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Even an infinite cosmos won't last forever

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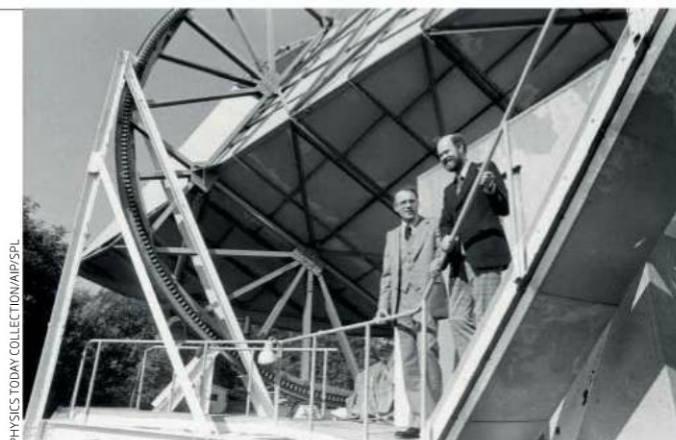


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Elephant in the room

Wildlife crime connects all of us to the conflicts in Africa

MORE than 200 girls abducted by terror group Boko Haram in Nigeria; 23,000 African elephants killed for their tusks last year. On the surface all these crimes have in common is that they happened on the same continent. But there is an intimate connection: like many terrorist organisations in Africa, Boko Haram is funded by sales of illegal ivory (see page 10).

Elephant poaching is usually framed as a conservation issue. But increasingly it is a national security and humanitarian one, too. According to a recent report from Born Free USA and data analyst C4ADS, ivory has become the "bush currency" militants, terrorists and rebels use to buy weapons and fund operations. Government corruption is thought to play its part too.

Most of this ivory ends up in east Asia, where demand is high and rising. According to the report,

a single tusk can fetch \$15,000.

The link between ivory and violence adds even more urgency to the need to quash this deadly trade. Previous campaigns to cut demand for ivory by reducing its acceptability have had an impact. As they have been replicated with other products such as shark-fin soup, this suggests that wildlife crime can be tackled in this way. Such campaigns always include

"It is easy to point the finger at China, but all affluent consumers contribute to wildlife crime"

a strong element of awareness-raising. The fact that ivory is used to bankroll conflicts provides yet more ammunition that conservationists should exploit.

Of course, the ivory trade is only one part of a web of wildlife crime that is itself part of a global criminal network dealing in

drugs, weapons and people.

Cutting demand for ivory won't on its own defuse Africa's conflicts. Militants will simply plunder other resources such as hardwood or the mineral coltan, which may end up as furniture in your house or electrical components in your cellphone.

When it comes to wildlife crime, it is easy to point the finger at Chinese demand for ivory, rhino horn and tiger penis while forgetting that all consumers contribute to some extent.

The illegal wildlife trade is worth an estimated \$20 billion a year; some of that money ends up funding groups like Boko Haram and their violent ideology. It is time for a global awareness campaign to alert us all to the ways we encourage the slaughter of endangered animals, the dubious trade in scarce natural resources and the terrorisation of vulnerable people. ■

Wake up to insomnia's impact

CAN'T sleep? You are not alone. Insomnia affects one in five men and one in three women at some point in their adult lives, making it the world's most common sleep disorder.

All that missed shut-eye has serious consequences. Insomnia has been linked to accidents and poor mental and physical health. It also causes economic damage because of reduced productivity and absenteeism. According to the America Insomnia Survey, published in 2011, the US loses 253 million days of productivity a year to insomnia at a cost to the economy of \$63 billion.

Insomnia can be remedied if it is the result of a treatable condition such as restless legs

syndrome or sleep apnoea. But for the majority of cases no underlying cause is found, and relief is hard to come by. People are told to buy blackout shades, reduce screen time or sort out whatever problem might be keeping them awake. Drugs are another option, but they don't offer a long-term solution.

The key problem is that we still don't really understand insomnia. Is it psychological? Is it a physical? Is it both? No one can agree.

That may be changing, thanks to one unfortunate group of insomniacs who think they cannot drop off even though laboratory tests suggest they are logging hours of solid sleep. For years they were dismissed as

"sleep hypochondriacs". Now better techniques for measuring sleep states have shown that their sleep is fundamentally different from normal, which probably explains their subjective reports of being unable to switch off (see page 32).

The same tricks hold promise for researchers hoping to pin down less exotic forms of insomnia. Advances can't come too soon: a 2012 survey found that cases in the UK have risen steadily over the past 15 years.

A better understanding of insomnia won't necessarily lead to a cure. But knowing that scientists are finally making inroads means there is one less thing to keep us awake at night. ■

Big bang ripple rumours

HAS the discovery of gravitational waves been reduced to dust? Not yet.

In March, the BICEP2 collaboration announced that it had seen an imprint on ancient cosmic light that it says was created by gravitational waves. Those waves are thought to be products of inflation, a period of rapid growth during the first sliver of a second after the big bang.

Almost as soon as the buzz died down, doubts cropped up. BICEP2's signal was based on the alignment - or polarisation - of the first light emitted in the universe. But other things could mimic the signal, such as the ashes of exploding stars or dust.

The BICEP2 team ruled out some of these alternatives, but there are others it can't rule out yet.

On 12 May, however, a rumour

emerged on the physics blog Résonances that the BICEP2 team has already admitted defeat. The blogger, particle physicist Adam Falkowski at CERN, says he has heard that the team misinterpreted a map created by the European Space Agency's Planck satellite in its analysis. That map showed many possible sources of polarised light. The BICEP2 team reportedly used the map assuming that it only charted dust. "The rumour is that the BICEP2 team has now admitted to the mistake," wrote Falkowski.

"We've done no such thing," says principal investigator John Kovac at Harvard University. "We are quite comfortable with the approach we have taken." The matter won't be settled until other work supports or opposes the finding.

Expensive delays

TIME is money, goes the saying. When it comes to climate change, two years of inaction has cost the world \$8 trillion.

A report from the International Energy Agency (IEA), published Monday, looks at the cost of converting to green electricity in order to keep global warming below 2°C. The agency found that it will cost \$44 trillion more than keeping the current mix, where most electricity comes from fossil fuels. The extra money will go on building wind and solar power

\$36 trillion, which is \$8 trillion less than this year's figure. To some extent, the rise is down to quirks in the calculations, such as changes in the value of the dollar. But there is one big factor: the longer we wait to take action on climate change, the more it costs.

Instead of investing in renewable energy now, companies are building coal power stations. These will have to be dismantled early to move to a greener grid, reducing return on the investment. What's more, a later transition must be faster so companies will struggle to roll things out in the cheapest way.

The good news is that, although going green costs more upfront, it brings long-term savings. That is primarily because a more efficient infrastructure uses less fuel. The IEA says that, at \$115 trillion by 2050, those savings more than offset the initial investment.

Ultimately, those savings should benefit everyone, whether they are paying for infrastructure through taxes, or spending less on gas for heating. "At the end of the day it is the customer who pays," says Elzinga. "It always comes back to society."

"Going green costs more upfront, but it brings long-term savings that offset the initial investment"

stations, efficient grids, electric vehicles and infrastructure.

"We're going to have to invest in our energy infrastructure anyway," says David Elzinga, an IEA analyst in Paris, France. "If we want to transition to clean energy, that is going to cost us a bit more."

In 2012 the IEA estimated the cost of the transition at



BICEP2: Happy with their approach

Meteor showtime

INCOMING! A major new meteor shower is set to streak across the skies next week as Earth passes through dust streams released by a comet two centuries ago. Counting the meteors may give clues to the comet's past.

"There are several new meteor showers discovered every year," says Bill Cooke, head of NASA's Meteoroid Environment Office in Huntsville, Alabama, but most are only spotted by skilled observers because the meteors are so scarce.

This time, observers in North America could see more than 200 meteors per hour.

The meteors are dust ejected from comet 209P/LINEAR in the 1800s. Earth is due to cross the dust stream for the first time on 24 May. Meteors will be visible from a point in the constellation Camelopardalis between midnight and 8 am GMT, with the best views likely from North America in the last two hours. Astronomers aren't sure when the two will next cross paths. "It's a one night thing," says Cooke.

Skywalker-style prosthetic arm

STAR WARS tech is going mainstream. The US Food and Drug Administration has approved a prosthesis for commercial sale that is controlled by the body's own electrical signals.

The Deka Arm System, developed by Deka Research and Development Corporation in Manchester, New Hampshire, uses electromyogram electrodes to pick up electrical signals from muscle contractions where the prosthesis is attached, or from a wireless controller operated

by foot movements. It learns to convert these signals into the arm movement intended by the user.

Approval follows a study in 36 people with amputations. Nine in 10 users managed tasks that were impossible with standard inert prostheses, including turning keys in locks and using zips.

The arm's developers dubbed the device "Luke" after Luke Skywalker, who was fitted with a prosthesis after losing his hand in a duel with his dad.

Dinosaur rescue

IT WAS part ostrich, part camel and part duck. The stolen skull and feet of one of the weirdest known dinosaurs were smuggled out of Mongolia, but have now been returned.

The first reasonably complete skeletons of *Deinocheirus* were

"The first skeletons were found in 2006 and 2009, but the heads and feet were missing"

found in the Gobi desert in 2006 and 2009. It turned out to be an ostrich-like dinosaur called an ornithomimosaur. It was 12 metres long, with long arms and a hump or sail on its back. But the heads and feet were missing.

After the discovery, François Escuillié, director of fossil dealership Eldonia in Gannat, France, spotted a strange skull and feet in a private European collection. Working with the original discoverers, he found that the skull was a perfect fit for the 2006 fossil. He acquired the fossil and has now presented it to the Mongolian government.

It isn't clear how the fossils were smuggled out of Mongolia. The European collector hasn't been identified.

The recovered remains show that *Deinocheirus* had a strange skull, with a long and flattened snout like a duck's bill.



Use the correct force

AFP



Far from home

Nigerian kidnap

THE #BringBackOurGirls hashtag has taken on a new lease of life. On 12 May, Islamist group Boko Haram said in a video that it will free the more than 200 Nigerian schoolgirls it has kidnapped if imprisoned militants are released.

In the video, one girl says they have not been harmed. Whatever the truth, if they are returned to their families, research

If the Nigerian situation drags on, financial prospects for the families are bleak. "Those parents are going to lose their jobs," says Dyan Mazurana of Tufts University in Somerville, Massachusetts, who has studied the effects of conflict on women in Africa. "They're going to spend all their time looking for their girls."

Ban killer robots?

WE HAVE finally caught up with Isaac Asimov. The UN discussed the ethics of autonomous killer robots for the first time this week.

Former military commanders, researchers and roboticists met at the UN Convention on Certain Conventional Weapons in Geneva, Switzerland, to talk about recent advances in lethal autonomous weapons. Topics included the ethical questions they raise and what laws they affect. The group will file a report with the UN in November.

The threat isn't hypothetical. Russia has equipped missile bases with armed robots that can engage intruders autonomously. On Monday, a Human Rights Watch report called for a ban on such weapons. "As inanimate machines, fully autonomous weapons could truly comprehend neither the value of individual life nor the significance of its loss," it said.

"Those parents are going to lose their jobs. They're going to spend all their time looking for their girls"

suggests that their prospects for psychological recovery are good.

The most complete picture of the consequences of abduction by armed groups comes from the Survey of War Affected Youth. It tracked the fates of 1300 of the young people taken by the Lord's Resistance Army (LRA) during the 20-year civil war in northern Uganda. Abduction could mean enlistment as a child soldier for the boys and forced marriage for the girls. Young women who had been abducted showed more symptoms of emotional distress than the men, but overall, the story was one of resilience: most successfully reintegrated into society (*Journal of Conflict Resolution*, doi.org/cszz69).

60 SECONDS

Fraternal sun

Our sun has a sibling. Astronomers say a star called HD 162826 was born in the same dust cloud as our own, because out of 30 potential siblings it is the most chemically similar to the sun and formed in the same neighbourhood of the Milky Way (arxiv.org/abs/1405.1723).

Stem cells heal stroke

Eleven people disabled by stroke continue to improve a year after they received an injection of stem cells. Some can move limbs and manage tasks they could not previously handle, announced ReNeuron, the company behind the treatment, last week at the European Stroke Conference in Nice, France.

Google must forget you

Europe's top court has ruled that Google must delete information from its search results in certain scenarios - a victory for people fighting for the "right to be forgotten" online. The decision arose after a man requested the removal of links mentioning that a house he owned years ago was being auctioned because he had failed to pay taxes.

Fusion postponed again

It was never going to be easy. ITER, the nuclear fusion reactor being built in Cadarache, France, may not fire up until 2023 - seven years later than originally planned, the director-general has told *New Scientist*. The difficulty of integrating parts from the project's partners - including agencies in China, Russia, India, Japan, the US and the EU - make it unlikely that even the current 2020 deadline will be met, he says.

Penguins get flu, too

Even Antarctica isn't free of bird flu. Penguins carry a strain, H11N2, which is unlike any other and may have been evolving in Antarctica for at least 50 years. The virus infects Adélie penguins but does not appear to be particularly deadly or contagious (*mBio*, doi.org/srh).



ZIGY KALUZNY/GETTY IMAGES

Many worlds, many yours

Quantum twist kills the multiverse

Goodbye eternal multiverse, hello the end of everything, says **Lisa Grossman**

THE multiverse is dead, long live the multiverse. A radical new way of looking at quantum mechanics suggests that even the multiverse will come to an end.

A popular view of the multiverse says that our universe is just one of an ever-inflating multitude of discrete “bubble” universes. These bubbles are eternally budding off new universes even as individual universes age and die.

But a new view of quantum effects – the brainchild of Sean Carroll at the California Institute of Technology and his colleagues – challenges this picture. It is also potentially very useful to

quantum theorists, as it does away with some thorny issues that currently dog cosmology, including a particularly baffling paradox involving disembodied consciousnesses known as “Boltzmann brains”.

Carroll’s insight comes from a fresh way of looking at random motions known as quantum fluctuations.

Quantum systems baffle our best physical intuition. Current models say that a tiny particle like an electron has no precise position: the best we can do is describe the probability of finding an electron in a particular spot, given by an equation called its

wave function. When you attempt to make a measurement, the wave function “collapses” and picks a single value – but until that instant, the electron’s position fluctuates. One upshot of such uncertainty is the emergence of quantum fluctuations out of seemingly empty space.

Despite their bizarre qualities, however, quantum fluctuations get the credit for our very existence. Studies of the first light emitted in the universe, about

380,000 years after the big bang, suggest that quantum fluctuations in the early universe made matter denser in some regions than others, resulting in a cosmic web of galaxies, stars, planets and, ultimately, people.

The random jitters also seemed to have another intriguing consequence. In the split second after the big bang, the universe is thought to have gone through an explosive growth spurt known as inflation, driven by quantum particles called inflatons. These would be subject to quantum fluctuations too, and every so often an inflaton would be randomly infused with extra

“I’m quite sympathetic. I believe Boltzmann brains fail the Monty Python test: Stop that! That’s too silly!”

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energy, blowing a separate bubble universe into existence. That bubble would itself go through inflation and in turn blow more bubbles, leading to the idea of the bubble multiverse (see diagram, right). By this thinking, once inflation starts it can never really end, and new universes are always being born – so this multiverse is infinite and endless.

That is the prevailing view, at least. Carroll and his colleagues decided to take a second look at this theory because it leads to some unresolved questions. In such an infinite multiverse, everything that has even a slight chance of happening is virtually certain to happen – you just need to wait long enough.

Some theorists have pointed out that, taken to its logical conclusion, that includes the spontaneous aggregation of matter so that it creates self-aware, disembodied brains. It's the same kind of logic that says an infinite number of monkeys typing randomly would eventually produce the complete works of Shakespeare. "It sounds like something a bunch of college sophomores would discuss while high. It doesn't sound like a real scientific problem," says Scott Aaronson at the Massachusetts Institute of Technology.

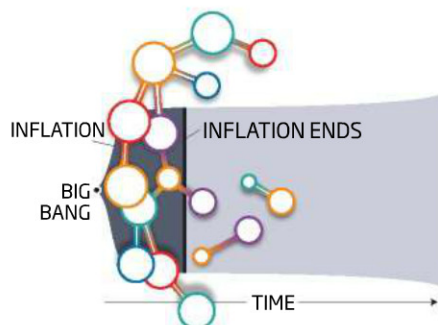
That may be true, but Boltzmann brains create some serious problems for theorists: over the entire history of the universe, such brains would outnumber consciousnesses such as ours. That's a big problem, because the starting point for our understanding of the universe and its behaviour is that humans, not disembodied brains, are typical observers. What's more, Boltzmann brains are just too bizarre for some people. "I believe they fail the *Monty Python* test: Stop that! That's too silly!" says Seth Lloyd of MIT.

Carroll set out to write a paper showing that Boltzmann brains are a real threat, but in the process he found a way to vanquish them.

Choose your multiverse

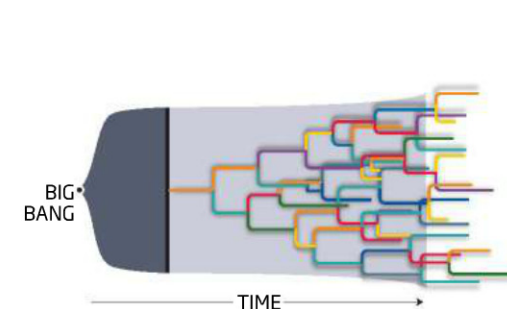
When the universe was born, it went through a period of rapid expansion called inflation...

BUBBLE MULTIVERSE



The standard picture is that quantum jitters in inflation's particles sparked the birth of separate bubble universes. These also inflate and blow more bubbles, making an infinite multiverse

BRANCHING MULTIVERSE



Now some physicists think quantum jitters were impossible until inflation ended. Only then could universes start branching off, creating an overlapping, finite multiverse

His starting point was the idea that quantum fluctuations are dependent on interactions with an external system or particle, known as an "observer" – a familiar concept in quantum

"It sounds like something a bunch of college sophomores would discuss while high"

mechanics. When he applied this thinking to our view of inflation, it changed everything. The inflaton must have preceded all the other particles in the very early universe. That means it was the only type of particle that existed, so there would have been nothing "external" for inflatons to interact with, says Carroll. In this case, the inflaton would not have undergone quantum fluctuations.

This "quiet" state lasted until the inflatons decayed into different types of ordinary particles, which could then interact with each other. "Then those quantum fluctuations finally come to life," says Carroll – allowing them to fulfil their crucial role of seeding the cosmic web but removing the need for an infinitely budding multiverse.

Still, his idea doesn't do away with the multiverse altogether.

That's because the mathematics that make fluctuations dependent on an observer rely on the "many worlds" theory of quantum mechanics. This says that each time a quantum system is measured, the universe branches into several different versions, one for each possible outcome. Unlike a multiverse in which each discrete bubble universe starts from scratch and evolves independently, a "many worlds" multiverse is made of overlapping branches that all started with the same initial conditions. "Maybe Hitler won the second world war in a different universe, that's one

outcome," says Carroll. "But the laws of physics are the same."

In Carroll's theory, even the branching multiverse must come to an end. The universe is expanding at an accelerating rate, so cosmologists think its death will have a lot in common with its birth, with no recognisable matter and only a single quantum field. In that case, there will once again be no observers to bring quantum fluctuations to life.

The simplicity of the theory impresses Aaronson: "I think he's fundamentally right about it. I'm basically sold."

Proponents of eternal inflation are sticking to their story, however. "I'm quite sympathetic to Sean's desire not to have Boltzmann brains," says Lloyd. Nevertheless, he and Alan Guth at MIT – one of the founders of the theory of inflation – both think it possible that the ever-bubbling multiverse can exist even if all of Carroll's mathematics are correct, and they are working on a paper to make that case.

There's currently no way to resolve the debate, but David Wallace at the University of Oxford says Carroll's theory may also have practical consequences, for example in helping us better understand the way matter behaves at the quantum level. ■



LAWRENCE LAWRY/SCIENCE PHOTO LIBRARY

Each one a universe

Ivory feeds Africa's wars

War and ivory are deeply linked. **Richard Schiffman** reports from Kenya



MARA ELEPHANT PROJECT

AT THE headquarters of the Mara Elephant Project, Marc Goss contemplates a jumble of squiggly lines superimposed on a Google Earth map. Each line represents the recent movements of a GPS-collared elephant in the Maasai Mara National Reserve in Kenya. Generally, the animals move too slowly to notice.

Occasionally, however, Goss sees what he calls “a streak” – when one of the lines suddenly lurches forward. It means the animal is being chased by poachers. If the streak stops cold, Goss surmises that another elephant has just been killed.

An unsustainable four elephants are killed in Africa every hour for the ivory in their tusks. But while impoverished locals are enlisted to pull the triggers, it is highly organised transnational crime syndicates and militias that run the poaching and reap the lion's share of the profits, fuelling terrorism and increasingly war.

That's the conclusion of a joint

report by the conservation group Born Free USA and C4ADS, a non-profit organisation that conducts data-driven analysis of security and conflict issues.

Varun Vira, a senior analyst at C4ADS and one of the authors of the report, says it is the first study to look at the problem through the lens of conflict and national security rather than conservation. The report, titled *Ivory's Curse*, draws on publicly available government data, news reports and interviews with government officials and conservationists.

It paints a bleak picture of a slaughter which is disastrous not

just for elephants, but for the stability of African nations, and claims that blood money from ivory has helped to bankroll almost every conflict in Africa in recent decades. “The modern ivory trade was built on war,” says Vira.

