a man with hard-nosed engineering instincts.

Those instincts were hampered by a lack of technical education – he studied astronomy, zoology, physics and palaeontology at the University of Berlin. His wide-ranging curiosity never found its academic niche, and his ideas on the history of science remained those of autodidact and outsider.

Buffeted by the currents of contemporary politics, he was often frustrated by his failed attempts to kick-start or be involved in research on rocket engines. But Ley was always driven by a greater vision, which went beyond the bid for outer space. There is a wistfulness about his strenuously argued belief that education and critical reasoning

"Ley was always driven by a greater vision, which went beyond the bid for outer space"

are the source of democracy and progress. The reality was more complex, as Sputnik showed.

While close to the main actors, but excluded from contributing technically to the development of rockets, Ley settled on the role of proselytiser, fearlessly (or maybe

shamelessly) preaching from all possible pulpits: television, radio and print media, but also via toy companies and Walt Disney, as a consultant for "Tomorrowland" in Disneyland in the 1950s.

He remained a public figure to the last, though his views became visibly dated as the heroic space narratives of the 1940s and 1950s, powered by an unbounded belief in technology, were replaced by more measured and critical views.

Buss's book has weaknesses, particularly in its earlier chapters. Short repeated sentences, clichéd expressions and overly detailed recounts of the plots of several of Ley's stories add to a sense of meandering. Some incorrectly spelled German text also suggests a lack of basic editorial checks.

More surprisingly for the work of a historian, the book, at least to start with, spins its tale from a thin set of sources, relying often on speculation rather than facts. Buss is happy to distance himself from Ley's world view and his reminiscences of the intellectual climate and rise of pseudoscience in Nazi Germany, but he doesn't offer the reader enough historical context to understand how those views might have taken hold.

In an odd way, Ley saves the book from beyond the grave, as it were. His indefatigable vision of space flight as part of humanity's next step into the cosmos, his optimism about the future and conviction that science is the key to bettering humankind are compelling values. Caught up in Ley's enthusiasm, the reader is almost tempted to consider them timeless. ■



BETTMANN/GETTY

Willy Ley spanned the gap between equations and aspirations

Michael Doser is a particle physicist working at CERN



WISCONSIN

UNIVERSITY OF WISCONSIN-MADISON

Professor of Chemistry

The Department of Chemistry of the University of Wisconsin-Madison is accepting applications for open positions at the tenured and tenure-track level, beginning August 2018. We seek outstanding candidates with research interests in all areas of chemistry. The position requires development of an internationally recognized program of scholarly research as well as excellence in teaching at both the undergraduate and graduate levels. Professional and university service is also required. Please go to www.jobs.wisc.edu to view posting and select "Apply Now" to begin the application process.

Application materials including letter of intent, current CV, and concise description of research plans will be required for all applicants. Applicants will also be asked to provide the names and contact information for three professional references.

To guarantee full consideration, applications must be received by **October 15, 2017**. However, applications will be accepted until all positions are filled.

The University of Wisconsin-Madison is an equal opportunity affirmative action employer. Women and minority candidates are especially encouraged to apply. Unless confidentiality is requested in writing, information regarding the identity of the applicant must be released on request. Finalists cannot be guaranteed confidentiality. A criminal background check will be required prior to employment.



THE UNIVERSITY OF CHICAGO

Position Title: Assistant Professor of Chemistry

Req # 03393

The Department of Chemistry at The University of Chicago invites applications for the position of Assistant Professor of Chemistry. This search is in all areas of chemistry, including the sub-disciplines of inorganic, materials, organic, physical, theoretical chemistry and chemical biology. Applicants must apply online to the University of Chicago Academic Career website at <http://tinyurl.com/y8x7tkvw> and upload a cover letter, a curriculum vitae with a list of publications, a succinct outline of research plans, and a one page teaching statement. In your cover letter, please specify one sub-discipline that best represents your research interests. In addition, three reference letters are required. Reference letter submission information will be provided during the application process. At the time of hire the successful candidate must have completed all requirements for a Ph.D. in Chemistry or a related field. Joint appointments with other departments are possible. Review of applications will begin on October 09, 2017 and will continue until all positions are filled.

