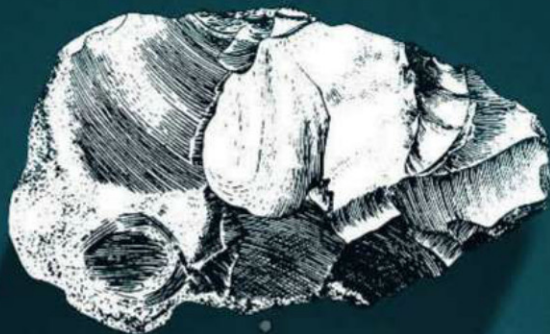


AWAKENINGS

Rousing people from the twilight zone

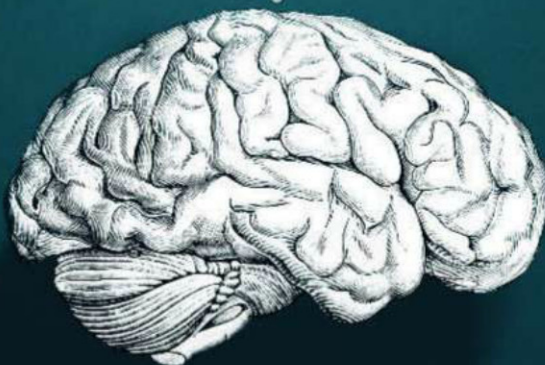
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Decisions, decisions

In a brain-damaged state, how would you want to be treated?

TERRI SCHIAVO died after 15 years spent in a state that many fear as much or more than death itself.

In 1990, Schiavo suffered a heart attack that left her in a persistent vegetative state. With no clear record of her wishes, her fate became the subject of a bitter dispute that pitted her husband against her parents, divided US public opinion and prompted the intervention of president George W. Bush before being settled by the US Supreme Court in 2005.

Sadly, the Schiavo family's heartache is not unique. In fact, it is becoming more common. Last year, for example, a UK court ruled against resuscitating a devout Muslim who was in a minimally conscious state. His family had argued that he would have preferred to live on,

believing this to be God's will.

Few people make "living wills" that specify how they would like to be treated in such situations. Once in a vegetative or minimally conscious state, they cannot express their wishes themselves, leaving physicians and family with the unenviable duty of

"Few people make 'living wills', leaving family and physicians to choose a course of action"

choosing a course of action.

This scenario is about to become more fraught still. This week brings news of a remarkable discovery: stimulating the brains of people in such conditions can rouse them, for short periods, to the point where they can answer

simple questions (see page 8).

This discovery has clear medical benefits: it should help doctors to make better assessments of patients' conditions. The hope is that researchers will be able to extend the stimulation, resulting in more significant brain activity and even, perhaps, a return to something resembling an acceptable quality of life.

Before then, there is a host of ethical issues. No one has yet asked the obvious questions: are you suffering? Do you want to live, or die? These questions will one day be asked, even if we don't yet know how to interpret any answers. We may not know any time soon. The only way to dictate our fate is to decide and record what we consider to be a life worth living. ■

Fake it until you make it

REWILDING is all the rage in conservation circles. The idea is to return large areas of land to their natural state, rebuilding ecosystems and reintroducing species that have long since vanished. That includes those animals exterminated because they were inimical to the interests of human settlers or farmers, notably large predators like wolves and bears.

The problem, of course, is that many of these species are gone for good. So ingenious rewilders are starting to introduce alien species that they hope will do the same job as the ones that have gone the way of the dodo – or the moa-nalo, a giant Hawaiian duck quickly eaten to extinction once humans found these islands (see page 40). Depending on who you ask, this is either a brilliant idea that will

restore the health of languishing environments, or foolhardy meddling that will cause innumerable headaches.

All this is forcing enthusiasts to reconsider what "nature" really is. In many places, true wilderness vanished thousands of years ago, and the landscapes we think of as natural are largely artificial. If rewilders are successful, thousands of years from now our descendants may think of African lions roaming American plains as "natural" too. ■

Society turns steampunk

POOR old Jules Verne. In recent years, the standing of the French science fiction pioneer has slipped below that of fellow author H. G. Wells. Wells's science tends to be wackier than Verne's. For example, in *The First Men in*

the Moon, people get there thanks to a metal that blocks gravity, whereas Verne's explorers in *From the Earth to the Moon* blast into space from a giant gun.

But Wells's grasp of social mores has brought him critical acclaim: the decadent Eloi and troglodyte Morlocks of *The Time Machine* are as apt an allegory for the class divide today as they were in 1895.

Now, however, society is once again warming to the kind of "steampunk" engineering that Verne celebrated in his books (see page 48). Verne's relevance may grow still further as more megaprojects come online. Geoengineering? Nemo, the renegade submarine captain of *20,000 Leagues Under The Sea*, would probably approve. ■

UK's North Sea push

BURN, baby, burn. The UK government has announced that it will fast-track measures to allow more oil and gas to be sucked out of the North Sea. But it is not all bad news for the environment: it will also fund the world's first commercial gas carbon capture and storage (CCS) facility to deal with some of the harmful CO₂ it pumps out.

On Monday, the Wood review on offshore oil and gas was published, which includes proposals to boost declining production, like a new independent regulator and more cooperation between oil and gas firms. Ian Wood said his measures could make it possible to extract the equivalent of an additional 3 to 4 billion barrels of oil, worth £200 billion to the UK.

Prime Minister David Cameron immediately backed the plan.

It might seem like an environmental nightmare. But it is small fry on a global scale, says Myles Allen of the University of Oxford. Far more important is the UK government's other announcement. On Monday, it said it will fund a multimillion pound project to design a carbon capture and storage plant at the Peterhead power station in Scotland. The CO₂ given off when oil and gas are burned will be captured and transported to Shell's disused Goldeneye gas field, where it will be pumped back underground.

"Anything the UK can do to promote CCS is far more important than anything the UK does with its own oil and gas reserves," he says, "so more power to the pumps."



ANDY BUCHANAN/PA WIRE/PRESS ASSOCIATION

Not so bad if you bury your carbon

Missing asteroid

MOBY DICK the asteroid has not yet caused destruction, unlike its fictional, white whale namesake. But by going missing, it has highlighted just how poor Earthlings are at asteroid surveillance.

The 270-metre space rock, officially called 2000 EM26, was slated to skim within 3.4 million kilometres of our planet early on 18 February, almost exactly a year after a meteor struck Earth in Chelyabinsk, Russia. But when a robotic telescope trained its eye

14 years ago, is on a very different path from its expected trajectory – perhaps nudged off course by sunlight. It also might be too dark in colour to be seen by the visible-light telescope that searched for it.

Despite such difficulties tracking even relatively close space rocks, some astronomers are sanguine because the chance of a serious impact is low. Meteors 20 metres in diameter – the size of the Chelyabinsk one – reach the planet only once or twice a century, and most hit oceans or unpopulated areas. Larger ones are even less likely to hit.

The moon, however, gets pummelled more frequently because it lacks an atmosphere like Earth's, which often fries any small meteors on a collision course. This week, a team led by Jose Madieto at the University of Huelva, Spain, revealed footage of what they calculate was a 400-kilogram rock hitting an area of the moon called Mare Nubium at 61,000 kilometres an hour. It is the largest rock caught striking the lunar surface yet (*Monthly Notices of the Royal Astronomical Society*, doi.org/rn9).

"The Moby Dick asteroid has not been seen for 14 years - perhaps due to a nudge from the sun"

on the predicted position, 2000 EM26 was nowhere to be found.