In 2013, roughly 400 tonnes of ivory was trafficked, representing the tusks of 50,000 elephants – a billion dollar a year business. The price of ivory in China, which is by far the largest market, has skyrocketed from \$6 a kilo in 1976 to \$3000 today – far more than most Africans earn in a year.

The report identified seven regions where conflict and ivory trade are deeply connected, and shows that much of the poaching takes place across borders (see map, above right). For instance, the report builds on previous findings that Somali terror group al-Shabaab funds itself with money from tusks poached in northern Kenya, adding that the ongoing civil war in the Central African Republic (CAR) is being

partly funded by ivory. Meanwhile, Nigeria's Boko Haram is targeting elephants in Cameroon.

In Sudan, government-allied militias complicit in the Darfur genocide fund their operations by poaching elephants in Chad, Cameroon, the CAR and northern Democratic Republic of the Congo. South Sudan, which boasted 130,000 elephants 25 years ago, is down to just 5000 animals today due to poaching by both sides in the recent conflict.

Some populations have been hit particularly hard and may never recover. The report predicts that African forest elephants could become extinct in the Congo basin within two decades. In addition to political instability, much of the blame lies with the proliferation of Chinese mining and timber operations in the area. These build roads through the rainforest that give poachers access to previously remote areas.

There are a few bright spots. Relatively wealthy Namibia and South Africa have so far kept elephant poaching largely in check through political stability, aggressive patrolling and community-based conservation. Remoteness also helps. Elephant numbers in sparsely populated Botswana are at an all-time high.

Elephants in east Africa are facing what Iain Douglas-

“Blood money from ivory has helped to bankroll virtually every conflict in recent decades”

Hamilton, zoologist and founder of Save the Elephants, calls “a crisis but not yet a catastrophe”. Elephants are “amazingly resilient creatures”, he says, and in regions where up to half of their deaths are caused by humans, the animals can still manage to maintain healthy communities. But when that number rises above 50 per cent – as has happened in much of Africa – reproduction rates can't replace the losses, and the species spirals into decline.

The price of a tusk

The purchasing power of one tusk in the Democratic Republic of the Congo



Average weight **3.8kg**

Bush value/kg **\$100**

Retail value/kg (Asia) **\$3000**

SOURCE: BORN FREE USA/ONG

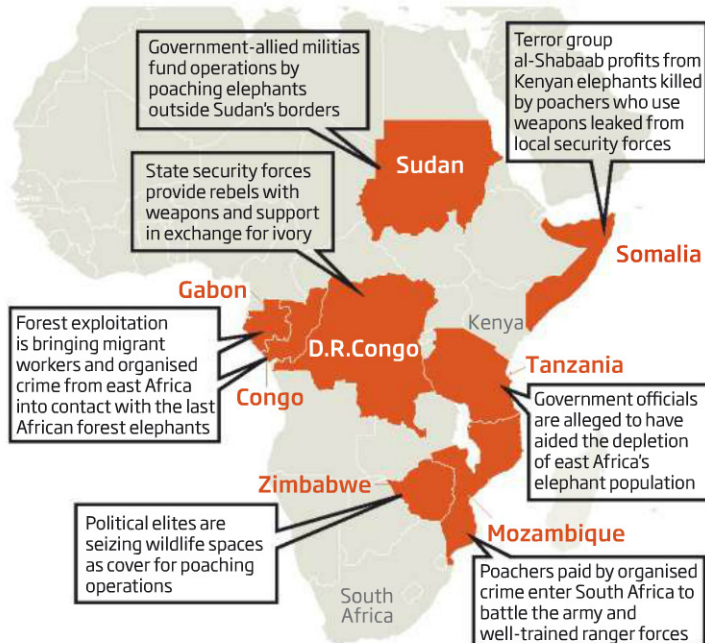
The more successful countries shouldn't rest on their laurels, Vira says. One way to tackle the problem in future is to predict the next poaching hotspots. The report's authors have developed an index that includes factors such as corruption and arms availability to predict at-risk reserves. As elephant numbers in central Africa decline, poaching is spreading, mainly to the south and east.

"Just looking at the diminishing numbers elsewhere in Africa and the economics of the trade, poaching has to eventually shift to southern Africa where 50 per cent of the elephants are today," Vira says.

There are signs this is already happening. Until a decade ago, the Selous Game Reserve in Tanzania boasted the largest concentration of pachyderms on Earth. But two-thirds of its elephants were killed between 2009 and 2013. The

Seven deadly regions for Africa's elephants

Crime and conflict are fuelling the ivory trade in seven regions of Africa, as groups use it to bankroll their activities



report alleges that poachers are being abetted by senior officials in the Ministry of Natural Resources and Tourism.

The report endorses data-driven methods, like Goss's live GPS mapping, to maximise the efficiency of gamekeeper patrols.

It also suggests that African governments should ramp up efforts to intercept ivory as it travels through the supply chain. Disrupting distribution networks can make the trade costlier and more risky for all those involved.

But even the best policing in Africa will fall short if demand for ivory remains high. A separate report will focus on the ivory trade in Asia. And Douglas-Hamilton is already working with China's celebrities to convince young people that owning ivory trinkets isn't cool. However, changing cultural values takes time – time Africa's elephants may not have. ■

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NewScientist



Why robots can never be conscious

Anil Ananthaswamy

SO LONG, robot pals – and robot overlords. Sentient machines may never exist, according to a variation on a leading mathematical model of how our brains create consciousness.

Over the past decade, Giulio Tononi at the University of Wisconsin-Madison and his colleagues have developed a mathematical framework for consciousness that has become one of the most influential theories in the field. According to their model, the ability to integrate information is a key property of consciousness.

But there is a catch, argues Phil Maguire at the National University of Ireland in Maynooth. He points to a computational device called the XOR logic gate, which involves two inputs, A and B. The output of the gate is “1” if A and B are the same and “0” if A and B are different. In this scenario, it is impossible to predict the output based on A or B alone – you need both.

Crucially, this type of integration requires loss of information, says Maguire:

“You have put in two bits, and you get one out. If the brain integrated information in this fashion, it would have to be continuously haemorrhaging information.”

Maguire and his colleagues say the brain is unlikely to do this, because repeated retrieval of memories would eventually

destroy them. Instead, they define integration in terms of how difficult information is to edit.

Consider a digital album of photographs. The pictures are compiled but not integrated, so deleting or modifying individual images is easy. But when we create memories, we integrate those snapshots of information into our bank of earlier memories. This makes it extremely difficult to selectively edit out one scene from the “album” in our brain.

Based on this definition, Maguire and his team have shown

mathematically that computers can’t handle any process that integrates information completely. If you accept that consciousness is based on total integration, then computers can’t be conscious (arxiv.org/abs/1405.0126v1).

“It doesn’t necessarily mean that there is some magic going on in the brain that involves some forces that can’t be explained physically,” says Maguire. “It is just so complex that it’s beyond our abilities to reverse it and decompose it.”

Disappointed? Take comfort – we may not get Rosie the robot maid, but equally we won’t have to worry about the world-conquering Agents of *The Matrix*.

Neuroscientist Anil Seth at the University of Sussex, UK, applauds the team for exploring consciousness mathematically. But he is not convinced that brains do not lose information. “Brains are open systems with a continual turnover of physical and informational components,” he says. “Not many neuroscientists would claim that conscious contents require lossless memory.”

Maguire acknowledges that their proof would not hold up if information integration in the brain is reversible. “Maybe, if you had a very clever algorithm, you could still break down peoples’ memories and edit them.” ■



EPA/CORBIS/SEGEILLNITSKY

Can't think what to buy

Zap sleeping brains for real-life *Inception*

IF YOU liked the film *Inception*, you’re going to love this. People have acquired the ability to control their dreams after a quick zap of current to their head while they slept.

Lucid dreaming is an intriguing state of sleep in which a person becomes aware that they are dreaming and can control what happens. Ursula Voss at Goethe

University in Frankfurt, Germany, has previously found that this heightened awareness coincides with stronger gamma brainwaves in areas called the frontal and temporal lobes. These brainwaves happen when cells fire together 40 times a second.

To see whether they could induce lucid dreams by triggering certain brainwaves, her team turned to transcranial alternating current stimulation. This can trigger different brainwaves by passing a small electrical current through the skull.

They asked volunteers to come into the lab on many different nights

to receive stimulation at different frequencies, or a sham treatment. Sure enough, the participants reported greater awareness and control of their dreams after stimulation at 40 hertz, the frequency of gamma waves, but not at other frequencies (*Nature*, doi.org/10.1038/nature12984).

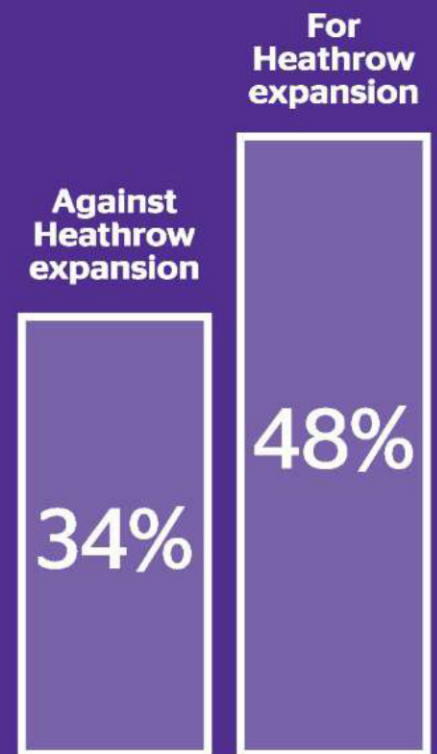
Gamma waves are thought to help different areas of the brain synchronise their activity, “binding”

“The gamma waves create a hybrid state with some attributes of higher consciousness”

thoughts and feelings to create a cohesive experience. Importantly, the frontal and temporal areas – involved in decision-making and memory – aren’t normally synchronised in REM sleep, but are in waking. Ramping up the gamma waves may therefore have created a hybrid state with some attributes of higher consciousness, even as the rest of the brain sleeps.

Voss suggests that the technique might help people with post-traumatic stress disorder to take control of their recurring nightmares and make them less frightening. ■ Helen Thomson

Contrary to
popular belief,
backing Heathrow
won't
make you
unpopular.



In a recent Populus poll*, nearly half of west London residents said they supported expansion at Heathrow, with just over a third opposed. In addition, 57% of voters said they felt positive towards Heathrow (just 6% were negative). The truth is, most local people appreciate the benefits that living near the UK's only hub airport brings to their communities, their families and the nation as a whole.

Heathrow

*Populus interviewed 1,000 adult residents in seven Boroughs local to Heathrow Airport between February and March 2014. In total, 7,000 residents were interviewed. Results were weighted to be demographically representative of all adults in each borough.



DAN FORGES/GETTY IMAGES

Squeeze the arm, protect the heart

Clare Wilson

COULD the humble blood-pressure cuff hold the secret to a life-saving new treatment? Briefly restricting blood flow to a person's arm seems to prime the heart and other organs to cope with a more severe loss of their blood supply.

The technique could improve recovery from surgery, a heart attack or stroke. "There's tremendous interest because it's a simple, cheap and non-invasive form of protection," said Derek Yellon of University College London at a conference on the approach in London last month.

The effect relies on a phenomenon called ischaemic conditioning, first seen in animal experiments that temporarily cut off the heart's blood supply. Researchers found that there was less damage to the heart if its blood supply was briefly lowered beforehand. It was as if the heart muscle had been trained to withstand oxygen deprivation.

Surprisingly, reducing blood supply in one of the animal's

limbs, simply by squeezing it, produced the same benefit. The effect could even be passed from one animal to another with a blood transfusion, suggesting that the squeezed limb released some sort of beneficial chemical signal into the blood. Researchers are now trying to uncover the exact mechanism involved.

Using the method in the clinic involves four cycles of inflating a blood-pressure cuff for five

"It is as if briefly lowering the heart's blood supply trains it to withstand oxygen deprivation"

minutes, then deflating it for five minutes. Several studies show that this cuts damage to heart muscle by about one-third following surgery to bypass blocked arteries, when the heart's blood supply must be stopped for up to an hour. It can also be used before the artery-widening treatment given immediately after a heart attack, to lessen damage caused by the sudden return of blood.

Such studies suggest that ischaemic conditioning can lower death rates by as much as two-thirds. But not all trial results have shown a significant effect, although none has found the technique to cause harm. We need to wait for evidence from larger trials, says Gerd Heusch of the University of Essen in Germany, who carried out one of the artery-bypass studies.

Even so, a few hospitals in India and China are already using ischaemic conditioning before heart surgery or as a treatment for heart attacks. In Europe, a computer-controlled cuff that carries out the procedure will be launched later this year. It is already on trial in ambulances in several countries for use following heart attacks.

Work on animals suggests the technique also benefits the brain and other organs. It is now being investigated as a treatment for newborns deprived of oxygen and adults after a stroke, as well as before organ transplants.

"All the data so far suggest that if you get the right patient and you deliver it in the right way, you can have profound effects," says Andrew Redington of the Hospital for Sick Children in Toronto, Canada. "But people can't believe it – it seems too simple." ■

Antarctic ice collapse seems unstoppable

PARTS of the West Antarctic ice sheet are already collapsing and probably can't be saved. Two studies suggest that several glaciers are doomed to fall into the ocean, causing metres of sea level rise over coming centuries.

"A large sector of the West Antarctic ice sheet has gone into irreversible retreat," says Eric Rignot of the University of California at Irvine.

In one study, Ian Joughin of the University of Washington in Seattle and his colleagues used radar to map the rocks beneath the Thwaites glacier, part of the ice sheet. This allowed them to determine where the glacier starts to rest on open water rather than on rock – the grounding line. The further inland the grounding line, the greater the risk of collapse.

They modelled the Thwaites glacier's likely fate and project that a rapid collapse will begin between 200 and 900 years from now. Once under way, the collapse would make seas rise by at least 10 centimetres a century (*Science*, doi.org/srg). The glacier keeps much of the ice sheet in check, so its collapse could destabilise the sheet, releasing enough ice to raise sea levels by a further 3 or 4 metres.

The other study, led by Rignot, tracked the retreats between 1992 and 2011 of several major glaciers. Measured at their centres, Thwaites glacier had retreated 14 kilometres, Pine Island glacier by 31 kilometres, and the Smith-Kohler glacier system by 35 kilometres (*Geophysical Research Letters*, doi.org/srf).

The studies found no obstacles further inland, such as rocky outcrops, that could halt the retreats. "There's no barrier to stop it," says Rignot. "Even if the ocean was not warming up, it's now a chain reaction."

One hope is that icebergs calved from the glaciers might block the flow of warm water under the ice. "If this happens, then the cause of the retreat will be turned off," says David Vaughan of the British Antarctic Survey in Cambridge, UK. Andy Coghlan ■

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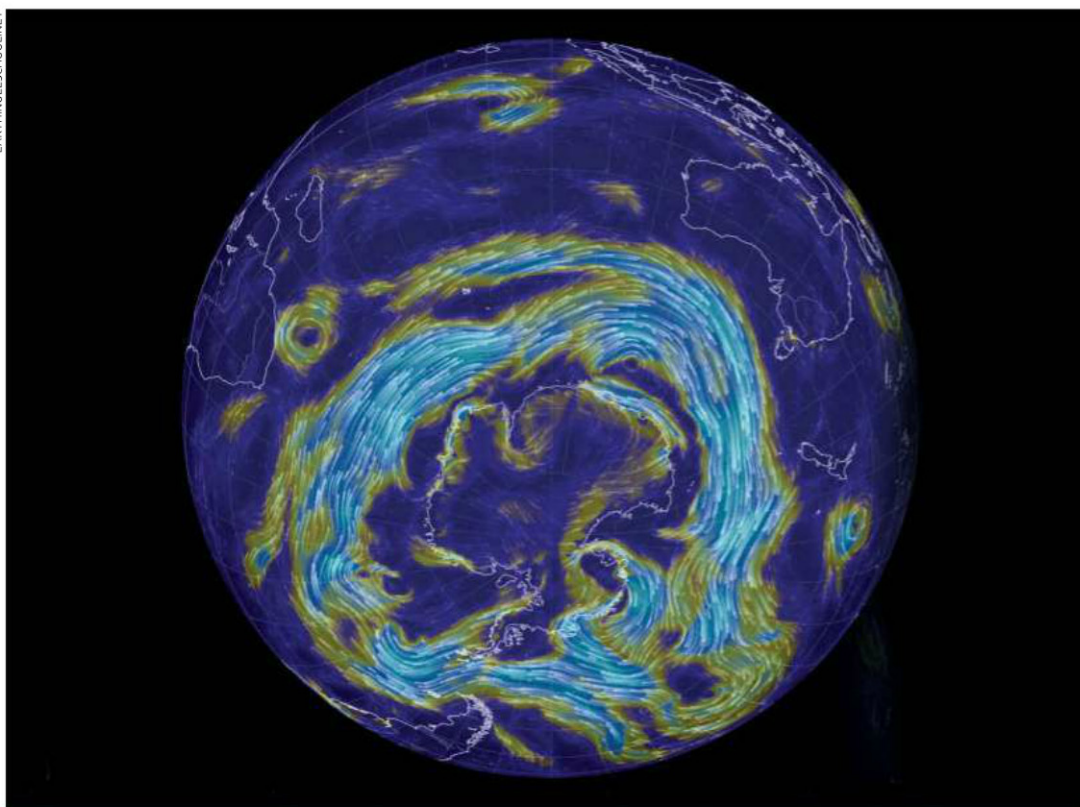
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Vortex of winds circling the Antarctic hits 1000-year high

OUR greenhouse gas emissions are boosting a vortex of winds around Antarctica. As this maelstrom accelerates, it shrinks, dragging rain away from Western Australia.

Earlier studies suggested that the hole in the ozone layer above Antarctica was boosting the winds. Now Nerilie Abram of the Australian National University in Canberra and her colleagues have shown that global warming is just as important.

The team reconstructed Antarctic temperatures over the past 1000 years using an ice core. The temperatures correlate with wind strength, and the team found that

the winds are now the strongest they have been in the past millennium. But the gain in strength began in the 1940s, decades before the ozone hole. So the team simulated weather patterns in the last 1000 years using climate models and greenhouse gas levels from ice cores. All the models predicted that the winds would pick up by the 1940s, suggesting that greenhouse gases were playing a role (*Nature Climate Change*, doi.org/sqv).

As the ozone hole heals, its effect on the winds will weaken. But rising temperatures will counteract this. The two factors may balance until 2045, says Wenju Cai from the CSIRO, Australia's national research agency, in Melbourne. After that, unless we reduce emissions, greenhouse gases will boost the winds further, and Western Australia will lose even more of its rain.

Polar bears have genes to scoff blubber

A LUCKY few can eat anything. Polar bears devour a steady stream of seal blubber, but they cope with the deluge of fat and shrug off the cholesterol that would cause heart attacks in humans.

These abilities evolved fast. A new analysis suggests the species is less than 500,000 years old.

Polar bears (*Ursus maritimus*) eat the fat-rich skin and blubber of seals. But their ancestors probably

ate healthier things like berries.

A team led by Rasmus Nielsen of the University of California, Berkeley, sequenced the genomes of 89 polar bears and 10 brown bears, their closest relative. The team identified the 20 polar bear genes that differed most from brown bear versions. Nine of these relate to the heart in humans, for instance, removing cholesterol from the blood (*Cell*, doi.org/sp3).

The changes happened quickly. Nielsen estimates that polar and brown bears split from their common ancestor 479,000 to 343,000 years ago, when Arctic conditions were mild.

"Polar bears are remarkable organisms to have adapted so rapidly to a very different diet that is ultra-high in fat," says Nielsen.

However they are losing habitat as the Arctic ice melts, so may be forced to move and breed with brown bears, wiping them out.

Fringe stars show galactic flaring

OUR galaxy really has some flare. A rare glimpse of stars on the opposite side of the Milky Way supports the idea that our galaxy fans out at its edges.

The stars on the other side of the galaxy are largely obscured by dense material at the bulging galactic centre. Using telescopes in South Africa, Michael Feast at the University of Cape Town and his colleagues have now managed to spot five stars on the far edge.

These stars are either far above or below the galactic plane, which tallies with maps of galactic gas that suggest the galaxy is thicker at its edges (*Nature*, DOI: 10.1038/nature13246). Astronomers think this is due to a dark matter halo that surrounds the Milky Way.

At the edges of the galaxy, dark matter dominates and starts to pull regular matter away from the plane. Mapping the flare may help us better understand the size and shape of that dark matter halo.

Depression gets a brand new twist

MENTAL health is never straightforward. People with depression seem three times as likely as those without it to have two brain lobes curled around each other.

Jerome Maller at Monash University in Melbourne, Australia, and his colleagues scanned 51 people with and 48 without major depressive disorder.

About 35 per cent of those with depression and 12.5 per cent of the others showed signs of occipital bending, in which lobes at the back of the brain's left and right hemispheres twist around each other (*Brain*, doi.org/sp6).

Maller says these lobes could squeeze the hippocampi, which are linked to depression, upping the chances of getting the condition.

Bullying leaves lasting scars

STICKS and stones may break your bones, but childhood bullying could damage your long-term health.

William Copeland at Duke University in Durham, North Carolina, and his colleagues tracked 1420 children from 9 years old right through their teens. Each child was seen up to nine times during the study and quizzed about bullying. The team then measured levels of C-reactive protein in their blood. CRP is a marker of inflammation linked to higher risk of cardiovascular disease and problems like diabetes. Although CRP levels rise during adolescence, levels were highest in children who reported being tormented by bullies.