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<http://tinyurl.com/y8x7tkvw>

Berkeley

UNIVERSITY OF CALIFORNIA

Department of Chemistry Faculty Position in Chemistry

The Department of Chemistry, at the University of California, Berkeley, invites applications for one faculty position at the assistant professor level with an expected start date of July 1, 2018. Preference will be given to candidates in the broadly defined fields of experimental physical and/or analytical chemistry. However, we will consider creative and energetic candidates who show extraordinary promise or accomplishment in research and teaching in any area of chemistry. The basic qualification for this position is a Ph.D. or equivalent degree in chemistry or a related field at the time of application.

All applicants should submit their most recently updated curriculum vitae, a statement of research plans, and provide at least three but no more than five letters of recommendation. A cover letter, a statement of teaching, and a statement of possible contributions to enhancing diversity in higher education are optional. Applications should be submitted electronically through our web-based system at: <https://aprecruit.berkeley.edu/apply/JPF01453>.

All recommendation letters will be treated as confidential per University of California policy and California state law. Please refer potential referees, including when letters are provided via a third party (i.e., dossier service or career center), to the UC statement on confidentiality (<http://apo.berkeley.edu/evaltr.html>) prior to submitting their letters.

The deadline for receipt of application material is November 1, 2017. Please direct questions to Lauren Nakashima (lnakashima@berkeley.edu).

The University of California is an Equal Opportunity/Affirmative Action Employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, disability, age or protected veteran status. For the complete University of California nondiscrimination and affirmative action policy see: <http://policy.ucop.edu/doc/4000376/NondiscrimAffirmAct>.

UC Berkeley is committed to diversity in all aspects of our mission and to addressing the family needs of faculty, including dual career couples and single parents. The Department of Chemistry is interested in candidates who will contribute to diversity and equal opportunity in higher education through their teaching, research, and service.

KANSAS STATE UNIVERSITY

ASSISTANT PROFESSOR

EXPERIMENTAL ULTRAFAST AMO PHYSICS
J.R. MACDONALD LABORATORY
DEPARTMENT OF PHYSICS
KANSAS STATE UNIVERSITY

The Department of Physics at Kansas State University seeks a faculty member in an area of experimental ultrafast laser science who is expected to join the Department of Energy-funded efforts at the J.R. Macdonald Laboratory (JRML). An applicant's AMO physics research focus should thus complement these efforts and fit within the JRML group research theme. A brief description of current research and publications in the JRML can be found at <https://jrm.phys.ksu.edu/>.

The successful candidate will be appointed at the rank of tenure-track Assistant Professor in the Physics Department. The candidate must present credentials that will justify appointment at this level, including a Ph.D. or equivalent in AMO physics or a related discipline, also demonstrate a strong commitment to teaching and mentoring students and to serving a diverse population.

The Department has outstanding experimental and theoretical AMO physics programs, directed by 11 faculty members. It has extensive laser and accelerator facilities in the JRML that are being used to address an array of questions at the forefront of AMO science.

Applications, including a cover letter, CV, statements of research and teaching interests as well as contact information of at least three references should be submitted to:

**[http://careers.k-state.edu/cw/en-us/
job/502370/assistant-professor-physics](http://careers.k-state.edu/cw/en-us/job/502370/assistant-professor-physics)**

Screening of applicants will begin on **November 10, 2017**, and continue until the position is filled. **Background checks are required.** Kansas State University is an affirmative action equal opportunity employer and actively seeks diversity among its employees.



**CONCORDIA
UNIVERSITY
WISCONSIN**

School of PHARMACY

Department of Pharmaceutical and Administrative Sciences Assistant, Associate or Full Professor Faculty Position

Concordia University Wisconsin, a Lutheran higher education institution in Mequon, Wisconsin, committed to helping students grow in mind, spirit, and body, is currently seeking a qualified and motivated professional to fill a permanent full-time position as Assistant, Associate, or Full Professor in the Department of Pharmaceutical and Administrative Sciences of the School of Pharmacy.

The successful candidate will be dedicated to excellence in teaching, research, and service, and should meet the following qualifications:

- Ph.D. in Pharmaceutical Sciences, Biomolecular Chemistry, or related field;
- Excellent verbal and written communication skills;
- Exemplary teaching or research scholarship in the pharmacology of biologically based therapies;
- Experience teaching professional students (e.g., Pharm.D., M.S., M.D., Ph.D.).