Astronomers then nicknamed the asteroid Moby Dick after the elusive, fictional whale, and called on amateur sky-watchers to hunt it down. The most likely explanation for the no-show is that Moby Dick, which has not been seen since its discovery

UK sued over smog

TIME to choke on writs. Last week, the European Commission began legal action against the UK, which has failed to cut nitrogen dioxide smog to levels set by the European Union. Several other countries could also be taken to court.

Nitrogen dioxide mostly comes from diesel engines and causes asthma and other lung problems. "Air pollution contributes to an estimated 4200 premature deaths in London," says Jenny Jones, a Green party member of

the London Assembly. Main roads in affluent Chelsea and the City of London exceed the legal limit.

Many other countries have breached the pollution targets, says the European Environment Agency in Copenhagen, Denmark. The EC will target them next. "We have opened pilot investigations in France, Denmark, Sweden, Romania and the Netherlands," says an EC spokesperson. The UK is being sued first because it is the furthest behind.

The UK government is considering its response.

Health cuts trigger Greek tragedy

AUSTERITY can be bad for you.

The Greek government made deep cuts to healthcare and social services between 2009 and 2012 as a result of the country's financial crash. Suicides increased 45 per cent between 2007 and 2011 and, over roughly the same period, cases of depression more than doubled and infant mortality rose by 43 per cent.

Needle-exchange schemes and free condoms for injecting drug users were cut. By 2012, new HIV cases in

this group were 32 times the 2009 level. Greece also had its first cases of locally spread malaria for 40 years (*The Lancet*, doi.org/f2p8qx).

It's a false economy to cut health spending, says David Stuckler of the University of Oxford, who led the analysis. Iceland and Finland survived economic meltdowns without doing so. Spain, on the other hand, cut health budgets a few years after Greece so could soon face similar problems.



Flu hits young

YOUNG adults, beware. The swine flu responsible for the pandemic five years ago is once again the dominant strain in North America. So people of working age are again hardest hit by the virus,

FREDERIC J. BROWN/AP/GETTY IMAGES



A disastrous toll

"We are seeing a battle for supremacy among flu viruses. People of any age should get a flu shot"

which has hung around since 2009.

So far, more than 60 per cent of people in the US who have caught severe flu this season, or died of it, are 18 to 64 years old. This is similar to rates during the pandemic but double the number of severe cases in this age group in the past three winters, when the H3N2 virus – which is more likely to hit older people – was top dog. Only about a third of severe cases in the US this year are people over 65.

Meanwhile in Europe, the flu season has been split between swine flu and H3N2. What we are seeing is a battle for supremacy among flu viruses, says Lone Simonsen of George Washington University in Washington DC.

This means people of any age should get a flu shot. While older people have some immunity to swine flu from previous exposure, H3N2 can be deadly. Younger adults have more resistance to H3N2, but are succumbing to swine flu.

Climate of disaster

IT IS a heavy price to pay. China paid out twice as much to mop up after natural disasters in 2013 as it did in either of the previous two years. The rising costs are partly down to climate change.

Earthquakes, floods, droughts, snow storms and other disasters cost China over 420 billion yuan (\$69 billion), according to the National Bureau of Statistics of China. The costs in 2011 and 2012 were just 260 billion and 220

sometimes possibly in places where they shouldn't be."

China's National Development and Reform Commission released a report in 2013, outlining how it will adapt to climate change. Their plans are hazy, but include more monitoring and early warning. "China has had a focus on trying to evaluate what trends there are in extreme events," says Moore.

"Drought is increasing, as is severe rainfall that causes floods, and there's an increase in extreme heat"

billion yuan, respectively. Payouts for five kinds of disaster increased in 2013 compared with 2012.

Climate change has left its calling card in some of those disasters, says Lisa Alexander of the University of New South Wales in Sydney, Australia. Drought is increasing in parts of China, as is severe rainfall that causes flooding and mudslides. "And in tandem with that there's an increase in extreme heat."

Economic growth is also a factor, says John Moore of Beijing Normal University in China. "Things cost a hell of a lot more because more high-value things are being built in recent times and

Prime currency

TRUST in Bitcoin may be low following the collapse of its biggest currency exchange, but a new virtual currency has an extra draw. Riecoin is designed to help solve a mathematical mystery involving prime numbers.

As with Bitcoin, Riecoin users "mine" virtual coins using a program that solves a difficult mathematical problem. But with Riecoin, this mining process also finds clusters of consecutive prime numbers. These "prime constellations" provide a way to test the Riemann hypothesis, a proof of which is worth \$1 million (see page 15). Riecoin can't find a proof, but it might find an example of a constellation that doesn't fit with Riemann and so offer clues as to how to disprove it – although most mathematicians expect it to hold.

Riecoin is the second currency based on primes, after Primecoin.

60 SECONDS

Oldest crust

A zircon crystal has been verified as being 4.4 billion years old, making it one of the oldest known pieces of Earth's crust (*Nature Geoscience*, doi.org/rpb). The crystal, from Jack Hills in Western Australia, is less than a millimetre wide, but it should teach us more about how the Earth's crust cooled.

No climate quick fix

Want to avoid dangerous climate change? The only option is to cut greenhouse gas emissions. It is possible to suck CO₂ out of the air, but without emissions cuts the effect is insignificant, while cooling the planet with aerosols has damaging effects on rainfall (*Nature Communications*, DOI: 10.1038/ncomms4304).

Cancer pee test

A urine test similar to pregnancy tests could one day be used to diagnose cancer. Mice were injected with markers that interact in the blood with proteins produced by tumour cells. Part of the marker was cut off by the proteins, ending up in the mice's urine. The test has so far been shown to work with colon cancer (*PNAS*, doi.org/rn8).

Plato lives

Europe is getting into the planet-hunting game. The European Space Agency has selected a space telescope mission called Planetary Transits and Oscillations, or Plato, for launch in 2024. The spacecraft, 34 telescopes strapped together, will search 1 million stars for potentially habitable worlds.

Bigger becomes norm

Being overweight or obese is now so common in European children that it has become the norm, reports the World Health Organization. A third of Europe's 11-year-olds and a quarter of its 13-year-olds are overweight, with numbers highest in the four countries worst hit by austerity – Greece, Portugal, Ireland and Spain.



GEORGIOS MAKKAS/PANOS

No money to treat brain tumours

An electric awakening

People asleep for years have been roused temporarily using brain stimulation

Helen Thomson

TALK about an awakening. People who have been in a minimally conscious state for weeks or years have been temporarily roused using mild electrical stimulation.

Soon after it was applied to their brains, 15 people with severe brain damage showed signs of consciousness, including moving their hands or following instructions using their eyes. Two people were even able to answer questions for 2 hours before drifting back into their previous uncommunicative state.

"I don't want to give people false hope – these people weren't getting up and walking around – but it shows there is potential for the brain to recover functionality, even several years after damage," says Steven Laureys at the University of Liège in Belgium, who led the research.

People with severe brain trauma often fall into a coma. If they "awaken", by showing signs of arousal but not awareness, they are said to be in a vegetative state. This can improve to a state of minimal consciousness, where they might show fluctuating signs of awareness, which come and go, but have no ability to communicate.

External stimulation of the brain has been shown to increase arousal, awareness and aspects of cognition in healthy people. So Laureys and his colleagues wondered if it would do the same in people with severe brain damage. They used transcranial direct current stimulation (tDCS),

which doesn't directly excite the brain, but uses low-level electrical stimulation to make neurons more or less likely to fire.