Even at the ages of 19 and 21, children who had once been bullied had CRP levels about 1.4 times higher than their peers who were neither the perpetrators nor victims (*PNAS*, DOI: 10.1073/pnas.1323641111).

In a cruel twist, the bullies had the lowest levels of all, suggesting they didn't suffer the same health risks. They may even see a benefit from their behaviour, although Copeland stresses it is not a vindication of their actions. Andrea Danese at King's College London welcomes the findings, and points out that care workers could monitor levels of CRP in children having psychotherapy to see if it is helping to soothe the stress.

Hard plastic oozes fluid to heal itself

PRICK this plastic and it will bleed. This self-healing material uses a process that mimics how blood can clot to repair wounds.

Previous materials inspired by biology could only heal microscopic cracks. Now Scott White at the University of Illinois at Urbana-Champaign and his colleagues have created a plastic lined with fluid-filled channels that can fix damage that is visible to the naked eye.

The key is the pair of liquids in the channels, which react when mixed together. One contains

long thin molecules and the other contains three-sided molecules. When the plastic is punctured, the fluids mix and the molecules link up to create a scaffold, similar to the way blood platelets and fibrin proteins join to form a clot.

After a few minutes of contact, the liquids turn into a thick gel that fills the damaged area. Over a few hours, other ingredients within the fluids cause the gel to harden. Test versions in the lab were able to repair holes up to 8 millimetres wide (*Science*, doi.org/spr). The team thinks using

foams in place of fluids would fill larger gaps, but they haven't tested that idea yet.

White and his team hope to create plastics that incorporate many criss-crossing channels of the fluids, to ensure that they always overlap with a damaged area. The material's first applications may be in objects in remote locations that are difficult to repair, such as spacecraft or deep-sea drilling equipment. Self-healing shields for the military are also a likely application – the work was funded by the US air force.

Dying stars spew cement into space

EXPLODING stars act like cosmic cement mixers, according to an analysis that looks at how to spot this building material in space.

Cement is made by mixing water with calcium silicates, which are molecules made of calcium, silicon and oxygen. When very massive stars die, they explode and litter space with a variety of elements – including all the ingredients of cement. So far, no one has looked for the material in space, so we don't know how much, if any, is actually produced.

Goranka Bilalbegović at the University of Zagreb in Croatia and her colleagues worked out how cement particles would show up on an absorption spectrum, which measures the frequencies of light an object absorbs to reveal its chemical composition. They found that cement would have a unique infrared signature (arxiv.org/abs/1404.7392). The European Space Agency's Infrared Space Observatory found a similar and so far unexplained signal in dust shells around 17 supernovae.

If cement is made in space, it may explain why interstellar gas contains less oxygen than expected. The missing part is tied up in cement, says Bilalbegović.



GRAHAM UDEW/CORBIS

Ancestral farms shaped your thinking

IT'S a cliché to say that East Asians think in terms of the group, while Westerners think in terms of the individual. But there is truth to it, and the explanation may lie in what our ancestors ate. Rice farming may have fostered collective thinking while wheat farms favoured individualism.

To grow rice, many people must work together on irrigation canals, but a lone family can grow wheat. So Thomas Talhelm at the University of Virginia in Charlottesville wondered if staple crops affect thinking.

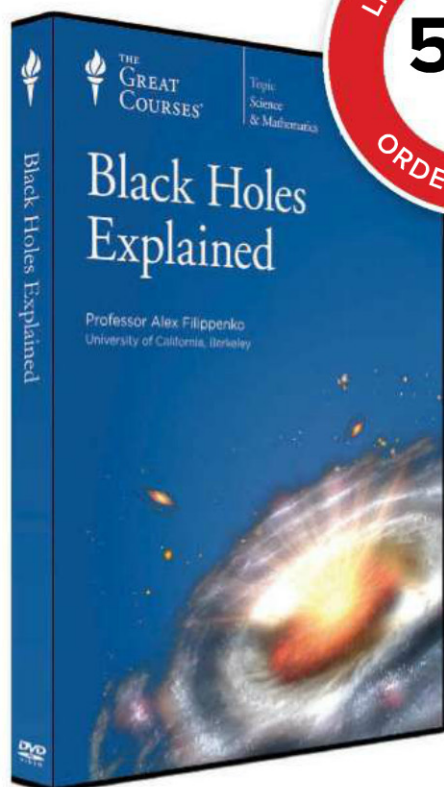
His team tested the cognitive styles, individualism and in-group

loyalty of 1162 students in China, in either wheat or rice-growing areas.

They found many differences. When students drew their relationship to others, those from wheat-growing areas drew themselves larger than others, but students from rice-growing areas did not. And when asked to group things, people from rice-growing areas grouped them by relationship rather than by physical similarities (*Science*, doi.org/sp4).

"Rice provides economic incentives to cooperate," says Talhelm, so people in those cultures become more dependent on each other.





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Guided by atoms

Lost without your GPS? Quantum navigation could keep you on the right path, finds **Paul Marks**

IN 2016 a British submarine will slip its moorings and set sail under the guidance of the quantum world. The navigation system it will be testing should record the vessel's position with 1000 times more accuracy than anything before.

If successful, the system, known as quantum positioning, could be miniaturised for use in aircraft, trains, cars and even cellphones. This would provide a backup navigation tool in cities' concrete canyons, or in autonomous vehicles, where a loss of GPS signal can be dangerous.

GPS doesn't work underwater, so submarines navigate using accelerometers to register every twist and turn of a vessel after it submerges and loses its last positioning fix. But this isn't very accurate.

"Today, if a submarine goes a day without a GPS fix we'll have a navigation drift of the order of a kilometre when it surfaces," says Neil Stansfield at the UK Defence Science and Technology Laboratory (DSTL) at Porton Down. "A quantum accelerometer will reduce that to just 1 metre."

To create the supersensitive quantum accelerometers, Stansfield's team was inspired by the Nobel-prizewinning discovery that lasers can trap and cool a cloud of atoms placed in a vacuum to a fraction of a degree above absolute zero. Once chilled, the atoms achieve a quantum state that is easily perturbed by an outside force – and another laser beam can then be used to track them. This looks out for any changes caused by a perturbation, which are then used to calculate the size of the outside force.

The DSTL team wants this set-up to be usable in the real-world setting of a submarine, where the size of the force would correspond to the movements as the sub swings around in the sea.

Their prototype quantum accelerometer, which resembles a 1-metre-long shoe box, will be trialled on land in September 2015, the team said at a conference at the UK National Physical Laboratory in Teddington this week. It will initially operate along just one axis, before two more sets of lasers and trapped atoms are added to accommodate motion in all three dimensions. Each will cool 1 million atoms of rubidium. "Once we have understood the first generations, we'll start to miniaturise it for other applications," says Stansfield.

It's not a done deal yet, though, because the accelerometer can't

distinguish between tiny gravitational effects and accelerations caused by a vessel's movement. "If the submarine passes an underwater mountain whose gravity attracts it to the west, that feels exactly like an acceleration to the east," says Edward Hinds at the Centre for Cold Matter at Imperial College London, who is developing the accelerometer for the DSTL. "This means that very good gravity maps will be required to navigate correctly."

"Super-accurate navigation would make sleeping easier for the captain of a submarine"

The DSTL isn't alone in pursuing quantum navigation: teams in the US, China and Australia are chasing the same prize.

"Super-accurate navigation makes sleeping easier for the captain of a submarine," says John Powis, head of the NATO Submarine Rescue Service in Faslane, UK, and a former navigator on Royal Navy submarines. It will also make it easier to go on patrol undetected, as submarines will no longer have to expose a mast to GPS, he says.

But Powis thinks this technology may have the greatest impact in future generations of weapons – once it has shrunk down in size. "The submarine does not need to know its position in metres and centimetres," he says. "But a projectile like a missile or shell might."

The DSTL team believes the technology has applications beyond warfare, though. "Ten to 20 years ago this would have needed a huge cryogenic cooler, but laser-cooled atom clouds are changing all that," says team leader Stephen Till. He says future generations of the technology are likely to make their way into everything from cars to our smartphones. "We're convinced the size and power will come down for broad use." ■



How did I get here?



Are you sitting comfortably?

Kindergarten bots

Chatting with social robots could enhance children's language skills

Hal Hodson

BLUE, a fluffy robot with cartoon eyes, is telling a little girl a story about a snowman. The tale plays out in pictures on a tablet that sits between the preschooler and Blue's soft plastic feet. Blue's eyes look down at the characters as it describes them, then up at the child to check that she's paying attention. The 5-year-old is one of the first children to learn language skills from a robot, and she is captivated.

The girl is part of an eight-week experiment by MIT's Media Lab now taking place in a preschool in the Boston area. The idea is to see how well children learn from robots – it is one of a handful of similar experiments being run by graduate student Jacqueline Kory.

Kory and colleagues are testing children to see how well they remember new words learned

from robots over time. As the weeks go by, Blue and other robots like it, dubbed DragonBots, will adapt their stories as a child learns new words, keeping pace with individual development. Kory and the team leader, Cynthia Breazeal, will be logging everything and tracking how well they learn.

The team believe robots represent a powerful new way to enhance children's education. Unlike educational TV shows, say,

“Robots that can pick up and learn from children's social cues allow a child to learn at their own pace”

the robots are physically present and have some of the same social skills as humans. That gives them the potential to tap into a child's appetite for one-to-one communication and help kids learn in many of the same ways a

human teacher does. This is especially important when it comes to language skills.

Through experiments conducted earlier this year, Kory has already shown that the robots' social abilities make a huge difference to how well children engage with what the robot says. In one experiment, children talked to two different robots about toy animals. One robot's reactions and movements were programmed to be similar to a child's own, while the other's were more random. Children seemed far more willing to trust the robot that mimicked their body language, learning better from it.

The team's work is still in the early stages. When the robot prompts a child to tell it a story, for example, the goal is for the bot to listen and gauge how well their vocabulary is developing. But speech recognition for

preschoolers is still an emerging area, hampered by a lack of data on which to train machine learning software.

The DragonBots' hardware will also need upgrading. Right now they only really work in a controlled research environment, but the next generation could find a place in homes and schools.

Kory and Breazeal see a future where young children's learning can be supercharged by socially intelligent robots that fit smoothly into their lives. Children already bond strongly with their stuffed animals, for example, so what if those toys had the ability to talk back? Previous work at the Media Lab has even used the DragonBots to teach preschoolers little snippets of French, centred on role play where robot and child share a meal together.

“I love the idea of delightfully designed, childlike robots scooting around and befriending children. I think there's a lot to say for this kind of effort,” says Michael Levine, who directs research on educational technology at the Sesame Workshop in New York, the non-profit behind the popular children's television show *Sesame Street*.

Levine says Breazeal's robots overcome one of the fundamental problems with developing educational content for television and tablets – individualisation. Even when testing the most popular episode of a kids' TV show, there will be a child in the room who doesn't like it. Robots can pick up on social cues and offer a solution, letting a child learn at their own pace, he says.

Breazeal has grand plans for the socially aware robots. “In the US there's a big issue with children entering kindergarten not ready to learn. And if you don't enter kindergarten ready, you never really catch up,” she says. “There is a tremendous opportunity to develop new technology to support children's education, especially early childhood learning.” ■

3D printing masters the art of soft toys

FROM aircraft to houses and even guns, just about anything can be 3D printed – as long as it's not soft and squishy. Now the repertoire is about to get a lot more cuddly.

The first 3D printer that can churn out soft objects made its debut last month at the Computer Human Interaction conference in Toronto, Canada. It has already made small woollen teddy bears, and could one day be used to create electronics that are easy on the skin. That could pave the way for a new generation of body-monitoring sensors and lifelogging devices that can be discreetly embedded in clothing.

"The things that we hold close to our body, we would like them to be soft," says Scott Hudson at Carnegie Mellon University in Pittsburgh, Pennsylvania, who led the team that devised the printer. He says he wants interactive devices, which are typically made of rigid materials, to be able to take on forms that we like having close to ourselves.

Initially, the machine could only work with melted plastic. Hudson replaced the print head with one he custom-built, which controls a needle threaded with yarn. Printing is then a matter of specifying the object using 3D design software and running a separate program to break the design down into instructions for the device. It executes these by laying down

successive layers of stitches, all the while keeping the yarn loose enough to avoid unpicking previous stitches (pictured below).

To go beyond making teddy bears, the printer must be able to combine yarn with other types of material. For the time being, the researchers have been able to manually place devices inside the bears as they are being printed. They have also created

"The object is specified using 3D design software, and the printer then lays down layers of stitches"

bendable joints at the elbow, wrist and shoulder by printing the bear's arms around tubes of nylon mesh.

The team is also experimenting with ways to embed electronics inside the bears without puncturing the circuitry or breaking the print needles. In one "torture test" they tried printing directly over rigid wires to see how much resistance the machine could cope with. Other objects the team printed had small internal pockets that could be used to hold devices.

The soft printer is a great example of how far such machines have come, says Stephen Ervin of the Harvard University Fabrication Laboratory. It could extend 3D printing's appeal to "a large and diverse audience of users and uses", he says. Aviva Rutkin ■



It's less hard this way

ONE PER CENT



Holographic chocolate is a trippy treat

Why settle for a bar of regular old chocolate when you can chow down on the holographic kind? Morphotonix, based in Lausanne, Switzerland, has developed a technique for "printing" credit card-style holograms on chocolate. The images are produced using microstructures that diffract light on an object's surface. The edible holograms require no additives – they are produced by etching the correct structure into the mould that shapes the chocolate. They will be presented at a conference in Düsseldorf, Germany, this week.

"The innovation we have seen to date happened in a world without discrimination"

More than 100 internet firms, including Google and Facebook, wrote to the US Federal Communications Commission calling for a stop to moves that would end net neutrality – the ideal that all internet traffic is given equal priority.

Robot boot gives you a boost

Take a load off. A new battery-powered exoskeleton boot built at the MIT Media Lab includes several supports that wrap around the calf. As you walk, it pushes off the ground with extra power, reducing the amount of energy needed to move and making loads feel about 7 kilograms lighter. Future versions could be worn by soldiers or by people who need help walking.

Flying truck to pull the troops out

What do you get if you cross a truck with an octocopter? A military ambulance that, when necessary, can take to the air and evacuate injured troops in double quick time. Advanced Tactics of El Segundo, California, has built such a beast with Pentagon funding. Called the Black Knight Transformer, it is a fully drivable, truck-like vehicle. In tests in a California desert, the eight rotors mounted around its roof spun into life and the vehicle undertook a series of successful, uncrewed hover tests.

INSIGHT Drone law



BRIAN EMFINGER

Unofficial eye in the sky

Flight in a twilight zone

Drones are taking off in the US, but their legality is up in the air too

SHORTLY after a powerful tornado struck Mayflower, Arkansas, on 27 April, storm-chaser Brian Emfinger flew a drone over the ravaged town, capturing dramatic aerial images of a wide swathe of wreckage, even as emergency services were flocking to the scene. The footage aired on local TV and quickly went viral online, but it also caught the eye of the US Federal Aviation Administration (FAA), which launched an investigation the next day.

Emfinger and others like him could be forgiven for failing to anticipate the agency's ire. Though he is one of thousands of drone-owners in the US – with most craft being the small, quadcopter variety – there are no official regulations on how to operate them in the US. Even the current ban against flying them for commercial purposes, which Emfinger flouted, comes from a 2007 policy statement, not a law.

Under congressional order, the FAA must open national airspace to commercial and civilian drones by the end of 2015. In the meantime, enthusiasts are taking to the air with little understanding of what's allowed and what's not. As they do, they are showcasing the many benefits of

civilian drones while risking running afoul of local authorities. "I'd describe this as a car crash in slow motion," says Matthew Waite, director of the Drone Journalism Lab at the University of Nebraska-Lincoln. "I'm afraid the situation we're in right now, the longer that this takes, the more people are just going to flout the rules."

Other countries are adjusting faster to the new air traffic. In Germany, drone operators are required to obtain licences and abide by a set of safety

"It doesn't make any sense to have the same regulations in the farm fields as in Times Square"

and privacy regulations. In Canada, businesses that use drones must submit detailed flight plans.

The FAA's reluctance to move quickly may be down to safety concerns: drones can be dangerous in the hands of untrained operators. In a road map for regulation released in November, the FAA hinted at a long list of possible licensing requirements, such as medical tests, pilot training, and drone airworthiness certificates.

Brendan Schulman, a lawyer

specialising in drones at law firm Kramer Levin in New York City, says the list indicates a "burdensome future landscape" for drone enthusiasts. For the inevitable cases in which a drone injures someone or damages their property, there is no need for special regulations, he says. Existing tort laws, which vary from state to state, generally dictate how much the injured party should be compensated.

"Tort laws would apply to any kind of conduct that is negligent or reckless, regardless of the device they're using: it could be a lawnmower or a golf club or anything else," says Schulman. "That's the framework that we've had in place for decades with regard to model aircraft operation."

Ella Atkins, an aerospace engineer at the University of Michigan, Ann Arbor, says the FAA needs to consider the many different ways drones can be used. Future regulations should ask more or less of operators depending on whether they want to use their drones for business, for research or for fun – and where they want to use them.

"It doesn't make any sense to have the same regulations in the farm fields as in Times Square," she says.

Aviva Rutkin ■

Gaze-tracking gadget knows you want to move

COMBINE a £50 gadget with some smart software and you get a life-changing solution. People who can't move their arms and legs will soon be able to attach such a device to their wheelchair and steer using just their eyes.

Similar technologies exist, but they involve people staring at arrows on a computer screen, and keeping their gaze fixed as they move. Aldo Faisal at Imperial College London and his colleagues have developed a more natural system, with software that uses subtle eye movements to distinguish when a person is looking around and when they want to move.

"Our software can tell the difference between looking at someone using a coffee machine, and wanting to walk over to that coffee machine," says Faisal.

And unlike other systems, this one responds to a user's intention to move within 10 milliseconds. Typically anything under 15 to 20 milliseconds feels instantaneous, says Faisal.

The team showcased the device at the Imperial College Festival in London last week and hopes to have the system ready for sale within three years. If successful, it could be adapted for other uses, like piloting a drone or a plane. Helen Thomson ■





Nobody has all the answers to the world's energy questions, so *New Scientist* has teamed up with Statoil to create a special section of The Last Word to search for solutions. The best answers, published here, win their authors £100

Energy unleashed

How can toddlers expend seemingly boundless energy when they eat so little?

■ We can think of each child as having an energy budget, which it can spend on different biological functions. Human children evolved to allocate their energy optimally between these functions, and this allocation depends on environmental conditions.

It costs energy just to stay alive, which we call maintenance. This is primarily determined by the body's lean tissue, and within that the brain is the biggest single cost. At 1 year, half the maintenance costs are spent on the brain, and less than one-quarter on muscle mass.

In many populations, infectious diseases cause mortality during the first few years. It takes energy to resist infections and survive, and running an immune system is expensive. This is a key reason why babies naturally store substantial fat in the first few months. On average, a baby is 25 to 30 per cent fat by 3 months, a level we would consider very unhealthy in adults. In a Western setting, however, with high levels of sanitation and vaccination against many diseases, the allocation of energy to immune function has been reduced substantially.

A third demand on the energy budget is growth. But in fact toddlers use only a minute fraction of their energy budget for this purpose. Whereas a 3-month-old baby allocates one-third of its energy to growth, by 1 year this has declined to only 4 per cent.

Another possible use for energy is keeping the body warm – thermoregulation. In general, animals lose heat faster when they have a high ratio of surface area to body mass, so babies inherently use more energy per kilogram to keep warm than adults. But in centrally heated homes, this is another cost that has been reduced.

So what's left for the Western toddler to spend its energy budget on? You guessed it: physical

activity. And while this might seem to require a lot of energy, it generally comes in brief bursts, interspersed with naps, and so does not cost so much over the entire day.

In the 1990s, measurements of energy expenditure taken using a sophisticated stable-isotope probe showed that young children expended 10 per cent less energy than the requirements recommended by the World Health Organization. This mismatch is probably because up until that time, energy requirements were calculated from food intakes, not energy utilisation. The children were being

fed more than they actually needed.

Toddlers don't need huge energy intakes, and in the West we have reduced many of the budget costs that required energy in the past. Some children run around and shout a lot, and a high-sugar diet may make the activity bursts more noticeable by accelerating the release of energy into the bloodstream. Other children put on more fat, and we find that fatter children are less likely to take as much exercise as their leaner peers. So, we can influence the energy budget through providing a healthy diet and encouraging the physical activity. And they will sleep eventually...

Jonathan Wells

*Professor of Anthropology and Paediatric Nutrition, UCL Institute of Child Health, London
Author of The Evolutionary Biology of Human Body Fatness (Cambridge University Press, 2009)*



■ Like pro cyclists, toddlers are lightweights, so they need to expend far less energy to move at a given speed. Unlike pro cyclists, toddlers also move slowly compared with adults, no matter how wildly they flail their limbs.

The numbers speak for themselves: a 75-kilogram adult moving at 6 metres per second has kinetic energy of 1350 joules. A 15 kg toddler moving at 2 m/s has kinetic energy of 30 joules.

Anthony Hasseldine

Eltham, Victoria, Australia

■ The answer is simple. They don't expend boundless energy. Toddlers spend much of their day and all of the night (hopefully) at rest; they have personal chefs who make their food and feed it to them; they have someone to dress them, drive them around, make all the difficult choices and so on.

If you consider the energy they save and the energy we burn looking after them, it becomes easy to understand where their "boundless" energy comes from. They are just fortunate enough to be able to save their energy for the important stuff, like making us look bad.