Preferably, that candidate would also:

- Have experience in structural chemistry, design, and development of biologics, e.g. antibodies and cytokines;
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EDITOR'S PICK

Sight, insight and psychedelic drugs

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

Sam Wong reports men with colour blindness dropping out of a study on psychedelic drugs because of visual effects (17 June, p 22) and Tony Durham suggests this may inform how we see colour (Letters, 9 September). Colour blindness is a result of faulty

detection in the eyes. But if the brain can still process trichromatic vision, hallucinations could appear in full colour, resulting in "seeing" colours never experienced before.

I cannot even conceive what this would be like, but I imagine it would be very disorientating.

From Arnold Maude, Ely, Cambridgeshire, UK

Durham's question about colour blindness and hallucinating reminds me of a story told by the late art forger Eric Hebborn about his form of colour blindness, which sometimes caused him to paint fierce greens when he thought he was using delicate greys. He claimed that after unknowingly eating cake laced with LSD and hallucinating, the colour blindness seemed to go away.

You can help re-examine Barnard's star for planets

From Alex Saragosa,

Terranova Bracciolini, Italy

Richard Swifte suggests resuming research on the movement of Barnard's star to see if it has a planet (Letters, 26 August). The High Accuracy Radial Velocity Planet Searcher at the European Southern Observatory's 3.6-metre telescope at La Silla in Chile is studying the movement of several close stars, among them Barnard's star. Swifte and others can contribute to checking results through the Red Dots project.

Hero of Alexandria's steam engine

From John Bradshaw,

Belgrave South, Victoria, Australia

You ask: what if the ancient Greeks had invented the steam

engine (9 September, p 5)? Hero or Heron of Alexandria described a sphere containing water mounted over a fire on a horizontal axis, with small jets emitting steam. It spins – he thus invented both the steam engine and the jet.

From Hugh Kolb, Logie Coldstone, Aberdeenshire, UK

You say, rightly, that if Darwin had not written the *Origin of Species*, evolution would still have been discovered. It is, however, unlikely that the Greeks could have invented a practical steam engine – despite Hero of Alexandria's efforts. The steam engine as we know it was invented to pump water out of deep mines. The supply of coal was the main force behind its development.

The editor writes:

■ We indeed meant to say that the ancient Greeks didn't invent

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 **"And suddenly, holding a hungry grandchild has become infinitely creepy..."**

XD is alarmed by the news that sacrificial virgin spiders let their nieces eat them alive (23 September, p 19)

a steam engine that could power an industrial revolution.

Generating nuclear power also emits carbon

From Ann Wills,
London, UK

Eric Kvaalen points out that nuclear energy production isn't green because no way has been found to deal with the problem of nuclear waste (Letters, 2 September). Nuclear power is being "sold" to the public by saying it doesn't emit carbon dioxide. Though nuclear reactors emit little CO₂ at the point of generation, they are just a small part of the nuclear fuel cycle.

Uranium mining, milling the ore, converting it to uranium hexafluoride, enriching that and fabricating fuel rods all emit large amounts of CO₂. Much energy is also used in the treatment,

conditioning, transport and disposal of nuclear products.

Jan Willem Storm van Leeuwen and Philip Smith found that nuclear generation produces a third as much CO₂ per unit of electricity generated as conventional, mid sized, gas-fired electricity generation – and more if lower-grade ores have to be mined. Decommissioning old radioactive nuclear power stations also consumes energy.

Drawing lines between interbreeding species

From Eckart Breitschuh,
Hamburg, Germany

Colin Barras's piece on the confusing history of our species offered more evidence that evolution is a messy business, not working towards any goals (26 August, p 28). I am puzzled, however, by his conclusion that

there might be no "true" *Homo sapiens*, because our species, Neanderthals and Denisovans all interbred. That implies there were no "true" Neanderthals or Denisovans either. "True" is unhelpful, especially when it smacks of unsavoury race theory.

From Ditlev Petersen,
Termestrup, Denmark

So most non-African modern humans have small amounts of DNA from Neanderthals and some other still-exotic prehistoric humans. Reporting of this has sometimes included tales of romantic meetings between Neanderthals and modern humans. This coincides with the change in representation of Neanderthals from brutish cave-dwellers with clubs to smiling and friendly avuncular types.