The team worked with 55 people who had experienced a traumatic brain injury or lack of oxygen to the brain and were in a minimally conscious or vegetative state. They placed electrodes over their left dorsolateral prefrontal cortex – an area involved in memory, decision-making and awareness. Then they delivered 20 minutes of stimulation to some of the people and a sham treatment to the others. The next day, the two groups received the opposite therapy.

During brain stimulation, 13 people with minimal consciousness and two people in a vegetative state showed signs of awareness that were observed neither before the stimulation nor after the sham treatment.

For most of these people the changes were moderate, but some recovered the ability to

"It shows there is potential for the brain to recover functionality even several years after damage"

communicate, says Laureys. "Two patients emerged from a minimally conscious state altogether." When asked questions such as "Am I touching my nose?", they were able to answer by nodding their head or making specific eye movements.

Others were able to respond to simple commands to nod, or squeeze their hand. All the effects



PLAINPICTURE/PHOTOALTO/MICHELE CONSTANTINI

lasted for about 2 hours. The findings will be published in the journal *Neurology*.

For some patients, it was only weeks since their trauma had happened, but others had been minimally conscious for years. This is important, says Laureys. "There's this dogma that if you don't see a change in 12 months you will never see it. This research challenges that."

"This is a very important study," says Tristan Bekinschtein, who studies consciousness at the University of Cambridge. If this treatment becomes a standard practice, he says, it will reveal a lot about how different brain networks become reactivated after severe head trauma.

It's not clear exactly how the treatment works, but it is likely that the stimulation pushes previously suppressed brain activity over a threshold. This possibly enhances processes that are involved in attention and working memory and underlie conscious tasks such

as decision-making and moving.

John Whyte, director of the Moss Rehabilitation Research Institute in Philadelphia, Pennsylvania, says that tDCS might be used both as a treatment in its own right, and for screening people to diagnose their state and assess what treatment they might respond to. "This research is of considerable interest as it suggests another potential treatment avenue," he says. "First, we need to determine whether these short-term effects can be amplified and made more durable."

Laureys's team is now doing just that – assessing the potential for more lasting arousal. The brain can be stimulated for longer periods of time as there seem to be no side effects, just a little tingling, Laureys says. Trials involving a full week of stimulation are under way. They also involve stimulating other areas of the brain. The results are not yet available.

This isn't the first time that medical interventions have

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Treatment might be possible

aroused a silent brain. In 1999, Louis Viljoen – who had been in a persistent vegetative state for three years – began to make erratic movements at night. His doctors prescribed zolpidem, a sedative used to treat insomnia. Within minutes of being given the

drug by his mother, Viljoen turned his head and said “hello mummy”. The effect lasted a few hours. The drug now allows him to communicate for about 10 hours a day. Such a response is rare. Laureys’s team found that zolpidem had no significant

effect on any of 60 patients with brain damage (*Functional Neurology*, in press).

It isn’t known how a sedative can rouse some patients – it may be that the damaged brain reacts differently. A drug used to treat Parkinson’s called amantadine has also been found to help

“It’s like we are opening and shutting a window for a few hours. That could be perceived as cruel”

minimally conscious patients recover – possibly by increasing dopamine levels in brain networks vital to awareness and attention.

When people temporarily emerge from a minimally conscious state, it’s hard to gauge how much they are really aware of. Laureys suggests that it might be like that moment when you wake up in a hotel and don’t know where you are. But these trials raise uncomfortable questions. Is it right to rouse someone only to send them back to sleep a few hours later?

It can be challenging, admits Laureys. The patient’s family is often in the room during the trials. “We explain to them that the effect will be of limited duration and that there is no

room for subjectivity so we can’t just ask any question. We need to keep all the trials the same.” In his experience, though, the families are just happy that there are people trying new therapies.

“It’s like we’re opening and shutting a window for a few hours, and that could be perceived as cruel,” says Joseph Fins, at Weill Cornell Medical College, New York, who was the first person to trial deep brain stimulation in a minimally conscious person. “But we didn’t give these people brain damage, we are trying to make it better. These kinds of experiments show that a window exists, and now you know that you might be able to use other interventions to enhance that window.”

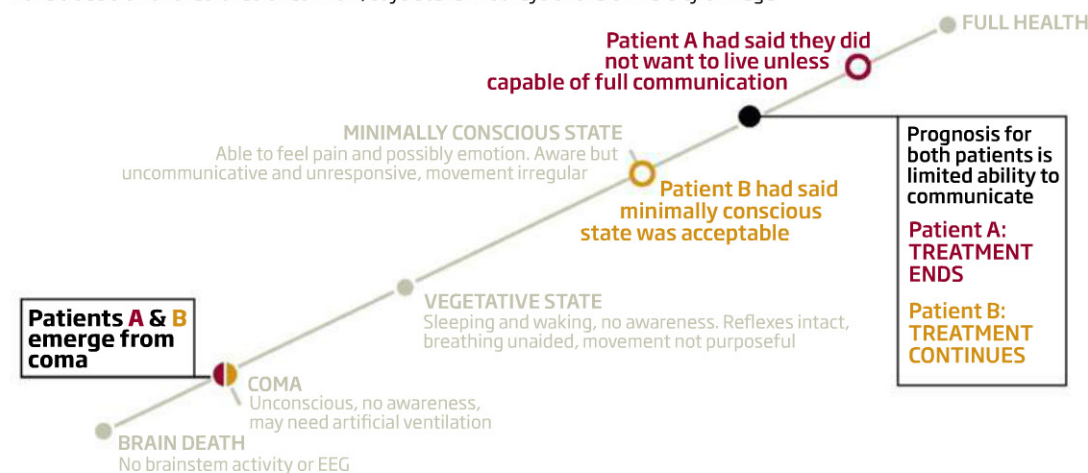
The worst scenario, he says, is that the person has some aspects of awareness but they have been misdiagnosed as persistently vegetative. Brain stimulation could now be added to the tests used to make that diagnosis. It’s an important distinction – someone in a vegetative state is thought to be unable to feel pain. Someone with minimal consciousness can feel pain and possibly emotions, too. “The key thing is getting the diagnosis right, that’s the game-changer,” says Fins.

It could also give doctors another tool to decide whether a person is likely to recover. About 5.3 million people in the US are living with a traumatic brain-injury-related disability, ranging from mild sensory impairment to persistent coma. “In some cases, members of your family can be left with difficult decisions about whether to remove life support,” Laureys says. “And we can’t make any decisions ethically if we’re not sure about the diagnosis, prognosis and therapeutic options.”

He says that while you are still healthy, you should discuss with friends and health professionals what you think is an acceptable quality of life and where you draw the line (see graphic, left). ■

Decisions in life

When do you decide there is no point keeping someone alive? While brain stimulation can improve diagnosis (see main story), it would be helpful to know what the person believes is their acceptable quality of life. Make a decision and let loved ones know, says Steven Laureys of the University of Liège



The DIY gut-bug swap

Why are people doing faecal transplants at home, asks **Jessica Hamzelou**



ANJA WEBER-DECKER/PLANIPICTURE

LAST year wasn't kind to 27-year-old Jim. He was diagnosed with ulcerative colitis and it was causing him a lot of pain. Drugs failed to provide relief, and it seemed as if the only option was to surgically remove his colon. Instead, he opted for something else. Two weeks after having filtered faeces inserted into his guts, Jim improved massively. "The blood and pain are reduced, and I'm not having to worry about going to the toilet."