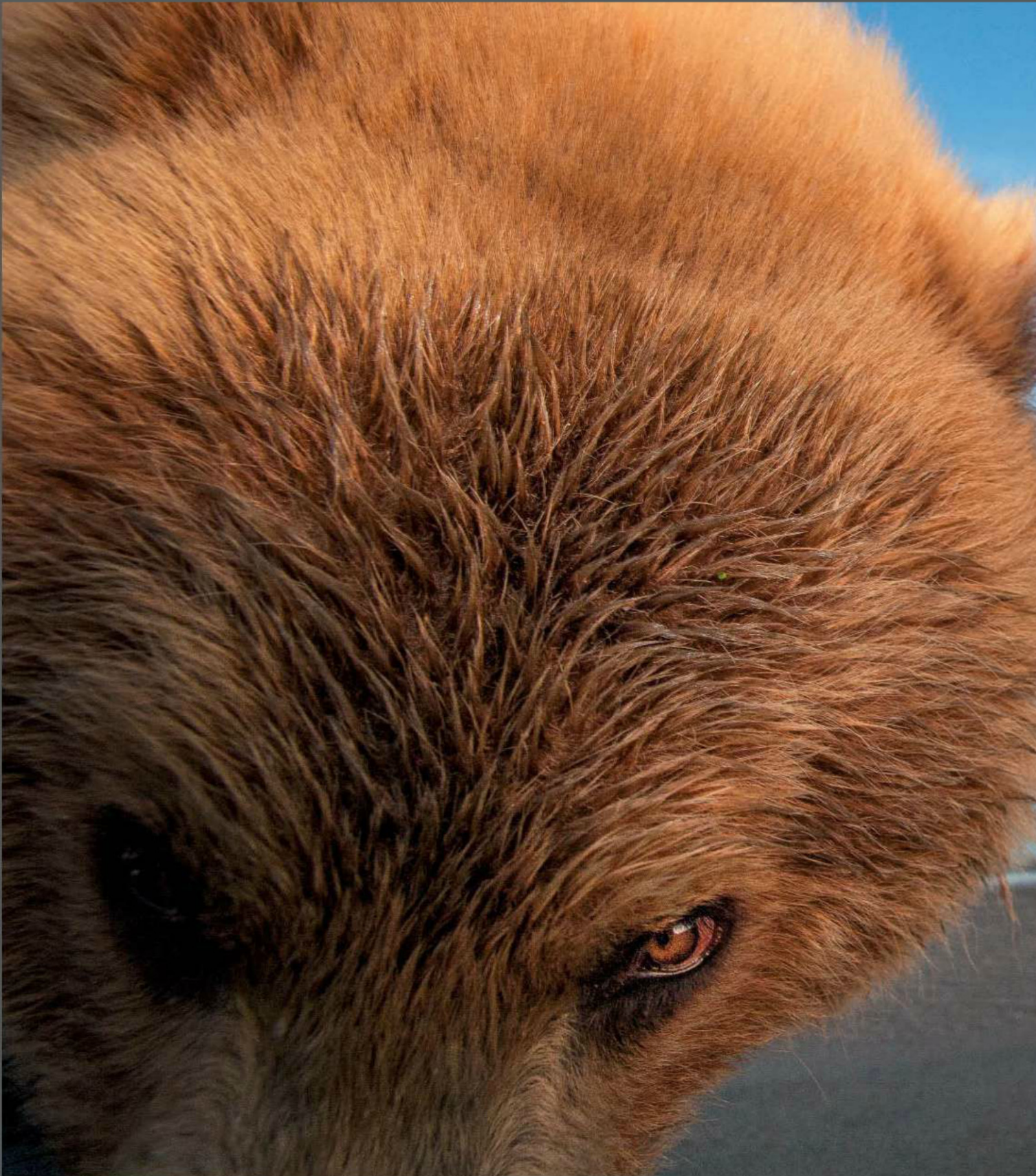
Jason Boyd

Fountain Inn, South Carolina, US

Your next question

Fridge magnets must constantly overcome the force of gravity, which suggests they are expending energy. So why don't they run out of juice and fall off after a few years?

Send your answer, to be received by 2359 GMT on 3 June 2014, to answers@newscientist.com or visit www.newscientist.com/topic/energy, where you will also find our terms and conditions.





You lookin' at me?

"SHE is a massive and well-fed mama bear," says Ingo Arndt, the award-winning German photographer who captured this powerful beast in a moment of curious investigation. The female lives on the south coast of Alaska in Lake Clark National Park. She is one of hundreds of resident brown bears (*Ursus arctos*) in these parts.

Coastal brown bears are huge, fearsome creatures with a mean bite and long sharp claws that they use for digging clams out of the mud, among other things. The mild climate and rich ecosystem lets them grow to 750 kilogrammes. They graze on protein-rich sedges, hunt salmon, and are often seen ambling across the mudflats, with noses skimming the sand, hot on the scent of a buried clam. They eat razor clams, soft-shell clams, cockles and the Alaska surf clam. Some carefully pry the shells open with their hooked claws. Others simply crush them beneath their powerful paws and spit out the shattered bits, or swallow the shells and excrete them later.

Given the bears' size, you can forgive Arndt for sending his camera out on its own to capture this image while he retreated to a safe distance. He mounted it on a custom-made, remote-controlled, four-wheel buggy and left it on a section of beach the bears liked to frequent. After a time, this mama strolled over. Arndt snapped the shot when she was just 50 centimetres away from his lens.

Arndt's photographs feature in his latest book, *Coastal Bears*. Catherine Brahic



Photographer

Ingo Arndt ingoarndt.com

Smallpox must die

There are no good reasons to let an organism responsible for mass death and destruction live on, says **Gareth Williams**

DELEGATES from across the world will meet next week at the World Health Organization in Geneva, Switzerland, to consider an irrevocable act: the deliberate and final extinction of a species.

Everyone agrees that the world is a better place without this particular species roaming free. There was universal celebration when it was all but wiped out more than three decades ago. Even so, the WHO debate stands a fair chance of stalling because the group is well practised in not quite making things happen where this species is concerned. It will be the sixth attempt to resolve this issue. So what's going on?

The species is the *Variola* virus, which causes smallpox, and the group deciding its fate will be the 67th World Health Assembly, the WHO's decision-making body.

At its height, smallpox killed 1 person in 12 and mutilated hundreds of millions more. During the 20th century, vaccination steadily edged it towards extinction. Like most doctors of my generation, I never saw a case after qualifying in 1977 and hopefully never will, because the global eradication of smallpox was confirmed in 1980.

The disease may have disappeared globally but the virus is not extinct. After eradication, the WHO closed smallpox research labs across the world and destroyed all stocks of the virus except for two duplicate sets of representative strains, which were kept for research in two high-security establishments. This was in 1983, when US president Ronald Reagan's Star Wars initiative



dominated the headlines. In true cold war symmetry, the WHO handed one batch to the US Centers for Disease Control (CDC) in Atlanta, Georgia, and the other to the State Research Centre for Virology and Biotechnology in Koltsovo, Novosibirsk, then part of Soviet Russia. At both sites, the virus samples were locked away in liquid nitrogen. The WHO has repeatedly postponed the date of destruction because of US and Russian opposition.

Not much has changed since the last time the stockpiles were spared in 2011. Experimental smallpox drugs are in the pipeline. The intact virus is pretty redundant as a research tool: the

genomes of many strains have been thoroughly sequenced and key proteins required by the functioning virus can be made in the lab. Over the last 30 years, the stocks of virus have contributed little to scientific understanding, other than confirming that new drugs aimed at other viruses still plaguing us are not much use against smallpox.

The Advisory Group of Independent Experts, convened by the WHO, recently argued that keeping the virus will never serve

"The *Variola* virus is a genie which must not be allowed to escape from its bottle into the world again"

any useful purpose. It has been overruled by another expert committee, also convened by the WHO; the Advisory Committee on Variola Virus Research says the stockpile can help the work on antiviral treatments.

Talk of the need for new treatments is undoubtedly influenced by past misuse of the virus for military ends and contemporary fears that terrorists or a rogue state might commandeer smallpox as a bioweapon.

During the 1760s, the English hatched a plot to exterminate Native Americans by deliberately infecting them via blankets that had been exposed to smallpox. They didn't wipe them out, but many died. This theme was picked up and refined 200 years later by the Russians. It is an unfortunate coincidence that their highly virulent strains of weapons-grade smallpox were developed at the VECTOR germ warfare laboratory in Koltsovo, on the same site that now houses the virus stock that was entrusted to the Soviet Union.

The *Variola* virus is a genie which must not be allowed to escape from its bottle into the world again. The chances of smallpox being released, inadvertently or deliberately, from either the CDC site or Koltsovo are vanishingly small, given the elaborate security.

However, that risk will never be zero while stocks remain. Destruction removes that risk and might allow the WHO to focus on what we will really need if smallpox ever comes back, either

because a related virus evolves to replace it, or a human villain releases some unknown cache.

There is no proven treatment for smallpox and our vaccines, while effective, are in short supply. The vaccine issue is where we should focus our efforts. A handful of countries have enough to immunise just 20 per cent of their populations; the WHO used to hold hundreds of millions of doses but destroyed most when freezer space was in short supply during the 1990s. In an emergency, it would take months for vaccine production to get up to speed, and even then this would be on a pathetically small scale.

Today's transport networks are capable of spreading the virus quickly through the biggest susceptible population in the history of our species. Immunity was lost as vaccination, which carries health risks, stopped soon after eradication. So a smallpox outbreak could easily become a global catastrophe, which the WHO's stocks of *Variola* would do nothing to mitigate.

So what should happen in Geneva next week? Above all, the World Health Assembly should vote to destroy the stocks of *Variola* virus without further delay. This would prevent yet another unedifying and expensive cycle of indecision. If the threat of smallpox staging a comeback is at all credible then our capacity to deal with it must also be credible.

Also, we must not forget the wider significance of smallpox. It is not just one of the nastier exhibits in the museum of medical horrors. It is the only human infection that we have successfully exterminated. It is time for the WHO to move on. ■

Gareth Williams is emeritus professor of medicine at the University of Bristol, UK, and author of *Angel of Death: The story of smallpox*. He will talk about his latest book, *Paralysed with Fear: The story of polio*, at the UK's Hay Festival on 29 May

ONE MINUTE INTERVIEW

Revolution in the classroom

Tracking how tens of thousands of people learn online will reshape education, says Duolingo creator **Luis von Ahn**



PROFILE

Luis von Ahn is a computer scientist at Carnegie Mellon University in Pittsburgh, Pennsylvania, CEO of Duolingo, a free language-learning app, and founder of reCAPTCHA, an anti-spam service that was acquired by Google in 2009

Duolingo users are making new courses for people who speak Asian languages like Chinese and Hindi. How does that work?

We give people a skeleton of what the course should teach. Then they make it and we give them tools and access to a lot of data to figure out if the course is doing well and how to improve it.

What kinds of tools and data do you use?

For example, right now we're teaching adjectives after plurals, so let's try teaching adjectives first. We pick a subset of 50,000 users and see if they learn better – if they come back more often and make fewer mistakes. We can see the statistics and if they're positive, switch all users to the new method. We then give the community making the courses access to the same information so they can run experiments to work out how to do better.

What can conventional language teachers take away from these experiments?

We're in a position to discover how people learn on a much larger scale, and we're going to release

a lot of that information. Let's say moving a single word forward in the curriculum improves learning outcomes by 0.1 per cent. You can't measure that with 50 students. You need tens of thousands of students to see those differences: 0.1 per cent is not a lot. But if you do 10 of these changes you have 1 per cent improvement; if you do 100, you have 10 per cent improvement. That's big. These are the types of things that you can't do offline.

Will ventures like Duolingo reshape the model of education that we use?

I think it's going to take some years to figure out what will actually work. The point is it's not going to be quick. Our new language certification test will not replace the TOEFL, one of the current standards for English, in six months. But I do think we're in the process of figuring out what the next wave of education will look like.

You helped create CAPTCHA, the anti-spam test that distinguishes human users from computers. Google software can now solve most CAPTCHAs. Does that worry you?

This happens. It is a good thing that computers can do more than they used to be able to do. They can crack some CAPTCHAs and some distortions, but not everything. So it's still the case that humans can read better than computers, but this will continue happening. I'm not concerned, really.

But do we need to move the goalposts?

Yes, we do. Either the CAPTCHAs will get harder or we'll see a switch from distorted characters to different types of questions, like showing you pictures and asking what is in them. Humans are a little better than computers at reading text. But humans are way better than computers at recognising what is in an image.

What about when computers crack pictures?

You know, spam is a problem, but I would say that the applications of artificial intelligence that can recognise what's in any picture are so much more important. I think it's worth the spam.

Interview by Aviva Rutkin

Treat violence like a plague

A background in infectious disease made it apparent to **Gary Slutkin** that street violence can spread like a contagion. And that means it can be contained like one too, he tells **Madhumita Venkataramanan**

You began your career working on infectious diseases. What was your focus?

I began to understand how diseases spread – and how to control them – with tuberculosis. From 1981 to 1984, I was an infectious-disease fellow at San Francisco General Hospital and was then made responsible for controlling TB in the whole city. I had to learn all the characteristics of spread and how to find active cases and “contacts” – people who can transmit it invisibly. Later, I worked on cholera and TB in Somalia. And from 1987, I worked at the World Health Organization for seven years on HIV and AIDS epidemics in Africa.

What strategies were most successful for stopping the spread of disease?

Controlling HIV was almost entirely about changing behaviour. I ended up hiring a lot of psychologists and others who understood how to change community norms. In Uganda we ran an education campaign to destigmatise HIV-positive patients, explain how HIV is transmitted, and promote prevention, including using condoms. The dominant message was “stick to one partner”.

What prompted your shift from disease to street violence?

After 10 years working in Africa, I moved back to the US in 1994 and was looking for how I could be useful at home. Two incidents from that time had a big impact on me. One was a 12-year-old boy who performed an “execution style” killing under a bridge. The other was another 12-year-old who threw someone, making them fall seven to 10 flights from a housing project, for not giving him some candy.

When I looked into it, I thought the strategies being used against violence had no chance of working. They had little

scientific basis and grossly misunderstood and overvalued punishment. I knew violence was a behaviour – just like exercise, smoking, overeating or having sex. It looked to me like a field with a giant gap.

Why did you think your background in infectious disease might be useful in this area?

I was particularly compelled by one thing: the greatest predictor of a shooting is a prior shooting. That’s what distinguishes infectious disease; it causes more of itself. That’s the case with flu, a cold or TB. On a map, violence looks like circles with high concentrations in their middles. It’s the same with cholera or malaria.

Did you see other parallels?

Just as more exposure to colds or flu makes people sick more frequently, exposure to aggression causes people to exhibit violence

“On a map, violence looks the same as outbreaks of cholera or malaria”

more frequently. We have seen this directly in our work – nearly 85 per cent of our outreach workers in Chicago report that their clients were targets of abuse at home.

We know that as many as 30 per cent of those exposed to child abuse as victims become abusers themselves. As psychologist Albert Bandura showed years ago in his famous Bobo doll experiment, children copy the behaviour of adults.

Why does violence reinforce itself?

Through mirror-neuron circuits, our brains retain and regenerate repetitions of complex behaviours we witness, as behavioural

scientist Marco Iacoboni at the University of California, Los Angeles (UCLA), has shown. These circuits help us to learn unconsciously, by copying or modelling what they see. But it also means that people who have observed violence are 30 times more likely to commit it. Under certain conditions it can be up to 100 or 1000 times more likely.

So is exposure the primary factor that perpetuates cycles of violence?

A second process that kicks in later through your teens has to do with needing peer acceptance. Naomi Eisenberger at UCLA has shown that avoidance of the pain of social rejection is represented in the brain in similar locations as physical pain. So social slights or insults can promote recruitment of new “infected” persons and groups, and spur outbreaks of killings.

You have developed a research-based “cure” for violence in the real world. How does it work?

One-third of shootings are retaliations, so that is the point at which you have an opportunity to interrupt the cycle of violence. We train disease-control workers – or violence interrupters – to stop potential shootings. We teach them how to talk someone down, distract them, change the setting and change their perspective. They make potential shooters take on the perspective of their own child or parent,

PROFILE

Gary Slutkin is a professor of epidemiology and public health at the University of Illinois at Chicago. He is the founder and executive director of CURE Violence, a programme that interrupts cycles of violence, partly using strategies from infectious-disease control

Photographed for New Scientist by Roark Johnson



and realise that it's socially safe not to shoot. When they realise it's not expected of them, they don't do it.

When did you first try this out?

In February 2000, we tested our theory in West Garfield Park, the most violent neighbourhood in Chicago. To begin with, we organised responses to shootings, so people would see there was social objection – not just from the police, but from their own community.

How well did that pilot programme work?

The summer after we launched, there were no shootings or killings for three months straight. This was unheard of. It went from 43 shootings in 1999 to 14 in 2000. Three years later, it went down to about seven.

You now have programmes running in seven countries. Does your approach change for different situations?

We have worked in Basra in Iraq, Cape Town in South Africa, and in parts of Honduras

in an intense gang/drug cartel situation. In many of these situations the groups are in-fighting, so that changes who we need to hire as interrupters. In Basra, for example, we hired people with tribal connections and religious credibility. In its first year, 2009, we intervened in 112 violent incidents and prevented a potential killing in 105 of those cases. It is different in Iraq versus central America and Africa, but lethal street violence has been our main focus.

Have you tried to tackle other types of violence, beyond that at street level?

Since 2011 we have been using this approach in a juvenile detention facility in London, where we're employing some of the prisoners themselves to be interrupters.

We also have a three-year plan to explore new adaptations. We've met with the US Centers for Disease Control, and they want to talk about adapting to other areas of violence, such as honour killings and military suicides.

Have you done much work on prevention – vaccinating against violence, so to speak?

Well-placed interruptions prevent outbreaks. But with high-risk individuals in groups or cliques, we have a specialised intervention even before a precipitating event occurs. We work to develop new behavioural patterns around triggers – like feeling insulted or disrespected by another clique – to practise new sets of responses, and ensure social rewards and peer recognition. Changes in social expectations are the best immunisation.

As a society, do we need to change how we think about violence?

Violence is a public health issue. The health system includes government departments, hospitals and healthcare practitioners. They all have a role in preventing relapses after a gunshot victim is released, just like after a TB or HIV-positive patient leaves. It is not about good and bad people. Violence should be seen as a disease: it is interruptible and treatable. ■

War and peace

From Robert Eales

We should be able to test Ian Morris's hypothesis that war has created a more peaceful, and hence prosperous world by creating larger, unified societies (19 April, p 28). Yet since 1900 and perhaps earlier, no war I can think of seems to fit. Since then no military invasion has succeeded in its objectives, established an enduring occupation or brought greater peace or prosperity to the invaded nation.

Consider the conquest of two southern African republics by the British Empire during the Boer war of 1899 to 1902. The conquest began to unravel in less than a decade when the Boers won the first elections after that war and resumed effective control of their former republics. They remained part of the Commonwealth until 1961, when a unified South Africa declared itself a republic.

The impoverishment and embitterment caused by the war resulted in a deeply troubled society which still struggles to reduce violence.

Every military invasion since that time was either unsuccessful in the first place or came unstuck later. From the point of view of the aggressors, the two world wars were disastrous.

Sydney, Australia

Ian Morris writes:

■ Robert Eales takes on the argument about what's happened globally over the past 10,000 years by looking at what's happened locally in the last 100 years, and he often focuses on still shorter timescales. This, I think, leads him to misunderstand the effects of the world wars. Like a lot of modern historians, I suggest in my book that we should see them and the cold war as phases in a single struggle, running from 1914 to 1989 (or 1991), and that the Boer war is best understood as part of the wider post-1870 breakdown of the British world system.

As far as aggressors losing since 1900 goes, one of the main points that I touched on in *New Scientist* is that the indirect, long-term effects of war – making the world safer and richer – slowly affect everyone involved, not just the aggressors.

Pass it on

From Tim Stevenson

Andy Coghlan's article on the role of microRNAs in the inheritance of epigenetic characteristics was fascinating (19 April, p 14). But a hasty reading of it could give the impression that he is describing an evil mechanism that perpetuates the negative results of stress in future generations.

Surely, this is more likely to be an evolved mechanism for passing down survival strategies when bad times last for many generations.

Prestwood, Buckinghamshire, UK

Caveman cross

From Freya Smith

Ella Been suggests that *Australopithecus sediba* did not exist (12 April, p 11). If so, it does not necessarily follow that the hominin fossils found at Malapa, South Africa, are from four individuals. They may show *Australopithecus* and *Homo* characteristics because of interbreeding between the two genera. The adult skeleton may well be that of a single individual. A cross-bred population would show a random assortment of characteristics from each lineage.

Mosgiel, New Zealand

Cogs in the machine

From Bryn Glover

Interviewed about the automation of work, Andrew McAfee comes across as either naïve or evasive (26 April, p 28). The question of what will happen

to all the workers displaced by encroaching technology was put to him in several different ways, and McAfee either ignored the point or answered obliquely.

History teaches us that it is always the simplest and most basic tasks that are the first to be eliminated by automation, and those tasks are most often performed by the least able, the least articulate and the most vulnerable in our society. During the heyday of Victorian inventiveness and development, these people were simply consigned to the scrapheap.

I see no reason whatever to believe that McAfee's utopia will turn out to be any different from



the dystopias of the past (or indeed, of the present), unless some new radical way can be devised to persuade those who have acquired vast fortunes to relinquish enough for everyone to share the benefits.