Another story is possible: that interbreeding was sometimes the

result of rape. I, also, like the idea of peace, love and harmony in the Palaeolithic world and prefer the thought of a smiling Neanderthal ancestor sitting by the campfire sharing the hide of a cave bear with a woman from the new tribe. Both stories might be true, and likely were.

Are teenagers just trying to cram too much in?

From Rachael Padman,
Dalham, Suffolk, UK

Russell Foster suggests that teenagers' late waking relative to adults means they should start school later (9 September, p 26). It isn't at all clear to me whether this is caused by biological processes or is just the result of regularly staying up too late.

Humans aren't adapted for nocturnal living, and it would surprise me if there were truly a ➤

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biological reason for teenagers' habits, rather than it just being their wish to fit more into every day than there is room for.

Foster hints at the latter, in which case we would be crazy to pander to them. Is there any evidence of similar behaviour in adolescents in earlier times or in cultures where the concept of "teenager" was or is unknown?

The editor writes:

- There is some evidence for nocturnal living, for example the finding that in Hadza hunter-gatherer camps there is always someone awake (15 July, p 10), and in a reassessment of the "second sleep" in early modern history (30 November 2013, p 36).

Seeing eye to eye on eardrum movement

From Pauline Keyne, Beaconsfield, Buckinghamshire, UK

Aylin Woodward reports that our eardrums move in sync with our eyes (29 July, p 12). But given that the changes in the eardrums start before the eyes move, isn't it possible that hearing triggers the

eye movement? This makes intuitive sense: we tend to shift our gaze towards things we hear.

So what's so new about this genome project?

From Garrett Simpson, Reading, Berkshire, UK

You report on the UK's 100,000 Genomes Project and concerns over data privacy (2 September, p 22). This reminded me of the UK Biobank (7 April 2012, p 8). It has 500,000 members and, apart from blood, is interested in things such as lifestyle. What is the extra benefit of the new project?

The editor writes:

- The UK Biobank currently looks only at variations in single DNA base pairs. The 100,000 Genomes Project collects whole DNA sequences.

There is dispute over the safety of statins

From Aroha Mahoney, Te Awamutu, New Zealand

You state that statins are a safe way to reduce cholesterol levels

and prevent heart disease (26 August, p 5). But in 2015, David Diamond and Uffe Ravnskov published a bone-chilling study titled "How statistical deception created the appearance that statins are safe and effective in primary and secondary prevention of cardiovascular disease" (*Expert Review of Clinical Pharmacology*, doi.org/cc7g).

There are many types of earthquake zone

From Bill Quinton, Giggleswick, North Yorkshire, UK

John Pickrell's description of the use of interferometric synthetic aperture radar to study earthquake zones was interesting (2 September, p 40). He notes that earthquakes are generated where tectonic plates move against or away from each other.

There's a lot more to it than that. Plates move apart in places such as the Mid-Atlantic ridge where new crust is formed. Where two oceanic plates converge, the older, colder and denser one descends below the other in a process called subduction, such

as where the Pacific Plate is sliding beneath the Philippine Plate. Where an oceanic plate converges on a continental plate, it is subducted, as where the Pacific Plate is subducting beneath South America. Where two continental plates converge, neither is subducted and immense crumple zones result – for example, the Himalayas. Earthquakes are generated in all these situations.

They are also generated where two plates slide past each other, as with the Pacific and North American plates – the San Andreas fault is the prime example of this. And many earthquakes occur well away from plate boundaries.

Listen: transistors do analogue work too

From Sam Edge, Ringwood, Hampshire, UK

Liesbeth Venema says transistors are "electrical switches that either allow current to flow or not, and nothing in between" (5 August, p 33). In digital circuits, transistors are generally switched "full on" or "full off". But in general they modulate the output current by varying the input signal in an analogue fashion – as utilised in amplifiers, analogue radios and many other devices.