Jim is one of a growing number of people turning to faecal microbiota transplantation (FMT) to restore their gut bacteria to a healthy state. The idea is to reset the gut flora using bacteria in the stools of a healthy person.

Jim lives in the UK, where this procedure is not regulated so he was able to find a clinic to do it for him. In the US and Canada, however, the rules are stricter, and some people are taking the matter into their own hands. "People are turning to faecal transplants without any medical supervision. They don't even get the donor screened," says Emma Allen-Vercoe, a microbiologist at the University of Guelph in Ontario, Canada. "They're putting themselves at significant risk."

Last week, a group of microbiologists writing in *Nature* called for the US Food and Drug Administration to change the rules on FMT, and for regulators around the world to work out how to deal with the procedure. So how should such transplants be regulated? And is it worrying that people are doing it themselves?

The technique has shown most promise for treating people infected with *Clostridium difficile*, a bacterium that colonises people's gut when antibiotics have obliterated the other inhabitants, sometimes to fatal effect. The results of a clinical trial using FMT to treat people with recurring *C. difficile* infections, the first ever for any FMT treatment, were published last year. Fifteen out of 16 people

Have you refreshed your gut?

given transplants were cured of their infections, compared with 4 of 13 patients receiving standard antibiotics.

Several case reports suggest that FMT can also relieve inflammatory bowel disease, including Crohn's disease and ulcerative colitis, and a few reports suggest possible benefits for people with autoimmune disorders and Parkinson's, but clinical trials have yet to be done.

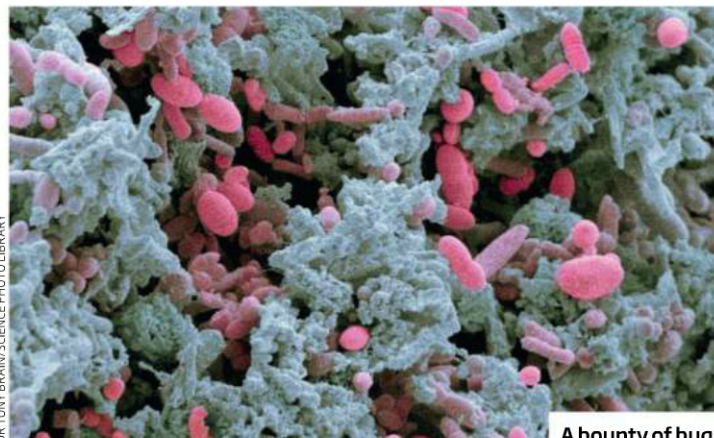
As a result, the FDA considers FMT as an investigational drug for everything apart from treatment of non-responsive *C. difficile*. This means doctors have to apply for a licence to use the treatment as part of a study. The situation is similar

into the gut is not without risk – there is a chance of introducing disease-causing bacteria and parasites, for example. Side effects have been rare so far, but there are reports of faecal transplants causing infection and gastrointestinal bleeding.

Microbiologists are just starting to understand the roles of the various bacteria that line our gut. Some types have been linked to diseases including cancer, obesity and diabetes – and there is no way to be sure the recipient of FMT isn't increasing their risk of these disorders, says Allen-Vercoe. "We shouldn't blithely be doing faecal transplants wherever we can just because we think it's a good idea," she says. "Nobody is monitoring what's happening long term."

But if people are going to take a DIY approach, might it not be safer to provide people, or their doctors, with safe samples?

Last year, Smith co-founded OpenBiome – a non-profit company in Cambridge, Massachusetts, that provides pre-screened, frozen faecal samples from healthy donors. At the moment, it offers samples only to doctors treating people with



A bounty of bugs

"People are doing this in the basement, with a stool from a family member, a blender and an enema kit"

in Canada. "It takes hundreds of hours to open an application and many more are spent monitoring patients," says Mark Smith at the Massachusetts Institute of Technology.

This means people are doing their own transplants at home, using little more than stools from a relative, a blender and an enema kit (see "From trash to treasure"). "People are making this in their basement," says Smith.

A quick online search offers up how-to guides and success stories, not just for gastrointestinal disorders, but for other conditions, for which evidence of FMT efficacy is even more scant. Some parents of children with severe autism, for example, are swapping notes on FMT on online forums, even though all they have to go on is limited evidence of an altered gut flora in autism, and a study that showed a species of bacteria could reverse some symptoms in mice with an autism-like disorder. "It worries me," says Allen-Vercoe. "This is a paediatric population. We have a duty of care here which is beyond that of adult patients."

Even in adults, inserting faeces

C. difficile infections – so it is of no use to people trying FMT at home. "It's really challenging, ethically," says Smith. "If a patient is dead set on getting treatment, it's probably a good idea to have a doctor help."

Writing in *Nature* on 19 February, Smith and two colleagues called on the FDA to regulate faecal transplants in the same way as tissue transplants of blood, bone and cartilage. "Transplanting these products into people requires meticulous record-keeping and screening for communicable diseases. These are exactly the safety precautions that should be taken with FMT," they say (*Nature*, doi.org/rnz).

In the UK, things aren't much clearer. Trevor Lawley, a microbiologist at the Wellcome Trust Sanger Institute in Cambridge, agrees FMT is more like an organ than a drug, but says it falls between regulatory categories. "It's tricky – it's a completely new way of thinking about a therapy."

The Medicines and Healthcare Products Regulatory Agency, which regulates drugs and medical devices in the UK, says FMT falls outside its remit. The UK Human Tissue Authority says it isn't accountable either, and intends to seek a decision from the European Commission on whether FMT should be regulated.

"We need some regulations in the UK," says Glenn Taylor, co-founder of the Taymount Clinic in Hitchin, which treated Jim. Since it was established in 2004, the clinic has carried out over 800 procedures on 100 people, including people from the US and those desperate to try FMT but unable to obtain it through the UK National Health Service.

This may soon change. The NHS recently asked researchers to apply for funding for projects that "make a strong case for how [FMT] could be standardised for routine use within the NHS". So with the promise of easier access to FMT to come, it is vital that proper regulations are in place now, says Lawley. "There's this great movement," he says, "but we just need one bad case and the whole thing is pushed back." ■

FROM TRASH TO TREASURE

The effectiveness of faecal microbiota transplantation (FMT) for gastrointestinal disorders is unclear, but that hasn't stopped people from trying it at one of a handful of clinics around the world, or at home.

In clinics, stool donors are selected for their healthy lifestyles and lack of disease, and donations are tested for potential pathogens. People doing their own transplants often seek donations from healthy friends or family members – ideally someone who lives nearby, to ensure a steady supply.

The method of preparation varies. Glenn Taylor, co-founder of the Taymount Clinic in Hitchin, UK, which specialises in FMT, keeps samples in an oxygen-free environment and

screens and filters them before adding a glycerol solution. The resulting mixture is then delivered by a rectal tube to the large intestine. Other clinics opt for a nasogastric tube, which runs from the nose, down through the stomach and into the colon. Most home users simply put samples in a food blender, add a saline solution and squirt the mixture into their rectum using an enema kit.

Emma Allen-Vercoe's team at the University of Guelph in Ontario, Canada, is working on a more palatable option. In a project called RePOOPulate, the team is isolating bacteria from healthy stool samples, growing them in a lab, and creating a bacterial cocktail that can be used in place of faecal matter.

Hint of dark matter made of neutrinos

Lisa Grossman

FLASHES of X-rays from crowded galaxy clusters could be the long-awaited sign that we have found particles of dark matter – the elusive substance thought to make up the bulk of all matter in the universe.