Harrogate, North Yorkshire, UK

Wet life

From Michael Paine

Colin Barras (19 April, p 36) describes the possibility that life originated in water-free conditions on Mars, before being transferred to Earth via an asteroid impact. He questions whether dry life from Mars could colonise a wet Earth, but there is ample opportunity for life on Mars to have evolved to inhabit wet locations before making

the journey to Earth.

Mounting evidence suggests that Mars was very wet several billion years ago, and I think it is more likely that this wet life took root on Earth.

Beacon Hill, New South Wales, Australia

Killing, warts and all

From Rod Tranchant

Michael Slezak needs to consider the importance of what is yucky, as well as humane, when discussing ways to kill pest species (26 April, p 40).

Killing a cane toad by running it over or hitting it with a golf club is humane because it is quick but has a high yuck factor. How does anyone know the pain and suffering that may be caused by putting the toad in a freezer for a few days? Probably not humane, but reassuringly yuckless.

Chichester, West Sussex, UK

The last cut

From Celia Berrell

Gareth Jones wants medical schools to stop using unclaimed bodies for dissection (19 April, p 26). When I die, I will no longer have any use for my body.

If I have surviving family who express their respect or emotional attachment for me in some way that prevents my body being used for anatomical education, respect their wishes.

If there is no one to claim my body and it can be put to good use, then please go ahead. I will have finished with it.

Brisbane, Australia

Ethical highs

From Brendan Woodford-Robinson

One major issue absent from your report on New Zealand's drug liberalisation (8 March, p 40) is that novel drugs which need to be proved safe will be tested on

animals, including experiments to determine a lethal dose.

Understandably, the public backlash here in New Zealand has been huge, with nationwide protests on the streets. People don't want legal highs tested on animals any more than cosmetics.

Prime Minister John Key has said he's not fond of the idea of testing drugs used for people's entertainment on rabbits, however he didn't mind using rodents. The opposition party leader David Cunliffe says he believes it would be unethical to test the safety of "pleasure drugs" on any animal.

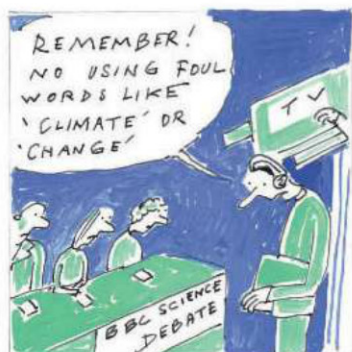
Wellington, New Zealand

Poor reception

From Liegh White

I don't know how Ceri Thomas, head of programmes at BBC News, has the brass neck to argue that their coverage of the science around climate change is impartial and balanced (19 April, p 33). I've lost count of the number of times Nigel Lawson, chairman of the political think tank The Global Warming Policy Foundation, has been invited to speak on Radio 4's *Today* programme as the "balancing" voice.

Time and again, interviewers make direct comparisons between the costs of green energy and fossil fuels, without including the costs of the carbon sequestration needed to clean up resultant pollution, which would give a



truly balanced comparison.

I could easily be convinced that there are interests at work in the BBC intent on discrediting any arguments relating to the case for climate change instigated by humans. I would encourage people to be vigilant and challenge news coverage wherever bias and inaccuracy is evident.

Keyworth, Nottinghamshire, UK

Just like us

From Jo Spencely

Assigning medical diagnoses to Shakespeare's characters seems to miss the point (19 April, p 43). Labelling his characters as "other" – differently wired or disabled – allows us to distance ourselves from them, whereas Shakespeare's genius was to show us how similar we are to them. Their flaws are our own, just magnified.

By making us empathise with them he shows us that we are all capable of feeling what they feel and behaving as they behave. His plays humanise, rather than pathologise, his characters' behaviour.

Edinburgh, UK

Moral education

From Anthony Richardson

I can only guess at where, and in which decade, Danny Colyer had his school science education (26 April, p 30), but I would like to assure him that many science teachers were already doing what he prescribes – encouraging a culture of honesty.

We explored with pupils precisely how scientists, as fallible humans, can fall into traps of various forms. Heating water while measuring its temperature allows pupils to confidently extrapolate their pattern to show water reaching a boiling point at well above 100 °C, albeit with increasing concern.

A post-experiment discussion

of why they had followed their pattern, rather than reporting the actual temperature at the boiling point allowed them to think about the fallible mind of the scientist – all of us, and them.

Investigating the variables



which might affect the period of a pendulum brought pupils hard up against why people want to defend their predictions even when patently wrong.

The format of school investigations can enable pupils not only to learn science, but also to confront issues about truth, honesty and even morality.

Ironbridge, Shropshire, UK

From Jonathan Arch

Reading about the manipulation of school science practicals reminded me of when, as an undergraduate, I and many of my classmates failed miserably in our quest to make p-nitroacetanilide – a chemical intermediate for some dyes. One day, somebody pointed out that the real stuff bears a remarkable resemblance to powdered milk. How easily the demonstrator was fooled!

Welwyn Garden City, Hertfordshire, UK

Eaten alive

From Tony Warren

I read your article on cannibal tadpoles (19 April, p 16). At the Open University in the 1970s we were taught that frogs over-reproduced so that all the tadpoles

could strip the food source when the going was good.

When the source was depleted, the ablest simply ate the rest to reach maturity.

Shorwell, Isle of Wight, UK

Hot-headed

From Perry Bebbington

Lawrence D'Oliveiro suggests in his letter that memory is a result of increasing entropy (12 April, p 33). I am known by my friends as someone with a poor memory, although I can't remember why.

Could it be that in my head entropy is decreasing?

Kimberley, Nottinghamshire, UK

Unnecessary pain

From Ken Pease

You report on an attempt to show that mice are less stressed by the sweat of female handlers than that exuded by male ones (3 May, p 14). Pain-inducing injections were given to anaesthetised mice and rats, and "when the animals awoke, the team recorded their facial grimaces, a measure of pain intensity". Pain intensity was thus used as a proxy for stress.

The researchers could have measured stress using pain-free and more externally valid measures such as observing the exploratory behaviour of the mice in open-field environments.

The infliction of pain in the study described was gratuitous and indefensible.

Stockport, Greater Manchester, UK

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FAST AWAKE AND WIDE ASLEEP

A mysterious insomnia has people thinking they haven't slept when tests show they have. Figuring out why this happens could overturn some big ideas, finds **Ann Finkbeiner**

believe?” asks John Peever, a sleep researcher at the University of Toronto, Canada.

After many decades, that question is finally attracting some answers, thanks to a type of analysis usually favoured by physicists. This has begun to pin down the underlying biology of this mysterious condition, and has uncovered some fundamental problems with the way we define sleep. It may even offer a new approach to understanding other long-standing mysteries of consciousness.

Insomnia is not to be taken lightly. Depending on the definition, anywhere from 15 to 40 per cent of the population worldwide has problems sleeping. It has recently been linked, in mice, to damaged brain cells.

The public health consequences are huge: people with long-term sleep problems run a higher risk of hypertension, diabetes, obesity, heart attack and strokes. As a result, billions of dollars are spent every year on medical care and medication for such conditions.

Despite all this we don't know much about insomnia, or indeed sleep itself. It's not for lack of trying – after all, doctors want to help their patients, and the pharmaceutical industry has a gazillion-dollar incentive. But the neurochemical system that regulates sleep must be one of the most complex systems in the brain, which is already the most complex known system in the universe. “What's being turned on and off with sleep is extremely complicated,” says Bonnet. “It has no single centre, no single neurotransmitter, no system.”

Back in 1968, however, two pioneering sleep researchers, Allan Rechtschaffen and Anthony Kales, put together basic guidelines to identify normal sleep and distinguish it from abnormal sleep. To do so, they looked at the electrical output of the brain.

Using an electroencephalograph (EEG) – a machine that reads the output of the brain's billions of neurons via electrodes placed on the skull – Rechtschaffen and Kales mapped specific stages of sleep to corresponding brain patterns, or waves. Alpha waves, for example,

are indicators of relaxed wakefulness and normally only show up in the early stages of sleep. The predominance of slower, languid delta waves is a sign of deep, restorative slow wave sleep, when growth hormones are secreted to repair tissues (see diagram, page 35). And so sleep analysis was formalised into a system that, with some minor revisions, has remained largely unchanged.

According to these criteria, verifying insomnia should be straightforward for a doctor: a predominance of “awake” signals and a corresponding lack of delta waves. But in the late 1970s, sleep researchers began to document a handful of cases that didn't follow the rules. One 39-year-old woman came to a sleep researcher claiming not to have slept properly in 13 years. But like Rennik, after the usual tests her nightly sleep tally came to a standard 6.9 hours of shut-eye.

These patients contradicting their sleep tests soon incurred an entire catalogue of epithets: pseudoinsonniacs, sleep hypochondriacs and subjective insomniacs. The condition itself has been called persistent psychophysiological insomnia or sleep state misperception. Assuming it was largely a psychological problem, sleep researchers invested little time in further investigation. “Sleeping insomniacs” were prescribed pills and told to stop watching television in their bedrooms, for example. Such treatments were unreliable, and tended not to work in the long term. Mainly, people like Rennik just went without sleep; or rather, sleep failed to restore them.

To understand how a physics technique changed the story, you first need to know what happens when a person goes to a sleep lab.

Over the past few decades, Rechtschaffen and Kales's original EEG analyses have been augmented with signals from elsewhere on the body that tell sleep researchers what goes wrong with sleep (see “Why you can't sleep”, page 34). When Rennik arrived at Bonnet's sleep clinic, he was fitted with sensors to record the electrical signals emitted by his

CHRIS RENNICK walked into the sleep clinic with a familiar complaint: he couldn't sleep, his nights were terrible, he was going nuts. Michael Bonnet duly checked Rennik into his clinic at Wright State University in Dayton, Ohio, to run the usual battery of tests. What he found surprised him – Rennik (not his real name) was in fact sleeping like a baby.

“Then somebody's made a mistake,” Rennik said, “or there's something here you don't understand.” Rennik was right about that.

People like him are a puzzle for physicians. They are tortured by their inability to sleep, but if you dissect their sleeping patterns in the lab, what emerges is hour after hour of perfectly normal repose. “So which do you

brain and by his muscles. A dozen channels were lined up like an orchestra score. The result, called a polysomnograph, or PSG, scrolled out of the printer and piled up neatly on the floor.

It then fell to a technician to closely read every page. Sleep techs pore over these vast tracts of rune-like squiggles, marking them off in 30-second increments, called epochs. On the basis of which EEG waves predominate, they make judgement calls and assign each epoch to one of the familiar stages of sleep.

But staging sleep in this way takes many hours and generates a daunting pile of paperwork. One night's printout of Rennik's sleep stretched to 900 pages. Michael Perlis, psychologist and sleep researcher at the University of Pennsylvania, Philadelphia, had a mentor who archived her research PSGs in a West Virginia salt mine.

The obvious solution was to automate the scoring: write an algorithm that could do everything the technician does, but within minutes. However, that software simply copied what the techs were doing: assess wave forms, assign sleep stages. Of the few commercial software packages that have been tested against trained technicians, none are more reliable. "Watch someone sleep for 8 to 10 hours?" says Sairam Parthasarathy, a sleep researcher at the University of Arizona in Tucson. "You'd have to

have pretty smart technology to do that." That's why the American Academy of Sleep Medicine still requires a trained technician to double-check the automated results.

But whether Rennik's sleep was scrutinised by human analyst or software, his results showed the same thing – a person progressing normally through the usual stages of slumber, sharply at odds with his own perception.

"The assumption was that the patient is wrong and the PSG is right," says Perlis. But the sheer number of people like Rennik made sleep researchers take a closer look at pseudoinomnia. "If anything, the patient is right," he says. "If you perceive something, you're not asleep, and the more you remember from the night's sleep, the less you experience sleep." Peever agrees. "I think the PSG is not giving you the full story."

Rethinking insomnia

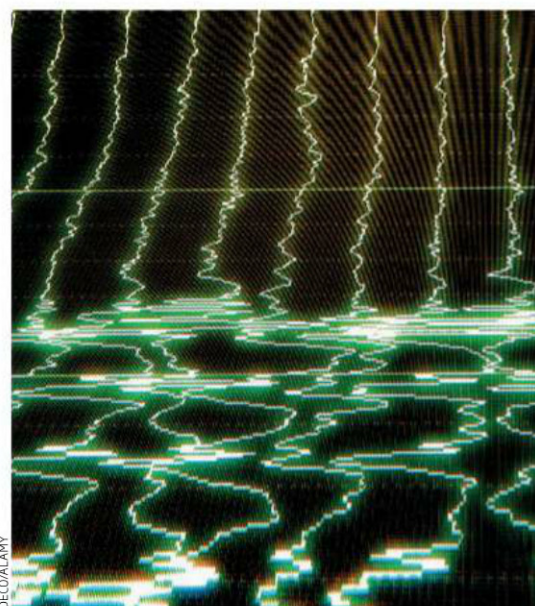
To reconcile the two conflicting realities, they needed algorithms written not to imitate sleep techs, but to dig deeper into the waves, spindles and spikes, to find out whether the EEG might hold information about sleep that Rechtschaffen and Kales had overlooked. "If you could find a signature that distinguishes these insomniacs, you could say maybe they really have something consistent about the way their brains function," says Daniel Buysse at the University of Pittsburgh, Pennsylvania.

But where do you start? And what do you look for? How could any sleep tech identify, in 900 pages of scribbles, patterns that no one had ever described?

Physicists have always needed methods to help them search through vast amounts of data for hidden signals. One of these techniques, called spectral analysis, has helped researchers in fields from atmospheric science to astronomy and geophysics.

Sure enough, spectral analysis has picked up plenty of stuff not obvious to a human wading through the sleep score, says Perlis, which "helps explain why the patient experiences sleep in one way and we score it another".

The first things it uncovered were subtle differences in the EEGs of sleeping insomniacs: alpha waves – signatures of wakefulness that are supposed to show up only in early sleep – were intruding into deep sleep. Alpha



intrusions can often be identified even without spectral analysis. "It looks like a choppy wave on top of a crown-like wave," says Perlis. But Andrew Krystal of Duke University in Durham, North Carolina, used spectral analysis to quantify just how much they were intruding.

Krystal's non-sleepers not only had a greater proportion of these alpha disturbances, but the alpha waves were bigger and the delta waves were correspondingly smaller.

That wasn't all. When Perlis and other researchers applied spectral analysis algorithms to the EEGs of their sleeping insomniacs, they found different patterns, fast waves known as beta and gamma (*Sleep*, vol 24, p 110). Normally, these are indicators of consciousness, alertness and even anxiety. Rechtschaffen and Kales advised sleep techs to ignore these. "If I see them," says Bonnet, "they look like junk to me, like an artefact you might see from tense muscles."

Like alpha waves, Perlis calls these beta and gamma waves "intrusions" into normal sleep: "It's as if somebody is playing with the switch – boop, boop – flipping at a mad rate between wake and sleep," he says. More studies confirmed the link between beta and gamma waves and pseudoinomnia.

In light of these findings, more and more sleep researchers have begun to seriously rethink pseudoinomnia. That's good news for people like Rennik. Bonnet trained him to recognise the difference between his perception of being awake and the EEG's report that he was asleep. Bonnet had identified this training as a possible treatment for Rennik's particular kind of insomnia back in 1992. With some practice, Rennik got better at knowing whether or not he was awake. He says his sleep problem has improved, that is, he still doesn't sleep well but he understands it better. At the very least, no one is calling him a hypochondriac.

WHY YOU CAN'T SLEEP

You haven't been sleeping and you want to know why. A sleep laboratory will fit you with sensors that record your brain and body. Here's what they can diagnose:

OBSTRUCTIVE SLEEP APNOEA

About 4 per cent of us will stop breathing briefly, wake up, and go back to sleep between 10 and 100 times every hour

RESTLESS LEG DISORDER

Uncommon disorder in which muscles twitch repeatedly in feet, arms or legs

CIRCADIAN RHYTHM DISORDER

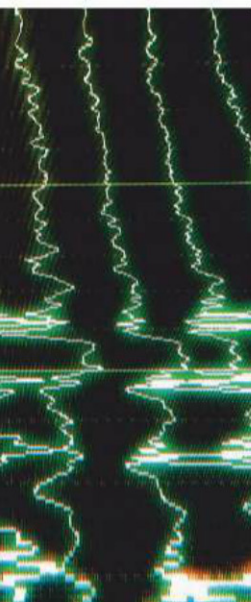
Problem with your body's internal clock, such as shift work sleep disorder

REM PARASOMNIA

Violent action in sleep that can hurt a co-sleeper. Caused by brain lesions, it can be a sign of later dementia

If none of these turn up, but you want to know why you aren't sleeping, they'll tell you they don't know (see main feature).

"It's as if somebody is flipping a switch at a mad rate between wake and sleep"



Your sleep, as measured by electrodes all over your body

But future treatments could go further. Spectral analysis could help people who battle with a wide range of insomnia. It could even take treatment beyond psychology.

Buyse says that spectral analysis could finally uncover the elusive objective “signature” of the brain’s output during sleep, the way blood pressure is a signature of the output of the cardiovascular system. This “objective quantifiable correlate,” says Martin Scharf at the Cleveland Sleep Research Center in Ohio, would mean a solid, measurable,

replicable number to quantify the symptoms of insomnia, which has been “one of the holy grails of sleep research”.

With this information, it would be possible to investigate whether these waves reveal an underlying biological difference in the brains of insomniacs.

Some researchers are trying to piece this together. The work is still in its early days, and like much of the basic science of sleep, is still unclear. But greater beta and gamma power – what Perlis calls a “gained-up system” – may mean that arousal levels are higher in the brain of a sleeping insomniac, says Richard Bootzin of the University of Arizona. In other words, their problem is not so much that they don’t sleep but that, asleep or not, their brains are never quite off. “It’s the major hypothesis of what insomnia’s about,” he says.

Researchers are beginning to turn to the “always-on” hypothesis to explain forms of chronic insomnia beyond Rennik’s group. Earlier this year, a study by Rachel Salas at Johns Hopkins University in Baltimore, Maryland, and her colleagues revealed fundamental biological differences in the brains of all insomniacs.

Around the clock, awake or not, their subjects’ brains showed enhanced activity compared with normal sleepers. One surprising consequence was that they picked up simple new tasks more quickly than their well-rested counterparts.

Always alert

The source of the “always on” disturbance seems to be neurons in the motor cortex. This, Salas’s team speculated, could point to new treatments that target the source of the hyper-arousal. They suggested transcranial magnetic stimulation (TMS) to regulate the electrical output of the misbehaving neurons with targeted bursts of high-intensity magnetic pulses. Indeed, a small study showed preliminary evidence of TMS’s promise for insomnia. But because it involves medical supervision and large medical equipment, TMS may be too cumbersome and expensive to be a viable treatment for the majority of people with insomnia.

A friendlier option is transcranial direct current stimulation (tDCS), which works with batteries instead of giant magnets. “We’ve thought a lot about how you might use brain stimulation to intervene in cases of insomnia,” says Michael Weisend, a neuroscientist at Wright State University who works with the US air force to treat insomnia in soldiers. “It should be possible to use it to modify sleep,” he says, in particular to dampen the gamma intrusions. But it will take a lot of research, he cautions, to find the exact locations where stimulation would be most effective.

Spectral analysis might even help us probe other mysteries of consciousness. For example, Krystal’s alpha intrusions seem to correlate with a host of problems that – like pseudoinsomnia – have previously been considered unrelated to sleep: chronic pain and chronic fatigue syndrome, depression, and post-traumatic stress disorder. Scharf and others have also found alpha disturbances in the sleep of people with fibromyalgia, which involves chronic pain throughout the body.