Going out on a limb over dodos' layout

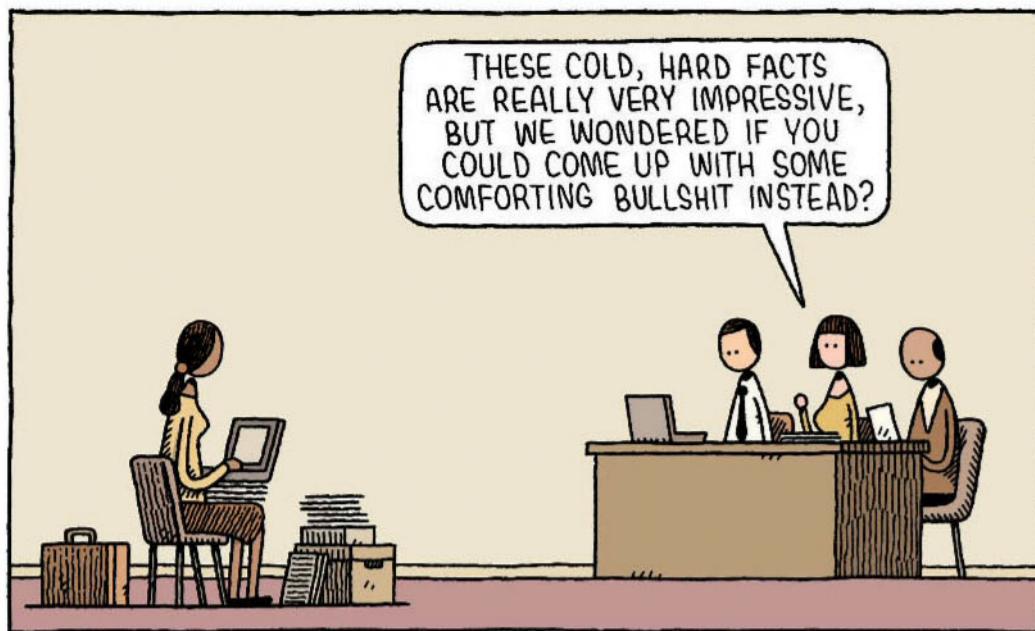
From David Muir, Edinburgh, UK

You report that the life cycle of the extinct dodo was worked out from analysis of 22 bones, all but one from the hind legs (2 September, p 14). The biggest surprise must have been the discovery of the hitherto-secret front legs.

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TOM GAULD



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STEFAN MARJORAM

Engaging students' drive

THE world land speed record for cars has seen its share of British success. The nation's latest such endeavour is encapsulated in the supersonic Bloodhound SSC, but it is about far more than building a fast car. It also aims to engage and inspire the next generation of scientists and engineers by showcasing STEM (science, technology, engineering and mathematics) disciplines in a variety of exciting ways.

In late October, Bloodhound SSC will start runway testing in Newquay, UK, at speeds of up to 300 kilometres per hour. This will provide valuable data and experience before the team heads for South Africa to chase a new world record speed of more than 1600 kilometres per hour. Importantly, it will also provide a real-life science showcase for the 250,000 young people who participate in Bloodhound-related workshops each year.

These activities, run by the charity Bloodhound Education, form one of the biggest STEM programmes in the UK, and one that engages students from primary school age to PhD level. Our various workshops combine hands-on activity with classroom instruction, along with a competitive element to involve and enthuse even the most laconic student.

The next stage of the programme will involve providing real data from the car, so students can participate in the decision-making as the engineers continue to develop the vehicle.

During the past year, Bloodhound has involved more than 125,000 students in its workshops in both primary and secondary schools. You can help us inspire more students, either by sponsoring the project or by joining our team of volunteers who run the workshops and support other activities.
Chris Fairhead, chairman of Bloodhound Education