If the results stand up, dark matter would consist of ghostly particles called “sterile” neutrinos. These tantalising particles would be the first kind found beyond the standard set known to science.

“There is no other obvious explanation for what could be producing the X-ray signal in galaxies”

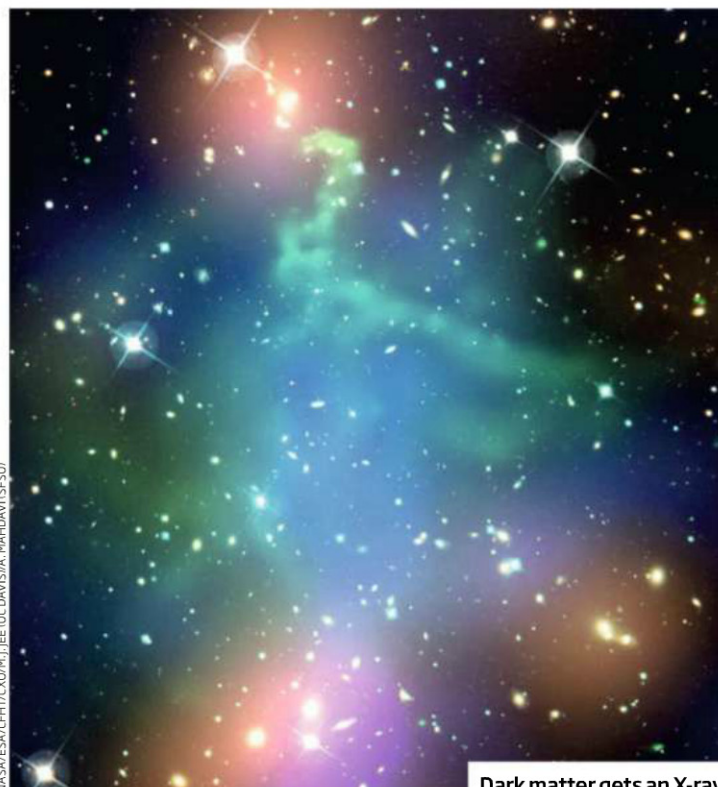
Dark matter interacts with ordinary matter via gravity but otherwise scarcely makes itself known. Physicists think its mass could be tied up in an unknown particle. The leading theoretical candidate is a weakly interacting massive particle (WIMP), but our best detectors have yet to yield a confirmed sighting.

Neutrinos also seem like good candidates, as they are long-lived and notoriously aloof when it comes to interacting with other

particles. But the three known types of neutrinos are not massive enough to account for all of the universe’s dark matter, so theorists proposed a fourth neutrino that would interact even less with regular matter. If this sterile neutrino is heavy enough – about 10 kiloelectronvolts (keV) – it could account for all dark matter, while lighter versions might solve other cosmic conundrums (see “Ghost in the galactic machine”, below).

This particle would be virtually impossible to detect directly, so we must catch it decaying into other particles that are easier to observe – X-ray photons and ordinary neutrinos. Two independent groups used archival data from X-ray telescopes to search for these decay products. They focused their searches on galaxy clusters, which should be rich in dark matter.

Esra Bulbul at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, and her colleagues used observations of 73 galaxy clusters from the European Space Agency’s XMM-Newton space telescope and NASA’s Chandra X-ray telescope (arxiv.org/



Dark matter gets an X-ray

abs/1402.2301). The other team, led by Alexey Boyarsky at Leiden University in the Netherlands, used XMM-Newton observations of the Perseus galaxy cluster and the nearby Andromeda galaxy (arxiv.org/abs/1402.4119v1).

Both teams saw X-ray emissions at energies of about 3.5 keV. That could correspond to the decay of a sterile neutrino with a mass of about 7 keV. There is no other obvious explanation for what could be producing the signal:

nothing else that we know of emits X-rays at that specific energy. Both teams were able to rule out noise from the telescopes.

“We tested every single scenario we could come up with and eliminated things very carefully,” says Bulbul. “The upshot is we just don’t know what this is. The most exciting explanation is the decay signature of sterile neutrinos.”

Signs of sterile neutrinos have popped up and been knocked down before, so the researchers are being cautious.

“It’s intriguing. There’s a consistent picture for it being dark matter,” says Kevork Abazajian at the University of California, Irvine, who was not involved in either study. “But I think confirming it would really require deeper observations of other things.” His wish list includes checking if the signal shows up in other objects that should have lots of dark matter – such as dwarf galaxies – and finding out if the signal is stronger in the centres of clusters, where dark matter should clump more. ■

GHOST IN THE GALACTIC MACHINE

If they exist, sterile neutrinos could explain dark matter. But even if they cannot account for it all, finding them may solve another mystery: where are the universe’s “missing” galaxies?

Maps of the first light emitted after the big bang have been used to measure how fast the entire universe is expanding and how readily regular matter clumps up. However, these data disagree with experiments that measure the same values in the local universe: the maps say the universe

is expanding more slowly, and that there should be almost three times as many galaxy clusters as we observe.

If sterile neutrinos existed in the early universe, they could resolve both problems, says Mark Wyman of New York University. His models show that a sterile neutrino with a mass of less than 1 electronvolt would speed up the map-based values for the universe’s expansion. In addition, the neutrinos’ reluctance to interact would let them escape

from early clumps of matter, meaning less mass gets left behind to pile up and build galaxies (*Physical Review Letters*, doi.org/rn3).

Wyman’s sterile neutrino is too light to account for dark matter, but it might be related to heavier sterile neutrinos, signs of which may be appearing in X-ray data (see main story). “It would be awesome if these sterile neutrinos were somehow related, but as yet no one has threaded all of those needles simultaneously,” he says.

INGENIO *et* LABORE



By natural ability and hard work

The University of Auckland **MAKING OUR MARK IN THE FIGHT AGAINST SUPERBUGS**

As antibiotic-resistant superbugs get stronger by the day, researchers at the University of Auckland are shedding new light on the issue.

Combining microbiology with bioluminescence, Dr Siouxsie Wiles and her team have developed a technique that renders the bacteria making up superbugs luminescent. Seeing the bacteria in their true light gives a far greater understanding of bacteria and how to combat them. In time, the team plans to develop new drugs for trial.

Combining microbiology with bioluminescence, Dr Siouxsie Wiles and her team develop luminescent derivatives of many different superbugs which they use to speed up the screening of potential new antibiotics. Seeing the bacteria in their true light also gives a far greater understanding of bacteria and how to combat them. In time, the team hopes that novel compounds they have helped identify will lead to the development of new drugs for trial.

She is one of many world-class researchers at the University of Auckland who have helped us become New Zealand's world-ranked university.

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Te Whare Wananga o Tāmaki Makaurau

Pancreatic cancer's weak spot found

Michael Slezak

PANCREATIC cancer's deadliest trick could be its undoing. Despite each person's tumours having very different genetic mutations, they all cause the same metabolic changes that help it grow. What's more, drugs already exist that can block the process.

Pancreatic cancer is the most lethal of all common cancers – 95 per cent of people die within five years of diagnosis. One reason it is so deadly is that no two cases are genetically the same. That means the tumour is more likely to evolve resistance to drugs, and that genomic studies aiming to find common mutations that could be targeted by treatment have fallen flat.

So Darren Saunders and colleagues at the Garvan Institute of Medical Research in Sydney, Australia, tried a different approach. As well as looking for variations in the genome of different people's tumours, they also looked at the biological processes at work in the cells.