The wide range of these links would come as no surprise to Parthasarathy. “In so many ways,” he says, “sleep is connected to our well-being.” It consolidates memory, improves mood, and boosts cognitive and physical performance. Perhaps it’s fitting that the people no one believed have yielded a key to understanding the whole field. ■

Hidden patterns

To understand which stage of sleep you are in, sleep technicians look for telltale waves in an EEG read-out. This system of characterisation has not changed significantly since the 1960s

TELLTALE WAVES

Alpha waves indicate you are awake

Dreaming

Stage 1 sleep is >50% alpha waves

Stage 2 sleep is shown by sigma waves

Stage 3 restorative deep sleep is characterised by comparatively slow **delta waves**

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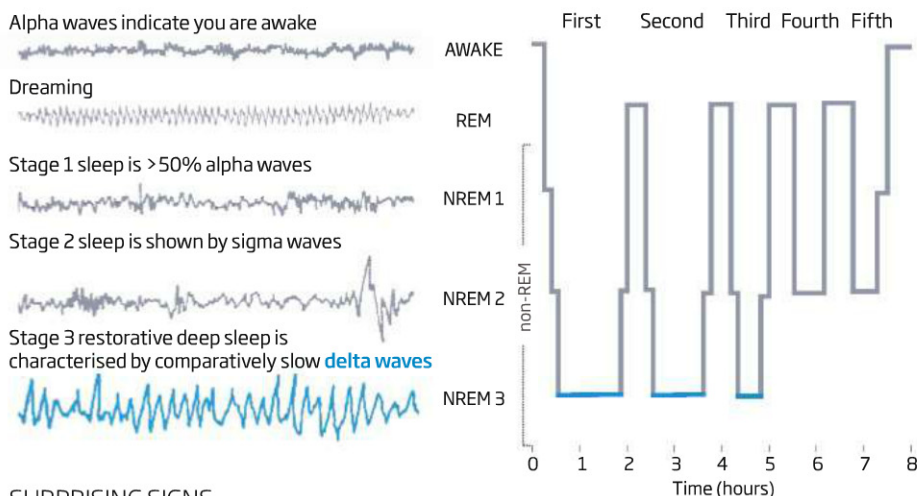
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Stage 3 restorative deep sleep is characterised by comparatively slow **delta waves**

CYCLE



SURPRISING SIGNS

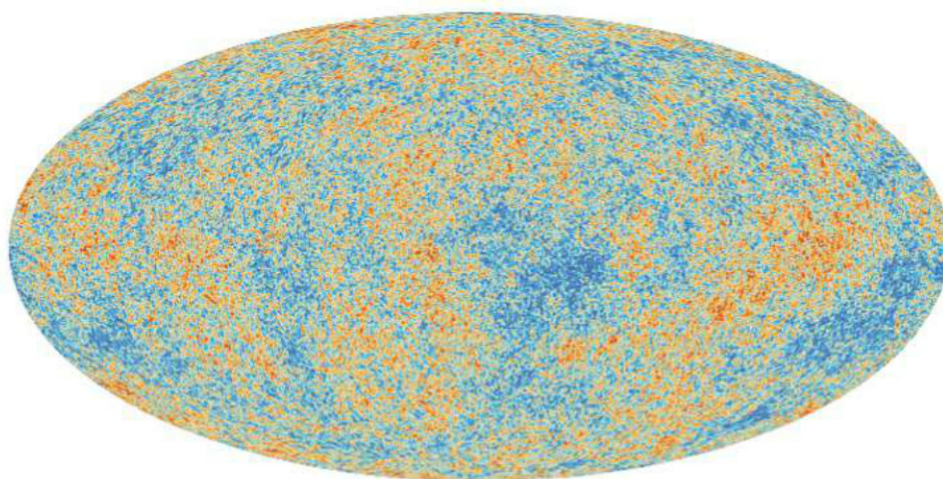
The presence of **delta waves** in this EEG read-out indicates that the sleeper is in Stage 3 sleep. Recently, algorithms applied to these read-outs have revealed the significance of previously ignored waves, such as **beta waves**, which indicates the brain is active, intruding into the sleep of some insomniacs



Ann Finkbeiner is a science writer in Baltimore, Maryland

Few people doubt the big bang now. Not so when the radical idea was accidentally proved a half-century ago, recalls cosmologist **Jim Peebles**

There at the birth



FIFTY years ago, on 20 May 1964, Arno Penzias and Robert Wilson of the Bell Telephone Laboratories in Holmdel, New Jersey, recorded their first astronomical measurements of microwave radiation from the supernova remnant Cassiopeia A. They were using a horn antenna system first assembled in 1959 to study microwave communication – an early step in the development of today’s cellphone technology.

The antenna had been carefully engineered to reject radiation from the ground. But once all known sources in the sky had been painstakingly accounted for, Penzias and Wilson were left with the same problem that had been bothering Bell’s engineers. The microwave sky seemed to be about 2 degrees warmer than anyone expected.

At the time, I was a young theorist just down the road in the physics department at Princeton University, in the research group of Bob Dicke. Bob was a fan of the idea that the universe began in a hot, dense state – a big bang. One idea he was exploring was that a big

bang should have left behind a sea of radiation uniformly spread across the sky. Bob had set two members of his group, Peter Roll and David Wilkinson, onto building a receiver capable of detecting this radiation, and suggested I look into the theoretical consequences of detecting or not detecting it.

The following February I presented the idea of our search in a colloquium. A few weeks later, Bob received a phone call from Penzias. A subsequent visit to Holmdel by Bob, Peter and David convinced us that we had been scooped. The universe’s origin had been discovered as an unintended consequence of a communications engineering project.

Looking back from the distance of a half-century, it is easy to forget that, back then, many physicists dismissed any investigations into how it all began as empty speculation. The sea of noise that was so troubling to Penzias and Wilson is the cosmic microwave background (CMB), which is now known to be clinching evidence for a big bang. But it wasn’t immediately seen that way, as a glance back

through the pages of *New Scientist* shows. In 1976 Martin Rees, then recently elected to the illustrious Plumian professorship of astronomy at the University of Cambridge, writes that “no plausible alternative theory” could account for the CMB’s observed characteristics (2 December 1976, p 512). Yet five years later, Rees’s Plumian predecessor Fred Hoyle still sees a chance for the rival steady state theory, writing that the latest CMB measurements “differ by so much from what theory would suggest as to kill the big-bang cosmologies” (19 November 1981, p 521).

Radiation resolution

The big bang and steady state theories both have their origin in the discovery in the 1920s that distant galaxies are moving away from us, as if the universe were expanding. The big bang theory, developed in the ensuing decades, postulates that everything here now was also there back then, so the universe must be expanding from a denser early state. The



FAR LEFT: ESA/SPL LEFT: PHYSICS TODAY COLLECTION/APS/SPL

steady state theory, which Hoyle co-devised in 1948, suggests instead that matter is continually created in the expanding universe, with new galaxies forming to fill the spaces that open up as already existing ones move apart. In this picture, the universe's past was no hotter or denser than its present.

Something like a CMB crops up in some of the earliest considerations of what a hot, dense early universe would have looked like. In the late 1930s, attempts to explain the relative abundances of the chemical elements – why is there so much more iron than gold, for instance? – included the proposal that the heat of the early universe produced violent collisions that thoroughly rearranged the neutrons and protons within atomic nuclei. These analyses implicitly assumed a sea of surrounding radiation hot enough to promote the right sort of reactions. This sea would have slowly cooled as the universe expanded.

George Gamow and his graduate student Ralph Alpher didn't mention this thermal radiation when they presented their famous

paper on big-bang elemental abundances in 1948 – a paper celebrated both for its content and Gamow's unsolicited introduction of the physicist Hans Bethe on to the author list, so it would approximate the first three letters of the Greek alphabet, alpha, beta, gamma. Their analysis, it turned out, also conflicted with known rates of nuclear reactions from weapons research during the second world war. A few months later Gamow redid the analysis, removing the conflict by adding in the sea of thermal radiation. He realised that the radiation would still be present, but he was silent about how hot it might be. Alpher, with Robert Herman, supplied a figure, arriving at a temperature of about 5 kelvin.

Gamow's analysis incurred Hoyle's displeasure, both because it ignored the steady-state cosmology and because it produced an abundance of helium of about 30 per cent of the total cosmic mass, far higher than observations could at the time support. When, by the early 1960s, improved evidence suggested this figure is in fact about right,

Penzias and Wilson's Holmdel horn antenna tests pre-date the Planck satellite's cosmic microwave background images (left) by 50 years

Hoyle was one of the first to note that it fits the big bang cosmology – but he took care to suggest that it might instead have come from explosions of supermassive stars, little bangs in a steady-state universe.

This is kind of where we were in 1964. Bob was taken by the idea that an expanding big-bang universe might have bounced back after a previous cycle of expansion had collapsed. During such a collapse, starlight would be compressed along with the matter, reaching temperatures and densities high enough to pull apart the heavy elements produced by stars in the last cycle and so provide new nuclear fuel for our cycle. This process would cause the radiation to reach thermodynamic equilibrium, with the same temperature everywhere, producing a characteristic spectrum of intensities at different



KEY FIGURES

Robert (Bob) Dicke (1916-1997)

A wide-ranging physicist who, besides his contributions to microwave physics, worked in laser and atomic physics, and developed precision tests of Einstein's theory of general relativity.



George Gamow (1904-1968)

A Russian-born US cosmologist who was an early champion of the big bang theory, he also made pioneering contributions to the fields of nuclear physics and molecular genetics. Gamow is also remembered for his *Mr Tompkins* series of popular-science books.



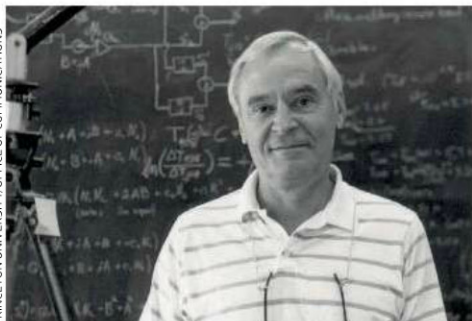
Fred Hoyle (1915-2001)

A British theoretical astronomer who played an important part in explaining the physics of stars and challenging ideas about an evolving universe. A champion of the steady-state universe theory, he coined the term "big bang" as a disparaging reference to its rival.



Robert Wilson (1936-) and Arno Penzias (1933-)

The Bell labs duo shared the 1978 Nobel prize in physics for their demonstration, published in 1965, that Bell's microwave antenna had detected what proved to be the cosmic microwave background (CMB).



David Wilkinson (1935-2002)

A cosmologist whose seminal contributions to CMB measurements were honoured with the naming of NASA's Wilkinson Microwave Anisotropy Probe, which was launched in 2001.

wavelengths known as a thermal Planck spectrum – a sure sign of our universe's origin in a hot, dense state.

Bob also knew microwaves. As part of the effort to develop shorter-wavelength radar with better resolution during the second world war, he had invented a microwave detector that was used to study radiation absorption and emission by atmospheric water vapour. As a sideline, he had written a paper in 1946 on the upper limits of cosmic microwave radiation. The experiments were done in Florida, whose muggy nights supplied ample atmospheric water to flood the detector with microwaves. Had they happened on a cold, dry winter's night in Princeton, Bob might have been the first to detect the CMB.

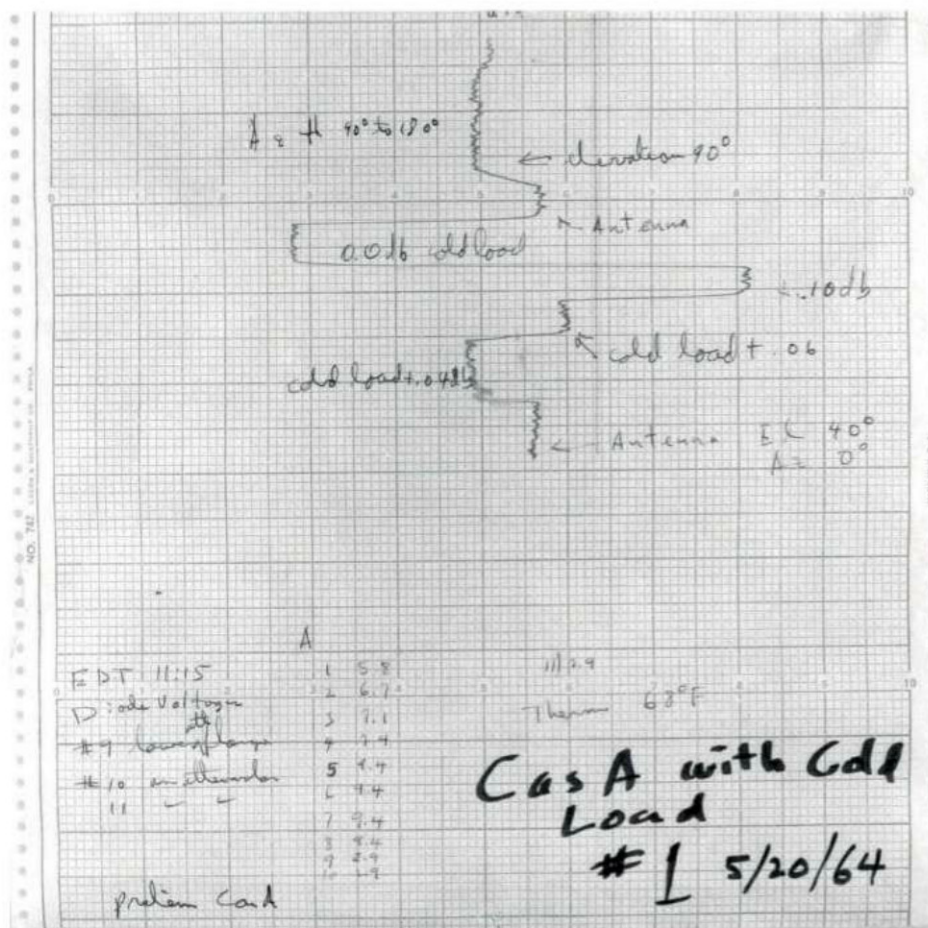
But people can be forgetful, and in 1964 we had to remind him that he had even set a limit. He also told us he had vague memories of hearing a lecture by Gamow, though not what it was about. But perhaps echoes of Gamow's thoughts, along with the Florida tests, were driving Bob's thinking in 1964. In the 1981 *New Scientist* article, Hoyle recalls a conversation he had with Bob in 1961 about the behaviour of interstellar CN, a molecule that rotates as if it were immersed in microwaves at about 2.3 kelvin. Bob certainly didn't remember that discussion, for it would have been quite out of character for him not to tell us, but this indication that the CMB might exist may also have been lurking in the back of his mind.

I suppose "back of the mind" is as good a way as any to account for the sudden disruptions of orderly research by surprising and exciting ideas. That unexpected, even unwanted, measurements – an annoying hiss in a glorified telecommunications antenna – on occasion prove to be wonderfully informative is just one of the ways science advances.

Proved beyond doubt

I don't remember any expression of regret by Bob or any of us at being scooped. Instead, there was excitement that something was there to be measured and analysed. Early on, our focus was on finding out whether the CMB did indeed have that telltale Planck spectrum. In the 1970s, this was still sufficiently disputed to support the differing interpretations put forth in Rees's and Hoyle's articles.

Roll and Wilkinson's experiment soon added another data point, and Wilkinson eventually added many more, culminating in his leading role in the COBE satellite mission that in the early 1990s finally showed the CMB spectrum is close to a Planck form with a



Penzias and Wilson's notebook first records unexplained microwave noise on 20 May 1964

off supernovae, and also for details of the distribution of the CMB. Its new name, “dark energy”, isn’t a sign of progress: we still don’t understand its nature.

Not least because of these two hypothetical interlopers, caution is in order. The fit of the Λ CDM cosmological model also depends on an optimistic extrapolation of general relativity from the largest tested scale of the solar system to the vastly bigger scale of the observable universe. But tests from the CMB and elsewhere are abundant enough now that I am forced to conclude that we have a convincing approximation to what happened as the universe expanded and cooled.

An elegant theory

Hoyle's steady-state cosmology is quite convincingly ruled out, although its philosophy reappears in the concept of the multiverse – the idea that universes like the one we live in are constantly budding out of some greater universe. The theory of eternal inflation, where this idea arises, postulates that our universe underwent a period of enormously accelerated expansion in its earliest instants, and offers an elegant way to understand what happened before the expanding universe had cooled to the point that it can be described by Einstein's general relativity.

The patterns by which the CMB's temperature deviates from uniformity over different distance scales matches what might be expected in a simple mathematical formulation of inflation, although the fit is not unambiguous. The recent discovery of polarisation patterns in the CMB by the BICEP2 experiment in Antarctica has been interpreted as the first definitive observational evidence for inflation, although many remain to be convinced that the polarising effect isn't a result of dust and electrons in the Milky Way's magnetic field (26 April, p 32).

However that story pans out, cosmology has matured beyond all recognition in a century. In 1914, Einstein was putting the finishing touches to general relativity, the theory on which it is all based. Today, ever more detailed explorations of the CMB could be taking us back to a universe even beyond general relativity. But a crucial way station was reached precisely 50 years ago: the identification of an unexpected hiss that tells the story of the universe's origin. ■

Jim Peebles is the Albert Einstein Professor of Science, Emeritus, at Princeton University

temperature of around 2.73 kelvin. (Herb Gush at the University of British Columbia, Canada, whose rocket-based experiment confirmed it one month later, might have scooped this finding, had it not been for launch delays.)

Few apart from Hoyle and his close associates doubted the universe's origin in a big bang by then. Penzias and Wilson had received a share of a Nobel prize in 1978, which is fair enough: they tracked down every conceivable terrestrial source of excess microwave radiation, and complained about their inability to account for the anomaly until someone at last paid attention. But Bob ought to have shared it, both for inventing much of the technology used to discover the CMB, and for proposing the search that led the Bell researchers to recognise they had already found it.

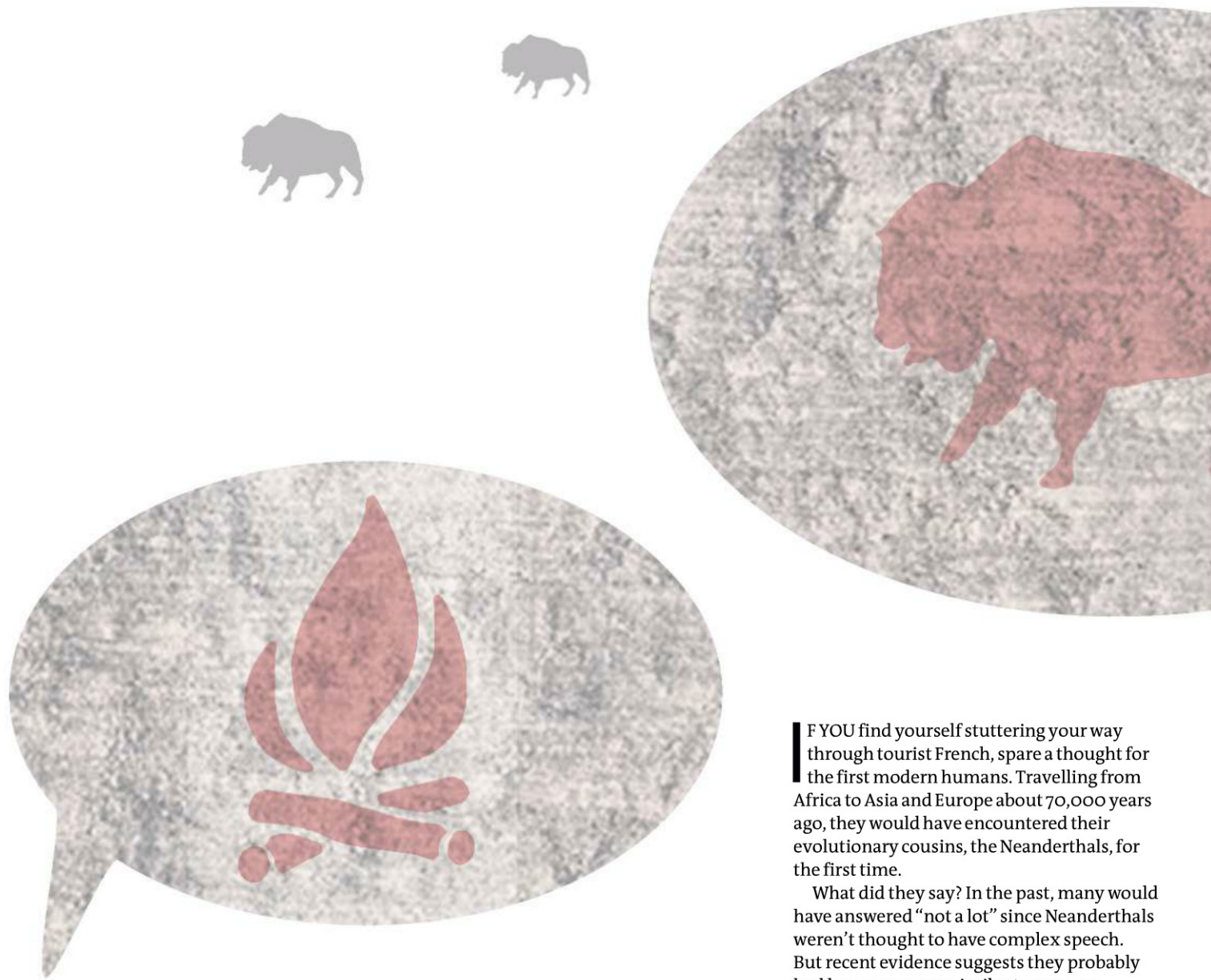
Meanwhile, my own theoretical thinking started down the road Gamow pioneered, but I kept seeing new things to do. The CMB would be disturbed by the gravitational attraction of matter, which in our universe is now quite clumped up, and by interactions with matter in the form of plasma in the hot young universe. More accurate measurements of how much the CMB departs from uniformity,

from Wilkinson and a growing list of colleagues, drove me to devise the now established Λ CDM cosmological model.

At the time I thought I was writing down a theory that involved disturbances to the microwave background too small to be detected. Thanks to COBE and its follow-up missions, however – NASA's WMAP, the European Space Agency's Planck probe, and a host of others – we now have precise measurements of how the CMB departs from an exactly uniform sea of radiation that inform us about the history of expansion of the universe and the nature of its material contents. I have written three books on the subject, each much larger than the last. Now the field has grown much too big for a monograph; it is richer by far than anything I imagined when I started following Bob's suggestion a half-century ago.

With Λ CDM, we now have an excellent fit of cosmological theory and measurements, albeit one that requires two hypothetical components: unseen cold dark matter – the CDM – to keep galaxies clumped together, and the cosmological constant, Λ . This constant is the quantity Einstein introduced into his equations of relativity to create a static universe, and then regretted as an inelegant and unneeded complication. Now it is needed to account for the accelerated expansion of the universe revealed by measurements of far-

"I recall no regret at being scooped - just excitement at something to measure"



How to speak Neanderthal

Traces of our ancient cousins' words are harder to find than a needle in a haystack – but that's not going to stop some linguists from trying

IF YOU find yourself stuttering your way through tourist French, spare a thought for the first modern humans. Travelling from Africa to Asia and Europe about 70,000 years ago, they would have encountered their evolutionary cousins, the Neanderthals, for the first time.

What did they say? In the past, many would have answered “not a lot” since Neanderthals weren't thought to have complex speech. But recent evidence suggests they probably had languages very similar to our own. Surprisingly, we may now have the means to glimpse those utterances in the words we speak today, with huge consequences for our understanding of language evolution.