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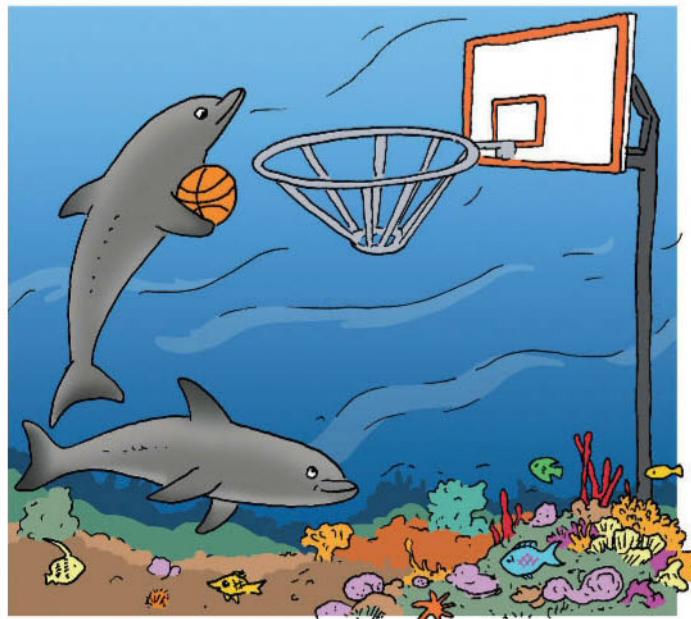
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STRANGER things are unfolding in Rhode Island, where beachgoers stumbled across a mysterious structure buried in the sand just beyond the waterline. The large, eight-legged metal object resisted all efforts at removal by hand, giving residents plenty of time to cook up outlandish theories about its origin.

After several weeks (of mounting dread about an invasion of robotic sea spiders, we presume), Peter Brockmann, president of the East Beach Association, arranged for an excavator to come and dig the structure out. However, this has only raised more questions.

The prevailing theory was that East Beach was playing host to the remains of an underwater acoustic Doppler profiler, a piece of equipment used to monitor currents and sediment flow.

However, the object removed from the surf - found to be a metal hoop measuring 3 metres in diameter with eight spokes raised to a point - no longer fits the bill. A gallery of the mystery structure can be seen at bit.ly/ns-seaspiders.

PAUL MCDEVITT

Tony Compton writes: "On BBC's Radio 4, a Silicon Valley representative described social media as an ecosystem. I misheard this as egosystem - but perhaps this word is more appropriate?"

Stringer ought to know: the Global Warming Policy Foundation was itself censured back in 2013 for breaching the Charity Commission's rules on impartiality. It then set up a non-charitable lobbying arm so it could "more effectively" take part in the UK climate debate.

WHAT could be at the heart of boys' continued domination of physics classrooms? A lack of female role models? A climate of masculinity that drives female students away? Or boys' toilet antics?

Writing in *Tes*, three Australian researchers make a case for the last of these possibilities, insisting that they are not taking the, er, mick. Anna Wilson, Kate Wilson and David Low propose that years of guiding streams of urine give boys a better grip on projectile motion, an area of physics that often forms the introduction to the curriculum. The researchers say that only a third of female pupils answer questions on projectile motion correctly, compared with two-thirds of male pupils.

Worryingly, this pattern is evident even among young women entering the "hyper-masculine environment" of the Australian Defence Force Academy, a career that is nothing if not about launching projectiles.

Feedback remains sceptical that guiding a stream of urine confers any special skills beyond being able to write one's name in the snow. And if our experience of public toilets is anything to go by, a lifetime of practice doesn't guarantee any competence in projectile physics, theoretical or practical.

EVERYONE has their role to play in history, but a walk-on part by Joe DiMaggio, New York Yankees centre fielder and Baseball Hall of Fame incumbent, has only just come to light.

Geneticist Mary-Claire King recounts in the *HuffPost* how the baseball star volunteered to babysit her daughter when they found themselves waiting in line together at San Francisco Airport

in 1981. This allowed King to escort her mother to her Chicago flight and return in time to make her own flight to Washington DC for a meeting with the National Institutes of Health.

Were it not for DiMaggio, King would probably have missed her meeting – which secured King her first major grant and led to the discovery of the *BRCA1* genes associated with breast and ovarian cancer.

A DIFFERENT type of fruitloopy?

Doctors writing in *BMJ Case Reports* relay the case of a man nearly killed by his penchant for apricot stones. After he went under anaesthetic for routine surgery, the 67-year-old was found to have abnormally low blood oxygen levels.

The man later revealed he had been taking two spoonfuls of homemade apricot kernel extract daily for the past five years, on top of herbal supplements containing fruit kernel extract.



Tests confirmed that his body contained high levels of cyanide. The doctors report that the man was ingesting around 4 grams of the deadly poison daily - enough to raise its concentration in his blood to around 25 times safe levels.