To do this, they switched from using dead tumour cell samples to patient-derived tumour cell lines, in which fresh samples of a person's tumour are grafted onto mice and grown to the required volumes. Growing them in animals makes for more lifelike tumours, and can produce large quantities of tissue for study.

This bank of living tumour cells allowed the team to study not only the genetics of the cells, but also how genetic mutations in the mitochondria – which drive energy production in the cell – caused changes in the cell's metabolism.

To analyse the tumour cells' metabolism, they used a technique called "metabolomics". This involves crushing live

tumour cells and measuring the metabolites they contain using a mass spectrometer.

"You can think of it like lines on a train map," says Saunders. "Metabolomics allows us to map those pathways and see which ones are switched on and switched off [in a cell]."

Putting together their analyses of the mitochondrial DNA in each tumour cell line and the metabolic pathways at work, the team were able to deduce how each cell line's genetics directly affected its ability to multiply.

They found that pancreatic cancer cells consume not only glucose, as normal cells do, but also glutamine. This leads to the production of fatty acids – the building blocks of new cells – thereby allowing the tumours to proliferate wildly. "Instead of using fuel for energy, they switch to using fuel to build new cells," Saunders says. The team presented its results at the Lorne Cancer Conference in Australia last month.

This process has been seen before in other cancers, but this is the first time it has been shown to be involved in all pancreatic

PERSONAL TREATMENT

When Andrew Biankin walked into the Garvan Institute of Medical Research in Sydney, Australia, in 1998 and said he wanted to study pancreatic cancer, the head of the department was unimpressed. "We have a problem," said Rob Sutherland. "You don't know anything about research, and I don't know anything about pancreatic cancer."

Sutherland couldn't know that he would be diagnosed with pancreatic cancer almost a decade later. By then Biankin, now at the University of



Target its metabolism

tumours, and that each tumour evolved different genetic mechanisms to do this.

The team was also able to see exactly how the cancers pulled off this trick. Each tumour they studied switched off the electron transport chain, which is involved in energy production. "The cells in each tumour are finding a different way to do that," Saunders says. Since this happened in all 12 cell lines studied so far, each originating from a different tumour, Saunders suspects it's

the key change that makes pancreatic cancer so aggressive. The team now plan to genetically engineer healthy cells to produce the same metabolic behaviour. If those become cancerous, it will further prove the hypothesis.

The find offers enormous hope for treatment, says Saunders. There are drugs already known to target this chain. So it doesn't matter that each person's tumour might find different ways to switch the chain off, drugs ought to be able to reverse the process.

The team is already testing the drugs in the tumour cell lines it created. If all goes well, animal testing could start within six months, says Saunders.

Finding these similarities between the tumours offers new hope for treating a cancer which seemed too varied to target effectively, says Claudio Santos at University College London. "So perhaps in this age of cancer genomics showing how diverse and heterogeneous human cancer is, we should be focusing on the common effects that different mutations lead to," he says. ■

Glasgow, UK, had sequenced the genomes of 100 tumours and found they were all different. So he created a way to graft tumours onto mice to test out treatments (see main story).

Biankin's team did this with Sutherland's tumour, "and hit it with about a dozen drugs to see which ones it would respond to". The drugs didn't work, and Sutherland died in 2012. But the finding that all these genetic differences trigger the same cellular pathway provides hope for others. Catherine de Lange

India unveils its own astronaut capsule

INDIA is about to take one small step towards human space flight. Last week the country's space agency unveiled a prototype of its first crew capsule, a 4-metre-high module designed to carry two people into low Earth orbit.

The Indian Space Research Organisation (ISRO) is planning a test flight for later this year – even though it still awaits government approval and funding for a human space-flight programme. The unpowered capsule will fly on the maiden launch of a new type of rocket that would otherwise have carried a dummy payload.

"We thought it better to gain some confidence in the design of our crew module," says Sundaram Ramakrishnan, director of ISRO's Vikram Sarabhai Space Centre in Thiruvananthapuram, Kerala.

Built by Hindustan Aeronautics in Bangalore, the prototype capsule cannot be hermetically sealed and so cannot take people into space. But if the rocket launch is a success, ISRO should be able to remotely test some in-flight controls and see how the module survives the stresses of re-entry and landing at sea.

The capsule will fly on a new variant of India's Geosynchronous Satellite Launch Vehicle, with its first test in a few months. When fully operational the rocket will loft satellites of about 4 tonnes to geosynchronous orbit, or place up to 9 tonnes into low Earth orbit. It could even be used to launch a future robotic moon mission.

The rocket's test flight will only explore part of its capabilities, but it should be enough to launch the crew capsule into sub-orbital flight, just over 100 kilometres above Earth. Instruments will relay data about the capsule's speed, acceleration and temperature.

Engineers will also monitor its structural integrity as it re-enters the atmosphere, as well as the

performance of heat-resistant tiles and a carbon nose-cap designed to protect astronauts from the heat of re-entry. The capsule will deploy two parachutes as it falls back to Earth, which should allow it to splashdown gently in the Bay of Bengal.

"Having this capability makes us a strong partner for any international effort to send humans to Mars"

India most recently launched its first Mars mission, and ISRO has plans to send a lander and rover together to the moon around 2017. But there is no time frame for government approval of human space-flight, and Ramakrishnan reckons it would take at least five years from getting approval to putting Indian

astronauts into low Earth orbit.

While about 70 per cent of the manufacturing for any given ISRO mission is done by India's private sector, it is unlikely that a single commercial firm will step in to the space race, as several companies have done in the US.

Still, Ramakrishnan thinks human space flight is a crucial component of any advanced space programme and an important step for India. A crewed mission to Mars, for instance, may have to be an international collaboration as it will probably be too expensive for any one nation to pull off alone. "In that context, our having this capability makes us a strong partner for any international effort," says Ramakrishnan.

Scott Pace, director of the Space Policy Institute in Washington DC, agrees. "India is a major spacefaring country, and it would seem reasonable to expect that it would eventually want to develop its own human space-flight capability." **Anil Ananthaswamy** ■

Prime numbers emerge from simple network

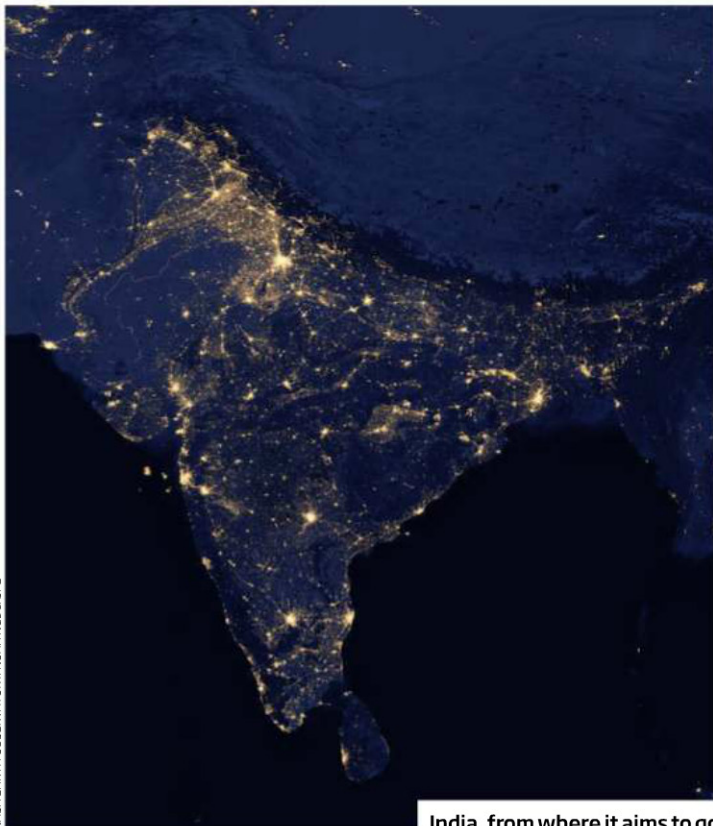
IS THERE a pattern behind prime numbers? This is one of the biggest questions in mathematics. Now networks that reproduce relationships between primes and non-primes could point the way to an answer.