The argument that Neanderthals spoke like us comes from many discoveries. Archaeological remains show that they had a sophisticated lifestyle, with human traits like caring for the infirm and the sick, and an advanced toolkit, including bone tools and body paint – complex behaviour that should only be possible if they had language. We also have some more direct anatomical evidence: traces of nerve pathways through bones in the skull suggest Neanderthals could control their vocalisations, for instance – an adaptation necessary for language that other apes lack. It also looks as if Neanderthals had many gene variants associated with processing language.

So it seems reasonable to assume that their speech would have been similar to our own, with the differences either being down to their vocal anatomy, the way their brains were wired, or simply cultural evolution around the



“We must act quickly, given the saddening rate at which languages are dying”

Neanderthal dictionary, but we have begun to investigate whether modern linguistics could, in principle, find any remains of our relatives’ speech in today’s languages. Then we can focus our search on more specific features.

Our starting point was the World Atlas of Language Structures, a database that documents hundreds of languages. We used a statistical method to split these into two groups, so that languages within one group were more similar to each other than to languages in the other group. We then tested whether there was a geographical divide between them, perhaps with one group mostly containing the African languages – as you might expect from our theory. Results were mixed, but comparing the overall structures – including things like word order and gender – showed a greater difference between African and non-African languages than simply comparing the vocabulary. This suggests that some kind of Neanderthal influence might linger in the grammar of non-African languages.

Along similar lines, we applied a separate technique that uses linguistic data to predict how populations must have migrated and mixed in order to arrive at today’s language diversity. The best-fitting model supported the idea of two main founding populations, one in Africa, and a second that had outside influence from the Neanderthals.

Finally, we turned to methods originally used to study the divergence of species, to map out the family trees of different languages based on their related features. The trees predict when those features first emerged, so we can then look for aspects that change slowly and could still reflect interactions thousands of years ago. We could then find out if there are different patterns in the African and non-African language families. If so, they might be evidence of Neanderthal contact.

It is very tempting to jump on initial results. For instance, the way different languages mark possession proved to be one possible candidate. In African languages, possession is marked by an inflection that depends on the class of word – words about humans would have a different rule from words about inanimate objects, for instance. Eurasian languages don’t make that distinction – “my dog” follows the same rule as “my son” or “my computer” – perhaps because the Neanderthals didn’t either. But this could easily be a fluke result.

However, rather than a single feature, we expected there to be a more general “fingerprint” left on the languages touched by Neanderthal interactions. So we trained a machine learning algorithm to rank how well different combinations of features could predict whether a language came from Africa, or elsewhere. African and non-African languages could be distinguished with over 90 per cent accuracy, but only by using a large number of features. This makes it difficult to say what caused this difference, but it’s possible that something, such as conversations with Neanderthals, pushed the evolution of European and Asian languages in a different direction to those in Africa.

Race against time

Before celebrating these results, we must make sure the statistics don’t pick up on other confounding factors. For instance, we are missing information on many of the world’s languages, especially those with few speakers. Since the choice of data isn’t random, any patterns that seem to emerge could be influenced by biases in the selection.

But the crucial point is that the methods seem to offer a way to test these ideas, and we won’t even need a time machine to get the extra data we need; the secrets may be hidden in undocumented languages. Several large-scale language databases are already being put together, although we must act quickly given the saddening rate at which languages are dying. If that helps amplify the faint echoes of our cousin’s voices, we will then be able to pick apart more specific features of their speech.

That could have important implications. The traditional view, championed by Noam Chomsky among others, is that the variation we see in world languages is constrained by our innate biases. But if these variations are, at least partly, the result of two different trajectories, one of which reflects Neanderthal biases as well as our own, we may be able to find new insights into the way genes and cultures interact to shape the words we speak.

The prospect may seem audacious, but 10 years ago, probing the Neanderthal genome was also a distant dream. Stranger things have certainly happened in science. ■

Sean Roberts, Dan Dediu and Scott Moisk research language evolution at the Max Planck Institute for Psycholinguistics in Nijmegen, the Netherlands

time they diverged from modern humans. The question is, can we guess what it sounded like?

Unlikely as it may seem, there is a way. Here’s the rationale: when two groups that speak different languages come into contact, they exchange bits and pieces of language, like words or grammatical rules. Linguists can detect traces of such interactions even after thousands of years have passed. We know that once modern humans left Africa, they lived alongside Neanderthals and sometimes bred with them. They may have shared cultures, and there is evidence that Neanderthals gave our ancestors the idea for certain tools – so it seems likely they conversed too. The task, then, is to find out whether languages differ between the populations, mostly in Africa, that never came in contact with Neanderthals, and those that would have met them.

Eroded influences

The traces will be very faint and are probably reflected in a combination of features, just as differences between human populations are usually caused by variations in hundreds of genes, rather than just one or two. To complicate matters further, these exchanges happened thousands of years earlier than most historical linguists would even dream of investigating – meaning that time could have eroded away the influence. Never mind looking for a needle in a haystack, it is like searching for a small patch of straw in a barn full of hay.

We certainly aren’t ready to build a

Mayor of Microbe Metropolis

When **Jop de Vrieze** met the microbes that call him home, he suddenly realised he had responsibilities

THERE they are: my microbes. I feel like someone who's just been introduced to a group of lost relatives. Staring through a microscope, I see a cluster of *Staphylococcus epidermidis* bacteria sitting together in a Petri dish. They look like a bunch of grapes. Until yesterday, they were living in my armpit.

I had set out on a quest to learn about my microbiome and how it affects my health. It soon made me think of myself quite differently. Looking down that microscope, I no longer felt like an individual – I was the mayor of my own microbe metropolis.

There are many trillions of microbial organisms living in and on our bodies, outnumbering our own cells 3 to 1. We have battled them for years, with antibiotics and disinfectants. But as we get to know them better, a lot turn out to be our allies. "It's like we've been breaking down our house and only started appreciating it when we've already destroyed it to a great extent," says Margaret McFall-Ngai at the University of Wisconsin-Madison. "It's a complete wake-up call."

It wasn't just my own cells I had to look after, but the multitudes that call me home – from the downtown districts in my gut to the suburban sprawl of my skin. Bad management could get me into trouble. Imbalances in microbial flora have been linked to many conditions, from inflammatory bowel disease and type 2 diabetes to cancer, heart disease and depression. Upset the good guys and I risk letting a bad crowd move in. So how do I keep them happy?

Let them eat veg

The gut is the powerhouse of my microbial world. Vast numbers of bacteria live in my intestines, feeding on my leftovers. They help break down undigested food, contributing about 10 per cent of my energy and producing a variety of molecules that have an effect on my metabolism, immune system and even brain. *Faecalibacterium prausnitzii*, for example, plays a role in regulating sugar uptake, and having too few has been linked to Crohn's disease. Then there's *Bacteroides fragilis*, which keeps my immune system on its toes, and the lactic acid bacteria that help me handle stress by producing appropriate neurotransmitters.

A healthy immune system creates the right environment to attract species like these, while keeping others out. "The microbiota shape the immune system and the immune system shapes the microbiota," says Martin Blaser at New York University. "It's a two-way system."

If they eat what I eat, how does my diet affect them? To get a rough idea, Willem de Vos at Wageningen University in the Netherlands helped me set up a small experiment. For four weeks, I followed four consecutive diets. The first week I ate as I normally would – a little bit of everything. In the second week I ate a vegetarian diet and in the third week I ate meat and starch but no fruit or vegetables. In week four I returned to my regular diet but ate probiotic yogurt with every meal. At the end

of each week, I took a stool sample to de Vos and his team, who analysed the fragments of microbial DNA it contained.

The dietary changes shifted my gut microbiome quite a bit – as a recent study showed, diet can alter microbiome make-up in just a few days. My microbes took a hit when I changed my normal diet. But the most interesting shift came when I gave up fruit and vegetables. During my meaty week, populations of certain species that reduce inflammation dropped, including *Clostridium* and *Prevotella* species. At the same time, other populations bloomed to take their place. For example, the number of *Bacteroides* went up (see diagram, page 44). *Bacteroides* are typical of Western diets that are high in animal protein and saturated fat and some studies have linked having too many of them to obesity.

Eating fruit and veg doesn't just keep different gut populations in balance, though. Bacteria also process plant fibres into short-chain fatty acids, which regulate several processes in the body and keep the gut barrier healthy. A weak gut barrier can allow harmful bacterial products to enter the body, with potentially dangerous results. For example, metabolic endotoxemia – a disruption of the metabolism that can lead to conditions such as type 2 diabetes – may be triggered by changes in gut flora. As for probiotic yogurts, after a week they had little effect on my relative population numbers. My lesson? Keep eating my greens, but don't worry too much about the rest. ➤



TIM MCDONACH

Set aside some stool

Nothing hits gut populations like antibiotics. These drugs don't just kill pathogens, they also wipe out most of the microbiome. The disruption can cause severe diarrhoea or even chronic inflammatory bowel disease. Even a relatively mild upset can have long-term consequences, like irritable bowel syndrome.

Taking probiotics alongside antibiotics can help. The lactic acid bacteria in probiotics don't replace all the eradicated species, but they can outcompete or kill opportunistic pathogens advancing to take their place. They can also help digest lactose, give the immune system a boost and strengthen the gut barrier.

The trouble with probiotics is that their strength varies. Populations of the commonly used types, *Lactobacillus* and *Bifidobacterium*, are weakened during the culturing and production process. They also take up temporary residence only, not settling in the gut for long. A second generation of

alike than those in unhealthy mouths," says Wim Crielaard at the University of Amsterdam in the Netherlands.

Some bacteria, like *Streptococcus mutans*, produce acids by breaking down sugars. Others, like *Porphyromonas gingivalis*, trigger inflammation. Too many of either can cause trouble. Acids break down tooth enamel, increasing the risk of cavities, and inflammation can lead to gum disease. Inflamed gums also let bacteria like *S. mutans* enter the bloodstream when we brush our teeth. Once there, it's only a short hop to colonising our joints, where they can cause rheumatoid arthritis, or our heart, where

they can cause infective endocarditis, a life-threatening inflammation of the heart-lining.

In a healthy mouth, both of these species are present but are counterbalanced by others like *Streptococcus sanguinis*, which competes with *S. mutans*. Though no species alone would be beneficial, together they keep each other in check. Your saliva also neutralises acids and kills inflammatory species by producing antimicrobial peptides that target certain bacteria. So chewing sugar-free gum can help by stimulating saliva production. Some brands also contain xylitol, a kind of fake sugar, which is taken up by acid-producing bacteria like *S. mutans* but not digested. It builds up inside these bacteria, disrupting their metabolism.

When Crielaard gave me my result, I was happy to find that my inflammatory species were low. But the balance between acid producers and neutralisers was shifted in the wrong direction, raising my risk of getting cavities. "It's not a sin to eat or drink sweet and sour products," says Crielaard. "But when the frequency of acid attacks is too high – more than seven times a day – your saliva and neutralising species can't keep up." I made a mental note not to snack too often.

"By showering on a daily basis we could be scrubbing off a natural shield"

probiotics is on its way, but they are more difficult to produce and haven't yet been approved for sale.

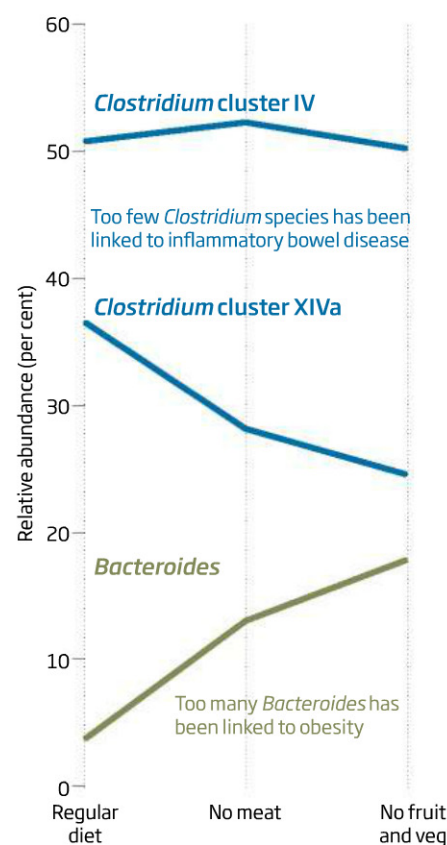
In the meantime, there's the DIY approach. One Dutch scientist told me in confidence that she stores two tubes of her children's faeces in her freezer – just in case. She hasn't used them yet, but came close after her children took a course of antibiotics. She thinks most people will have similar tubes stored in their freezers in a couple of years. Using your own stool is healthier than a faecal transplant, in which you take a sample from a healthy volunteer, she says. "These microbes are used to your body and your body is to them." It's a conviction born from her particular expertise. Personally, I'm not yet persuaded to clear a space between the ice cream and frozen peas.

Cut down on snacks

What about the bacteria living in my mouth? I spat in a cup to find out. As in the gut, the balance of bacteria in the mouth also depends on our eating habits. A healthy mouth should contain a wide range of species. But an unhealthy mouth can be dominated by just a few different types of bacteria. "The microbes in healthy mouths are a lot more

You are what you eat

When Jop de Vrieze changed his diet week to week, the relative abundance of the three largest populations of gut microbe changed markedly



After switching suddenly from his regular omnivorous diet, his healthy gut microbiome took a hit. But a healthier balance of microbe species was found after a week of eating a vegetarian diet than after a week of eating meat and starch but no fruit and veg

Skip the daily shower

It was time to learn about the needs of my skin microbes. For four days, I skipped my shower and instead took a daily swab from my armpit, cheek, back and foot. From these swabs, Dries Budding at the Free University in Amsterdam identified hundreds of species, including typical skin dwellers such as *Staphylococcus epidermidis*, but also *Streptococcus parasanguinis* – more usually at home in a healthy mouth – and potential pathogens such as *Staphylococcus aureus*, *Klebsiella pneumoniae* and *Haemophilus influenzae*. And over the four days the diversity increased.

That makes it sound like skipping showers is unhealthy. On the contrary. In fact, some researchers think that by washing our skin on a daily basis we could be scrubbing off a natural shield. The harmless bacteria on our skin help form a physical barrier against microbes that are potentially harmful, says Elizabeth Grice at the University of Pennsylvania in Philadelphia. "They protect us, educate the immune system, modulate the immune and inflammatory response and don't allow pathogenic or opportunistic bacteria."

Harmless bacteria also prime immune cells



Living with pets may keep us in touch with good bacteria

to respond to their pathogenic cousins, as well as raising the alarm to immune cells when a pathogen arrives by triggering immune-signal pathways. For example, one recent study showed that immunity to the protozoan parasite *Leishmania major* requires the presence of *S. epidermidis*.

I faced a dilemma. Did I want the best for my microbes or the people around me? Unwashed, I risked social exclusion. In the end I made a compromise: I now wash every other day and haven't yet lost any friends.

Get a good start in life

We are born sterile. But from the moment we leave the womb, bacteria begin colonising our skin and setting up home in our gut. Just a millilitre of stool from a 1-month-old baby contains a trillion microbes. Right from the start, bacteria influence our development by shaping our immune system and producing hormones that guide the growth of our brain.

The make-up of our early microbe populations seems to depend on how and where we are born. Infants that pass through the vaginal canal during birth pick up bacteria from the mucus of the vagina. But babies born by caesarean section will be exposed to different bacteria, picking up their first microbes from the skin of other people and the environment.

One-month-old babies born by C-section have been found to have fewer friendly bacteria and more harmful ones in their guts, like the diarrhoea-causing *Clostridium difficile*. Formula-fed babies were found to

have greater numbers of *C. difficile* and *E. Coli*. C-section babies are also more likely to develop a range of conditions, including asthma, type 1 diabetes and obesity. But whether this is due to a different microbiome or other confounding factors such as maternal obesity or premature birth isn't yet clear (*PLoS One*, vol 9, p e87896).

Still, a growing number of parents are choosing to supply vaginal bacteria by hand, including microbiome pioneer Rob Knight at the University of Colorado in Boulder. Using a sterile swab, he and his wife gave his newborn daughter an oral dose of microbes from her mother's birth canal shortly after she was born by C-section. Studies to look at what difference this might make are under way.

Hook up with old friends

Graham Rook of University College London has proposed a theory he calls the old friends hypothesis. Over our long symbiotic history, he says, microbes and humans co-evolved. We incorporate them into our physiology, and they regulate our immune system.

Thanks to our modern lifestyles, though, we may have exiled several old friends and, worse, welcomed new enemies. Large urban communities and intensive farming have allowed harmful microbes to flourish and spread. A recent study showed that a modern office has a characteristic microbiome and buildings with natural ventilation contain different microbes to air-conditioned ones.

Rook believes it all matters. For example, city-dwellers living next to a park have

been found to be healthier than less lucky neighbours just streets away. "Some psychological explanations have been proposed," he says. "But I wouldn't be surprised if the microbes turn out to make the difference."

So how should I win back my old friends? "It's not a matter of living a dirty life," says Rook. "In a modern environment, this would confront us with our new enemies." But simply stroking a cat or dog might help. Pet owners share skin bacteria with their animals that could be beneficial. Living with pets also seems to reduce asthma risk among young children, probably by boosting populations of gut microbes such as *Lactobacillus johnsonii*, which is thought to protect against allergies.

But my old friends may not be your old friends, as backpackers often discover: different human populations around the world tend to have established relationships with slightly different strains of bacteria. In Colombia, for example, most people have *Helicobacter pylori* in their stomach, which may protect against allergies. In some Colombians, though, the bacteria can also

"Bacteria shape our immune system and help guide the growth of our brain"

cause stomach ulcers and cancer. It turns out that the mountain strains of *H. pylori* were brought to Colombia by Europeans and the immune systems of the indigenous people at higher altitudes hadn't learned to cope with it.

On my quest, I learned a lot about what makes me who I am. If you, too, are urban and omnivorous, chances are we aren't dissimilar. But, of course, it's complex. We are only beginning to uncover the subtle relationship between us and our tiny inhabitants.

Questions of cause and correlation remain knotty. "Scientists should not run to conclusions about the microbiome," says Jonathan Eisen at the University of California, Davis, who thinks the microbiome will emerge alongside genetics, lifestyle and our environment as a major factor influencing our health. "When Darwin entered an island, he first catalogued all the species and only then started studying them," he says. ■

Jop de Vrieze is a science writer based in the Netherlands. His book *Allemaal Beestjes* ("Our Tiny Creatures and Us") is published in Dutch (Maven Publishing, 2014)

Hunting the Higgs

An up-close account of bagging the boson gets bogged down, finds **Michael Slezak**

Smashing Physics: Inside the world's biggest experiment by Jon Butterworth, Headline Publishing Group, £20



FINALLY! An insider's account of the most thrilling scientific event in decades. *Smashing Physics* by Jon Butterworth is a great idea.

He is an important physicist who has made key contributions to particle physics. He is also a senior researcher at ATLAS, one of the two big experiments at the Large Hadron Collider (LHC) at CERN, near Geneva, Switzerland. Better yet, Butterworth is an experienced writer.

The book contains a fascinating inside perspective of the discovery of the Higgs boson. It offers an insight into the intense, bewildering and intimidating media scrutiny that physicists aren't used to, combined with intimate details about the life of a high-powered physicist and some lovely explanations of the physics behind the discovery.

Disappointingly, though, the book as a whole lacks direction. Reading the introduction, it feels odd that Butterworth fails to say what the book is meant to be, only what it is not – not a travelogue, a diary, a textbook or a manifesto. Yet it soon becomes apparent that these descriptions do indeed capture what the book is. Probably unintentionally, it gives the reader a sense of what it is really like to be a physicist: it is a life with moments of great clarity

ATLAS helped make history with the discovery of the Higgs boson

and excitement embedded in a tedious, episodic mixture of travel, waiting, wading through exciting but difficult physics, and managing important but frustrating bureaucracy.

For example, Butterworth spends more than a page listing the 15 steps it takes to get a paper from the LHC into a scientific journal. When describing such excruciating tedium, there is really no need to make the poor reader experience it all at first hand.

And the many passages seemingly added for colour do not help. One "travelogue" section describes queues for the toilets in Sweden, and another the quality

of the tea on planes. Butterworth even acknowledges that these things aren't interesting, with a self-deprecating joke about the depth of his analysis. But we are left wondering why they weren't simply cut.

The truth is that Butterworth seems aware of the problems. Many paragraphs start with the word "anyway" or "anyhow", indicating he knows that he has wandered off track. And at one point he virtually apologises:

"Probably unintentionally, the reader gets a sense of what it is really like to be a physicist"

"I realise this is in danger of reading like a travelogue, but I sort of have to mention..." Moreover, his writing style, while mostly clear and lucid, is not inherently engaging enough to compensate for that kind of content.