Despite physicians explaining the consequences of his regime, the man said he would continue taking his supplements.

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Getting sucked in

How close would one have to be to the coalescing black holes recently detected by LIGO to actually feel the gravitational waves without the aid of instruments?

■ LIGO has confirmed at least two of these mergers. In the more exciting first one, a black hole of about 36 solar masses and another of around 29 solar masses formed a black hole of about 62 solar masses in less than half a second.

We can perceive acceleration of about 0.01 metres per second squared. Naively treating the pre-merger black holes as a single object of 65 solar masses, an attraction of 0.01 m/s^2 would still be felt about 930 million kilometres away. So the black holes could have been about 6.2 times the distance from Earth

"Gravity is very weak. It's astounding that LIGO can detect this merger over a billion light years away"

to the sun, and you would have maybe felt a little frisson as they came together – but only if you were paying attention.

Mostly, however, you'd be feeling crispy: three of the solar masses would be converted to energy in the merger. That's about a billion trillion times the normal output rate of our sun.

This little exercise highlights how incredibly weak gravity is and how astounding it is that

LIGO could detect this merger over a billion light years away.
*Ron Dippold
San Diego, California, US*

Out of the blue

The sky is blue because the atmosphere scatters the shorter wavelength (blue) end of the visible light spectrum more than the red end. As a result, more of this reaches the ground when the sun is high in the sky. Why then aren't we aware of being bathed in a bluish light? Or do we in fact see a bluer world, but, because we always see it this way, our senses accept it as neutral? And is that why a tinge of blue is often added, for instance to washing detergent, to make things look whiter?

■ Rayleigh scattering explains why light from the sky is bluer than light from the sun as seen from outside Earth's atmosphere, but it doesn't explain why we "perceive" it as blue. To explain that, you need to define "white".

Our vision evolved on Earth's surface, where the average illumination is a mixture of bluish light from the sky and direct sunlight, which is slightly yellowish because some blue has been removed by Rayleigh scattering. That average illumination is close to the colour of the sun as seen from outside Earth's atmosphere and is what we perceive to have no particular colour, in other words, "white".

On an overcast day we do, in fact, see the world as slightly blue.

If we were visited by astronauts from another planet whose star was bluer than ours, they would perceive our white as slightly yellow, or if their star was yellower than ours, they would perceive our white as slightly blue.
*Richard Parkins
Via email, no address supplied*

■ When the sun is in a clear blue sky, measurements show that only about 6 per cent of the illumination comes from the blue sky. Thus we perceive the world to be illuminated by the pure white light of the sun (and it really is white, not yellow, as the colour of clouds reveals: they only become yellow or red around dawn and dusk).

Objects in the shadows, however, are lit only by the sky's light and so are tinted towards blue, as artists have always known. They commonly add a bluish tone to represent outdoor shadows, with a violet tinge often preferred by watercolourists. Shadows can be complex, though, because the sun's bright white light is often reflected into the shadows from surroundings such as green trees, providing additional colouring of shaded areas.

The addition of dolly or laundry blue to white washing is a different matter. This was to counteract the natural yellowing of the white fabric, but its use has been superseded by the addition of blue fluorescence in the detergent, which is more effective.

*John Elliott
Stockport, Cheshire, UK*

■ We aren't living in a wash of blue because the blue light from the sun is scattered in all directions, not just down towards the ground. Thus the sun appears yellow, and the overall light received at the ground is reduced in blue wavelengths. The effect becomes much more extreme towards sunset, because the blue wavelengths are scattered to an even greater extent due to the longer passage of light through air. That is why sunsets are red.

However, the questioner is correct in saying there is some colour-balance correction going on automatically in the brain, and that we naturally react to, and to some extent correct for, the changes in light frequency throughout the day.

This processing becomes apparent if you ever observe a total solar eclipse during the middle of the day. As totality approaches, the light becomes very dim, but because the sun hasn't significantly changed its position, the light isn't reddened as it would be at sunset. The effect seems very washed out and unnatural.

*Tim Cutts
Milton, Cambridge, UK*

This week's question

WHISTLE DOWN THE WIND

When the wind howls, what exactly is making the noise?

*Janet Le Page
Johannesburg, South Africa*

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