Primes are numbers that are only perfectly divisible by themselves and by 1. They can be thought of as the building blocks of numbers, because any non-prime – or composite – can be generated by multiplying primes together. But they remain mysterious: no one has been able to find a pattern in the way prime numbers are distributed among the composites.

To investigate, Marián Boguñá of the University of Barcelona, Spain, and his colleagues turned the numbers from 2 to 1 billion into a network by linking composites to their prime building blocks. They also devised a way to generate similar networks using other simple rules to link the numbers, and wondered if they could get these networks to reproduce the pattern of links between primes and composites.

Their rules depend on probabilities, so the generated networks are different each time. On average, the researchers found that the webs are very close to the real network of primes and composites (arxiv.org/abs/1402.3612). Previous work made it possible to estimate how many primes there are below a certain number, but this is the first time a model has reproduced the relationships between primes and composites.

The next step will be to generate more prime-like networks. Testing theories about the real primes has been difficult because there was no other similar system before this research. "There is only one set of primes, but with their technique you can produce a thousand different networks," says Dave Platt of the University of Bristol, UK. This might even help tackle a problem called the Riemann hypothesis, a proof of which is worth \$1 million. **Jacob Aron** ■



NASA EARTH OBSERVATORY/NOAA/NGDC/SPL

India, from where it aims to go

No viruses? No skin or bones either

Michael Slezak

NEXT time you have a cold, rather than cursing, maybe you should thank the virus for making your skin. Genes borrowed from viruses seem to give cells the ability to grow into tissues and organs, and even reproduce sexually. Without these genes, animals could not have evolved beyond simple blobs of cells.

Our cells often need to fuse with other cells, making big cells with multiple nuclei. They do this with the help of proteins on their outer surfaces that stick the cell's walls together and then break them open, so the insides can mix. This mixing is essential for the production of most organs – such as muscles, skin and bone – and even for reproduction, when eggs and sperm fuse. For instance, fused cells form barriers in the placenta that prevent harmful chemicals crossing into the fetus, and internal tubes like blood vessels are also made of fused cells.

But despite its importance, nobody knows how cell fusion evolved. That is partly because the proteins responsible are hard to spot. Only two types of cell fusion protein have been identified so far. The first was syncytin, found in 2000, which is essential for the formation of the human placenta. The gene for syncytin came from a virus (*Nature*, doi.org/c53gpbz).

Then in 2002, a second protein called EFF-1 was found. It helps form the skin of the roundworm *Caenorhabditis elegans*, which biologists often study because it is so simple (*Developmental Cell*, doi.org/cd7mcf). By 2007 it was clear that EFF-1 was one of a family of similar proteins, called FF proteins, after a similar protein called AFF-1 was also found.

Now Felix Rey of the Pasteur

Institute in Paris, France, has found that the FF family of cell fusion proteins also comes from viruses.

Rey's team figured out the 3D structure of the EFF-1 protein using crystallography and X-ray diffraction – the same kinds of techniques that were used to determine the structure of DNA in the 1950s. The structure of EFF-1 resembles that of a protein made by viruses, and the active part – which does the work of linking one cell to another – is virtually identical. Viruses use the protein to rip open the membrane of a cell, which they can then infect. In the worms, both cells must

have the protein before they can fuse, but the protein still works in a similar way. He presented his results at the Lorne Conference on Protein Structure and Function in Australia last month, and they have been accepted by the journal *Cell*.

Since EFF-1 is so similar to the viral protein, the gene for it almost certainly came from a virus that infected one of the worm's ancestors, says Rey. That is not unprecedented: the human genome is littered with DNA that slipped in when viruses infected a cell of an ancestor. But few of these bits of code are known to have important functions.

While EFF-1 has only been studied in *C. elegans*, Rey says many other organisms may use the same protein. Since syncytin is also viral, all the cell fusion proteins found so far are from viruses. Does that mean early

animals picked up all these proteins through viral infections?

"That's the gut feeling we have," says Fasseli Coulibaly from Monash University in Melbourne, Australia. "It's the most enticing hypothesis but as scientists we need to look into it. If this is true, that's a huge advance."

It is plausible that all cell fusion stems from viral genes slipping into our genome, says Elizabeth Chen of Johns Hopkins University

"If cell fusion really is a gift from viruses then they are responsible for complex multicellular life"

in Baltimore, Maryland. "But the jury is still out." Right now her team is trying to find the protein responsible for cell fusion in muscle tissue. It is too early to tell if it came from a virus.

The findings so far suggest a pattern, says Rey. If cell fusion proteins came from several sources, you wouldn't expect the first two found to be from viruses.

If viruses really did gift us cell fusion, then they are responsible for complex multicellular life, says Coulibaly. Cells could have clumped together into clusters on their own, but without the ability to fuse they could not have evolved into anything advanced like sponges, let alone humans.

"Before cells can make something like skin or a digestive tract – as soon as you are thinking tissue and organs – usually you need some kind of fusion," says Coulibaly. "If it's proved, it could be a Nobel prize."

Rey goes even further. He speculates that viruses may be responsible for the very existence of multicellular organisms. Viruses come and go between different cells, exchanging genetic information between them. "This makes me think that viruses have contributed enormously to the communication between cells, and to the appearance of multicellular organisms on Earth," Rey says. ■



We'd be nothing without viruses

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Paws for thought: dogs respond to calls just like us

LISTEN up Fido! The brains of humans and dogs respond in the same way to vocal sounds like laughter and barking. The finding suggests that our voice processing areas are inherited from a common ancestor.

Attila Andics of the MTA-ELTE Comparative Ethology Research Group in Budapest, Hungary, and his colleagues trained 11 dogs to lie in an fMRI scanner. As the dogs listened to nearly 200 human and dog noises, the team recorded brain activity. They also performed the same experiment on 22 humans.

Animals are usually sedated for scans. But recently,

better training has meant some dogs will lie still long enough to be scanned while awake. Andics is the first to compare humans and dogs in the same experiment.

Human and dog brains lit up in similar areas, centred on the temporal lobes, in response to the sounds (*Current Biology*, doi.org/rnb). Dogs responded more to dog sounds, and humans more to human sounds.

Andics says the results hint at a single evolutionary origin for the voice processing area of human and dog brains, dating back to at least 100 million years ago – the last time humans and dogs shared an ancestor.

But Clive Wynne of Arizona State University in Tempe offers an alternative explanation. “The brain is a highly plastic organ, and the dogs’ responses could just be the result of a lifetime listening to human voices,” he says.

Bomb tests reveal youthful brain cells

YOUNG brain cells have been seen in a novel location in the brain. The finding raises hopes that the cells could be utilised to help people recover after a stroke, or to treat degenerative brain diseases.