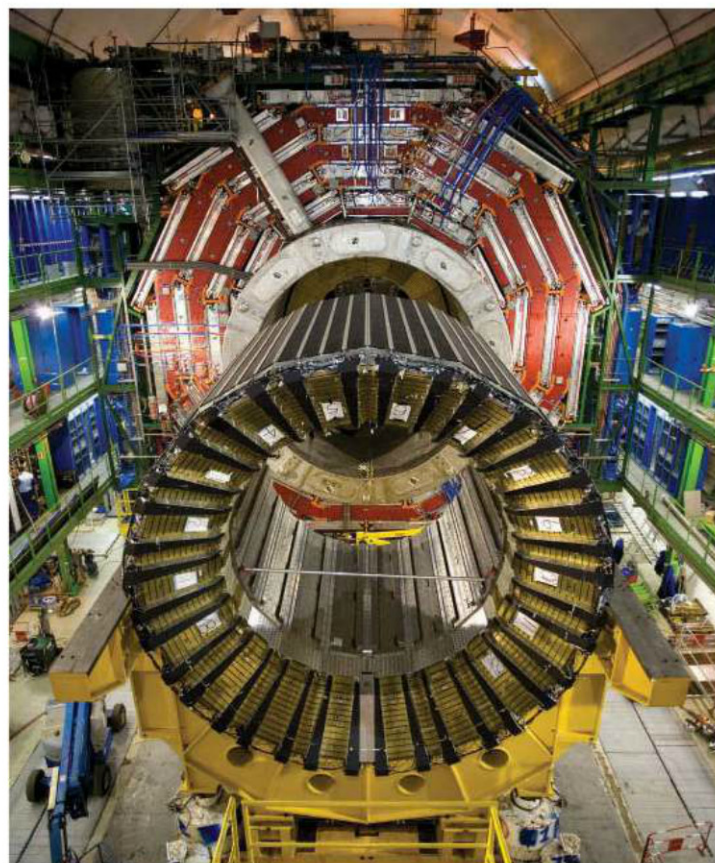
That said, the book has many virtues. The explanation of the Copenhagen interpretation of quantum mechanics is among the best I've ever read. And I was inspired and excited by his description of symmetries and apparent asymmetries in physics.

There are also some head-noddingly good arguments about the relevance of science in society. For example, Butterworth brings together several reasons why physics is essential for the modern world. Besides being of fundamental importance to human curiosity, he points out that it pays for itself: 8.5 per cent of the UK economy relies on research produced by physicists.

Good editorial advice might have led to the book being much shorter and perhaps being split into a nice collection of sharp, focused essays. To a large degree, I suspect the book's shortcomings are down to the publishers.

There are other books that give a better sense of the excitement of the physics behind the discovery and the discovery itself. Take the rip-roaring account in Sean Carroll's *The Particle at the End of the Universe*, which covers similar ground but with a fast-paced narrative and in gorgeous style.

Carroll's book wasn't an insider's account but, comparing the two, it seems that being on the inside of such an exciting event might have caused a loss of perspective rather than giving us a novel and interesting one. ■



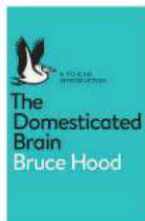
VALERIO MEZZANOTTI/THE NEW YORK TIMES/REX/VEINE

Where did our brains go?

Domesticating our own species is having some weird fallout, finds **Jonathon Keats**

The Domesticated Brain

by Bruce Hood, Pelican, £7.99



TWENTY thousand years ago, the average human brain was 10 per cent larger than it is today. Some people, such as

David Geary, a psychologist at the University of Missouri in Columbia, claim that the dip in cranial capacity marks our dwindling intelligence. Others, like John Hawks, an anthropologist at the University of Wisconsin-Madison, attribute it to improved brain efficiency.

But for Bruce Hood, the author of *The Domesticated Brain* and a psychologist at the University of Bristol, UK, the shrinkage is best explained by changes in society. “We have been self-domesticating through the invention of culture and practices that ensure that we can live together,” he writes. Our brains, he believes, are getting downsized by domesticity.

Domestication tends to have that effect. According to Hood, every species that has been domesticated by humans has lost brain capacity as a result. Bred for passivity, their testosterone decreases, reducing the size of all organs. Dogs are a good example and the effect on their behaviour is telling: where wolves will try to solve a problem through cunning, dogs are adept at soliciting help from their masters.

Drawing on his research in developmental psychology, Hood often enlists parallels between dogs and children to support the notion of human domestication. Like dogs, kids are highly skilled at enlisting assistance. Even infants



THE EVENING STANDARD/HULTON/GETTY

have the knack, getting parents to fetch an out-of-reach object with a glance. Also like dogs, they are great readers of social cues: only dogs and humans know to follow a pointed finger to an object.

Of course, human culture is more sophisticated than the domestication of dogs, and Hood is highly attentive to differences

“Our socially domesticated brains are responsible for prejudice, and can condone horrific acts, like genocide”

between humans and other creatures. Imitation is one interesting area of distinction. Chimps and pre-school children both mimic the actions of others in order to learn a new skill. But a chimp will imitate only the motions necessary to achieve the goal, whereas a child also mimics

steps clearly unrelated to the task. “Why would children over-imitate a pointless action?” asks Hood. Because they are more interested in fitting in than in learning how best to solve the task, he says.

Hood argues that our social adeptness is both a cause and an effect of our self-domestication, and suggests that our social behaviour is key to our species’ success. Knowledge can be broadly distributed, disparate areas of expertise collaboratively coordinated, and technology can develop over many generations.

Hood also acknowledges that our socially domesticated brains are responsible for prejudice, and can condone horrific acts, such as genocide. The importance we place on allegiances, for example, is all too easily manipulated by unscrupulous leaders, and deplorable actions are too readily

Only humans and dogs are capable of understanding finger-pointing

committed through what Hood calls “diffusion of accountability”.

Understanding the good or bad consequences of domestication is invaluable to us because the self-reflexiveness that made us who we are can also, potentially, improve us in the future. For that important reason, Hood is to be commended for writing *The Domesticated Brain* at a level that anyone can understand.

That said, in his effort to encompass all of psychology in just 300 pages – evidently the remit of a Pelican Introduction title – he often loses touch with his theme. The result is informative but, sadly, largely formless. ■

Jonathon Keats is an experimental philosopher and conceptual artist

A lot on their plate

How do you feed an extra 2 billion people within the next 35 years? **James Urquhart** meets the scientists on the case

AS THE world's population grows, so does its appetite. By 2050, there will be an estimated 9.6 billion mouths to feed around the globe – but we may not have the resources to meet that need. Current intensive farming practices rely on huge inputs of fossil fuels, land and water. They are also inefficient, unsustainable and damage the environment. But teams of plant biologists, animal scientists and veterinarians are working to change all that, with the aim of carving a path to a future in which no one goes hungry.

One of the biggest challenges lies in cutting our overuse of resources. Take meat production, for example. A third of the world's crops are used to feed livestock, and a quarter of the planet's ice-free land is devoted to grazing. In fact, it wouldn't be possible for the rest of the world to adopt the meat-rich diet of the average person in the US, who eats a whopping 120 kilograms of meat a year – compared with the 4.4 kilograms that Indians eat – there just isn't enough land on the planet.

The agriculture industry is also responsible for significant greenhouse gas emissions, which result from the manufacture of fertilisers and animal feed, for example. All in all, global food production is thought to account for between 19 and 29 per cent of human-induced greenhouse gas emissions. Ironically, climate change resulting from this is likely to harm the growing conditions of many crops, including staples such as wheat, rice and maize. At the same time, around 70 per cent of the world's fresh water supply is used for irrigation and food production.

"Globally, we're facing a significant increase in population, climate change and depleting fossil fuels," says Mark Eisler, a farm animal health scientist at the University of Bristol, UK. "Our food production system, as it is now, is probably not adequate to respond to these challenges of future food security," he says.

Eisler, who originally trained as a vet, thinks diseases that affect livestock represent an

important target. Sick animals might produce lower milk yields, or fail to gain sufficient weight or reproduce. Not only do these animals waste precious food and energy resources, says Eisler, they can pose a health risk to people – bovine tuberculosis, avian flu and salmonella can all be transmitted from farm animals to humans. Eisler is working with research farms in the UK, Australia and India to find and develop alternative farming practices that reduce the spread of disease among animals.

"Working with colleagues across a range of disciplines, who include soil scientists, animal nutritionists, biochemists and vets helps put my work into the broader context," Eisler says. "Together we might be making some contribution to the broader challenges of global health, sustainable food production and the viability of the growing human population that are facing society."

Rick Mumford, a plant scientist at the UK Food and Environment Research Agency (FERA), focuses on crops. "Part of the issue we have is that, globally, we lose a whole lot of what we grow to pests and disease," he says. A single

Agricultural scientists and geneticists work to boost the quality, yield and resilience of rice



HELDURNETOCNY/PANOS



ABBAS/MAGNUM PHOTOS

disease-causing pathogen can wreak a vast amount of damage in the agricultural industry. For example, the fungus-like *Phytophthora infestans*, which causes potato blight, is thought to destroy around £3.5 billion worth of potatoes globally every year.

The first step in tackling crop diseases is to catch them before they spread. Farmers and FERA plant health inspectors routinely take samples from plants and send them to laboratories, where they are subjected to lengthy and expensive screens for pathogens. Mumford's team has been working on a simpler, portable system that can be used by farmers or inspectors themselves, in the field. The system amplifies pathogen DNA for faster identification. The device will be put to use later this year by FERA health inspectors based at Heathrow airport in London, who will use it to test imported fruit, vegetables and other fresh produce for disease-causing agents.

While this kind of technology plays an important role in monitoring disease, inspectors themselves must be up to the job.



CASE STUDY THE ACADEMIC AGRICULTURALIST



You will probably have seen farmers ploughing away at the earth before sowing their seeds, but perhaps

the plight of the soil's resident earthworms and the release of greenhouse gases didn't cross your mind. It is Sofie Sjögersten's job to investigate the impacts of tillage and to work out if alternative methods could protect the planet - and its earthworms.

Before planting crops, fields are often tilled with a plough or another mechanical tool in order to turn the soil. This makes seed

planting easier, mixes nutrients and kills weeds. But it can also harm soil-dwelling creatures like earthworms, which improve soil fertility. And because soil produces greenhouse gases, agitating it can trigger the release of these gases.

Sjögersten, who is based at the University of Nottingham, UK, investigates whether tillage can be done away with altogether. She recently compared samples of soil taken from tilled and non-tilled farms and found that "zero tillage" practice could reduce greenhouse gas emissions by between 26 and 31 per cent.

It is this practical application of her academic work that

appeals to Sjögersten. "I really enjoyed this project," she says. "When people ask you what you do, you can say that you're doing something that could be useful to society."

Sjögersten initially trained in physical geography, but followed up her undergraduate degree with a PhD in biogeochemistry. "When I went into research I thought that I would sit quietly in my office or in my lab collecting data and thinking very hard, but actually a lot of what I do is working with people," she says. "It makes it fun and I enjoy interacting with people in other disciplines because I like to see the bigger picture."

FERA plant health inspectors tend to hold degrees in biology and horticulture, and receive on-the-job training to recognise pests and diseases by eye. Statisticians also play a key role in developing sampling strategies that aid better detection, while engineers develop devices to diagnose plant disease.

Mumford himself followed up an undergraduate degree in plant biology with a PhD in plant virus diagnostics at the Central Science Laboratory, now FERA. This helped him to pursue a career in plant health beyond academia, he says. "I think that the sort of experience gained by working in an industry or government science lab is really important and I would encourage people to do that."

"I love the idea that the work I do could actually benefit people"

Meanwhile, Cathie Martin, a plant biologist at the John Innes Centre in Norwich, UK, is more concerned about the nutritional value of the world's diet. "People tend to think of food security as producing enough food for everyone in the world to eat, but there's absolutely no point in having an objective to provide enough unhealthy fast foods to eat," she says. "It is the nutritious quality of the food that's important - everyone should have access to sufficient nutritious food for an active and healthy life."

Martin is working on ways to boost the nutritional content of existing fruits and vegetables. For example, she has attempted to make tomatoes even healthier by genetically modifying them to produce a compound called anthocyanin. This antioxidant, which naturally occurs in blueberries and plums, also turns the tomatoes a deep shade of purple.

In addition, the compound appears to extend the shelf life of fruit. When Martin compared the shelf life of her purple tomatoes with that of regular tomatoes, she found that they lasted twice as long. She hopes that the modified plant could help reduce the number of tomatoes thrown away by UK households each year, which in 2008 stood at 1 billion.

"One of the things that I find most interesting here is that we are very much applied scientists," Mumford says. "I particularly enjoy the idea of doing something with tangible results." Martin agrees. "I love the idea that some of the work I do could actually benefit people," she says. ■

James Urquhart is a writer based in Edinburgh



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Photograph: postgraduate entomology student, Eneree Gundalai, detects radio-tagged weevils



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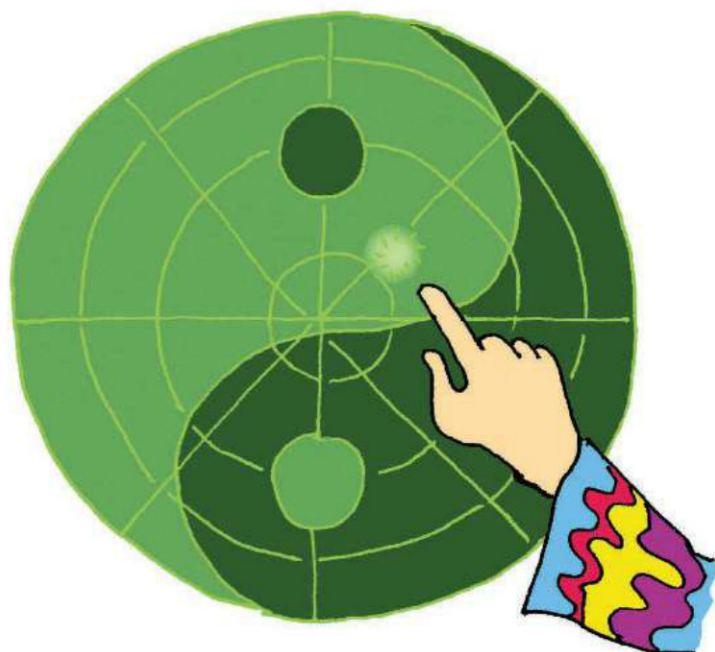
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GEORESONANCE? What would that be? Feedback's fruitloop-detector pinged when we read that, on 28 April, a firm by that name claimed to have found the wreckage of tragically missing Malaysia Airlines flight MH370.

Although inexpert in the company's field of mineral exploration, we were still surprised to read its claims at georesonance.com that "Subsurface deposits generate distinct electromagnetic fields that reflect physical and chemical properties of atoms [which] can be captured by airborne multi-spectral images."

Armed forces around the world have devoted highly secret but very large sums to detection of cigar-shaped metallic objects underwater, from the air. Water is recalcitrant in its opacity to electromagnetic fields (except for blue-green light, which it rapidly attenuates). Now this company claims success?

Our doubts were immeasurably strengthened when Graham Parkinson forwarded us an email discussion between Society of Exploration Geophysics members.

Passing over for brevity the fruits of technically expert scepticism, Feedback was fascinated by a member's discovery that three years ago the same website was devoted to "Geo-Resonance Rejuvenation - An Innovation in Holistic Healing".

Nevertheless, the *Sydney Morning Herald* reported on 2 May that Bangladesh had sent two navy frigates to the location in the Bay of Bengal mentioned by GeoResonance.

OTHER websites making very similar claims to georesonance.com, mentioned above, such as geonmr.com, have more of that indefinable "look" of quackery that has become queasily familiar at the Feedback desk. Have all these companies made enormous breakthroughs in physics?

ENTIRELY unrelated, apart from its aquatic theme, is the claim made by British newspaper *The Times* on 12 April that the "US navy makes plans to power its fleet with seawater". A diagram shows water

being electrolysed; the resulting hydrogen heated with carbon dioxide over an iron catalyst; and the reaction products converted into hydrocarbons. It seems to Sandy Dalkin that the US navy has "a way to violate the laws of thermodynamics".

Vice-admiral Philip Cullom is quoted as saying that this "is not alchemy, this is real science". A small clue to what this eminent naval-gazer is really hoping for is in the corner of the diagram, where the liquid fuel is fed to a jet. *The Times* didn't mention where the electricity comes from: we presume a nuclear reactor.

THERE may be nothing new under the sun – a phrase which would indeed be the wisdom of King Solomon, were he, as tradition has it, the author of *Ecclesiastes* 1:9. That verse probably inspired the author of Shakespeare's Sonnet 59: "If there be nothing new, but that which is / Hath been before..."

Now "the list of Shakespeare's scientific insights steadily grows", writes Michael Kusz in response to our series of articles on the Bard's dealings with scientific ideas (19 April, p 40). He directs us to an article in the June 1888 edition of *The Manufacturer and Builder* on "Shakespeare's Knowledge of Electricity". The anonymous author found references in Shakespeare to lightning, magnetic attraction and St Elmo's Fire discharges on ships' rigging.

Funnily enough, just as this arrived, a colleague was combing Shakespeare for references to calculus – without success, so far.

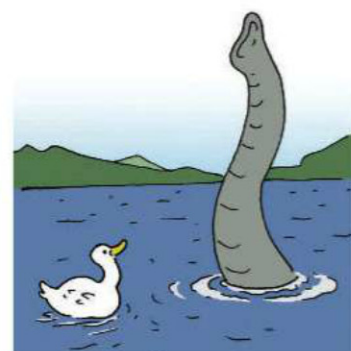
FEEDBACK was in fact aware that the textual origin of the phrase "hoist by your own petard" is, as John Davies points out, from Hamlet's observation that "'tis the sport to have the engineer / Hoist with his own petard: and 't shall go hard / But I will delve one yard below their mines, / And blow them at the moon". This practically defines the early modern usage of "petard" to name explosives placed under fortifications.

Recalling this merely reinforced our conviction that, in modern usage,

"petard" is a metaphor without foundation – which we have dubbed an "athelemic metaphor" (26 April), and more of which we seek.

WHILE we are considering matters theatrical, we present here the imaginative use of actorly units by Australian TV news channel 9MSN. Ed Lukin alerts us to its report of a record-breaking shark caught in Florida that was "as tall as Tom Hanks and Danny DeVito put together". Feedback is a little concerned about the possibility of doing arithmetic on such mixed-base units. Adding the length of two sharks, how do we know when to carry the Hanks?

FINALLY, and returning to matters aquatic, while discussing the use of the Windermere as a unit of inundation, Feedback reported David Williams suggesting: "3.4 million



elephants of rain is more acceptable, at the standard conversion rate of 5 tonnes per elephant" (8 March).

Given the prevalence of Feedback readers near here, we should not have been surprised to hear that "Windermere's volume is about 314.5 × 10⁶ cubic metres: 300 Windermere's of rain equates to about 94,350 million tonnes whereas 3.4 million 5-tonne-elephants is only 17 million tonnes." Thank you, Brian King.

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

In the basement of the building where Jeroen Gildemacher works is a mysterious machine, clearly labelled "Comfort Inverter". Gildemacher says it "explains a lot" about his environment

The eyes have it

My 9-year-old daughter has stumped me with a question. She asked me why the shape of eyelids differ in different races. She used the example of Japanese versus Caucasian people. Any thoughts?
(Continued)

■ I was surprised that neither of the answers published (15 February) mention sexual selection, Darwin's other great insight into evolution.

A memorable passage in Jared Diamond's *Guns, Germs and Steel* quotes a man from the New Guinea highlands on the great beauty of the local women, with their tight curly black hair, their eyes very close together, and their noses spread right across the face. He contrasts them to ugly western women, with their hair like dead grass, their eyes wide apart like a pig's, and their axe-blade noses.

These are all features for which it is hard to assign any evolutionary advantages, but

"The epicanthic fold may confer no advantage, but is considered more beautiful in some cultures"

which are easily accounted for in terms of sexual selection. It may be that the epicanthic fold confers no evolutionary advantage, but is considered more beautiful in some cultures, and so predominates.

Stephen Thomson
Ashfield, New South Wales,
Australia



Soil secret

These small pebble-like fungi (see photo, above) were dug up from the soil in the forest here in Nordfjordeid on the west coast of Norway. What are they?

■ The fungus that you have dug up is most likely to be the ascomycete, *Elaphomyces granulatus*. They are usually between 2 and 5 centimetres wide, grow underground and can be mistaken for truffles, which is why they are commonly known as false truffles.

Although the fungus isn't edible for humans, deer eat the thick outer skin but leave the black mass at the centre. These masses are packed with thousands of spores – each of which can grow into a separate fungus.

They are usually found in deciduous or coniferous woods similar to the one that the

questioner found them in.

The fungi aren't particularly beautiful but they are hardly ever seen. They often grow in symbiosis with spruce trees, forming special associations called ectomycorrhizas with the spruce's rootlets. The fungus benefits by absorbing sugars from the tree and the tree benefits by



being able to absorb water and dissolved ions from the fungi's branching mycelium network.

Interestingly, the fungus can be infected by another type of fungus, called *Cordyceps ophioglossoides*, which grows on it as a parasite. This parasitic fungus grows out of the soil around autumn, alerting watchful fungi lovers to the presence of hidden *E. granulatus*.
Christian German
Thornton Heath, Surrey, UK

This week's questions

THIN IRON LINE

When you demonstrate the magnetic field of a bar magnet using iron filings, the filings form lines. But isn't the field a continuous plane? What makes the lines form and why do they spread apart at the sides of the magnet and converge at the poles?
R. Milton
Hoo, Kent, UK

WINGING IT

In a park near Croydon in south London is a notice saying that white bread causes the geese to have distorted wings, such as those in this photo (left). There are two geese with this problem in the park. How is white bread harmful to geese and does it really lead to the damage to the wing feathers seen in the photo?
Jim Logan
Gatehouse of Fleet,
Dumfries and Galloway, UK

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Ngemelis Island, Palau. Marine biologist Michael Berumen uses an iPad with a waterproof housing to capture more data, more accurately. And he uses these findings to help protect the delicate ecosystems of our oceans.

A diver is shown underwater, holding an iPad in a waterproof housing. The diver is silhouetted against the bright blue light coming from the surface. The iPad is held up, and the diver appears to be taking a photo or recording video. The background is a deep blue with some light rays and bubbles.

Apple iPad Air

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