Last year, Jonas Frisén at the Karolinska Institute in Stockholm, Sweden, and his colleagues showed that brain cells younger than their owner turn up in the hippocampus,

a brain region crucial to memory.

They have now found that such brain cells also move to a golf-ball-sized structure called the striatum. This region is involved in a range of functions, including learning and memory. These particular traits, shared as they are with the hippocampus, lead Frisén to speculate that brain cells appearing here may also be involved in learning.

“New neurons may convey some sort of plasticity,” he says, which might help people learn and adapt.

To reveal the younger cells, the team exploited the fact that atmospheric levels of radioactive carbon-14 have been falling since nuke tests raised them up during the cold war. New cells incorporate this carbon-14, and its levels in the various cells of 30 donated brains revealed neurons that had been created during the lifetimes of the donors (*Cell*, doi.org/rm8).

Warmer world may slow the Atlantic

A **WARMING** world could slow the circulation of the Atlantic Ocean, triggering African droughts and faster sea level rise in Europe.

Eirik Vinje Galaasen at the University of Bergen, Norway, and his colleagues looked at deep-sea sediments from a site off south Greenland, which record short-lived climate shifts. During a warm period 130,000 to 115,000 years ago, the ratio of carbon isotopes in fossilised microbes shifted suddenly several times. That suggests abrupt changes in the circulation of deep water in the Atlantic (*Science*, doi.org/rnj).

If it happens again, European seas will rise faster. North Africa may suffer severe droughts, if the slow currents shift air circulation.

But it is unclear if such changes will happen soon, says Carl Wunsch at the Massachusetts Institute of Technology. We still know little about how ocean circulation varies over millennia, he says.

Alphabet to decode medieval text

LOST language, or gibberish? Some of the symbols in the 15th-century Voynich manuscript have been matched to sounds in an effort to decode it.

Earlier studies of the 240-page tome looked for patterns typical of a language. Stephen Bax at the University of Bedfordshire in Luton, UK, instead focused on single letters. He selected words that seem to label drawings of recognisable objects and compared them with the names of the items in various languages.

Knowing how these words are pronounced gave possible sounds for the different symbols making up the words. He then applied those to other labels, giving him 14 letters of a possible alphabet. The analysis is at bit.ly/1k37qvb.

Racial categories can be diluted

OUR race radar isn't fixed. People subconsciously identify others more strongly by how they work together than by their skin colour.

David Pietraszewski and colleagues at the University of California Santa Barbara introduced 1272 people to avatars that worked for one of two charities. Each charity had two white and two black avatars of the same gender.

The participants were first given 24 statements about charity work, each accompanied by the face of one of the eight avatars. Some hinted at the charity they worked for, whereas others were general. Next, the participants were shown just the statements and were asked to match them to the correct avatar.

In studying the errors made, the team could tell if people tended to confuse the correct avatar with someone of the same race, or with someone who volunteered in the same charity.

They found that the tendency to confuse avatars for someone of the same race dropped by half when the statements contained clues to their charity affiliation, compared to when they were general. This implies the participants categorised the avatars by their charity rather than their race, says Pietraszewski (*PLoS One*, doi.org/rnd). "It suggests that race is not a built-in, unchangeable feature of the mind," he says.



Quantum dewdrops produced for first time

A DROPLET of "electric liquid" can be squeezed from a semiconductor by shooting it with lasers. The quantum droplet is a new kind of particle that could help study how light and matter interact.

As electrons flow through a semiconductor, they leave behind "holes" – the absence of an electron. Holes are considered a kind of particle in their own right. Electrons can bind to holes, much as how an electron circles a proton in a hydrogen atom. Electron-hole pairs are called excitons, and they in turn can group to create quasi-

molecules called polyexcitons.

Mackillo Kira at the University of Marburg, Germany, and his team have taken this quasi-chemistry a step further. They found that certain collections of electrons and holes can have liquid-like properties, creating a quasi-particle they call the dropleton. "Our dropleton discovery adds a new element to the 'periodic table' of quasi-particles," says Kira.

The team produced the dropletons by firing a laser at a semiconductor, creating a large number of unbound electrons

and holes. When the laser has particular quantum properties, groups of these particles behave like liquids. Rather than binding in pairs, the electrons form circular waves around the holes, which are spaced similarly to how atoms are arranged in a liquid. Four electrons and four holes are enough to make a dropleton, and the team made them with as many as 14 of each.

They last for just 25 trillionths of a second, but that should be long enough to study them and their potential use in technology.

Electro-sock could replace pacemaker

PUT a sock on it. One day, you could have a silicone sheath put inside you that slips neatly over an organ to monitor health and treat disease. The transparent membrane is the first bendy implant that can cover the entire surface of an organ.

To make the prototype, John Rogers from the University of Illinois at Urbana-Champaign and his colleagues embedded 68 tiny sensors into a sheet of silicone that they fitted around a 3D printed replica of a rabbit heart. They then transferred this to a rabbit heart, kept beating outside the animal's body.

Comparing information from sensors on the sock to that captured by various imaging methods showed that the sensors could accurately detect the temperature and electrical activity of different regions of the organ (*Nature Communications*, DOI: 10.1038/ncomms4329).

Because the sock can contain electrodes and completely surrounds the heart, it could be used as an alternative to a pacemaker to help regulate heartbeat. Although human trials are a long way off, animal trials are planned in a few months' time.



Fanged frog is an evolutionary loner

FROGS might look cute, but some are lethal. The innocuous appearance of *Odontobatrachus natator* disguises a pair of fangs and a tendency to eat other frogs. It also belongs to a hitherto unknown group of frogs.

Michael Barej at the Leibniz Institute for Research on Evolution and Biodiversity in Berlin, Germany, and his colleagues wanted to find out which family *O. natator* belongs to. So the team collected wild fanged frogs from fast-flowing streams in west Africa and used molecular markers to assess their relationship to other frogs. To their surprise,

they found that the fanged frog's family split from other frogs some 100 million years ago, when dinosaurs still ruled the world (*Frontiers in Zoology*, doi.org/rms).

Finding a new animal family is rare. It is like discovering cats, which are all in the family Felidae. "The largest number of family descriptions go back to the 19th century," says Barej.

Frogs are an exception though, thanks to modern genetics. "The amphibian tree of life has been shaken up and reordered quite a bit," says Cameron Hudson of the University of Sydney in Australia.

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Altogether now, Mexican wave

Be part of the show

A system for getting Wi-Fi access to every fan at a gig or match gives a whole new meaning to the concept of audience participation

Paul Marks

EVERY fan in a packed sports stadium or music venue will soon be able to get bespoke content direct to their phones, thanks to a new wireless system that knows exactly where every person is sitting.

The system, developed by UK start-up Mobbra, will let organisers send football replays, backstage interviews with pop stars, or area-specific food deals direct to fans' phones. It will also encourage the audience to become part of the show.

Mobbra's technology forms part of a new wave of innovation in indoor positioning. For instance, last week, Google unveiled Project Tango – a phone with 3D sensors that can make a quarter of a million measurements every second to capture and map its position and orientation in any environment.

This means you will always know where you are. And so will Google, of course. Developers are due to receive their prototype Project Tango phones later this month to see what they can create with this data, such as turning the inside of your house into an augmented reality games world.

Meanwhile, Philips Research Eindhoven in the Netherlands last week launched a system that lets LED lighting in shops transmit position data to an app. Codes hidden in each LED's imperceptible flicker tell the app where the user is and so can steer shoppers to the right goods and, like Mobbra, alert them to special offers.

With Mobbra's system, dubbed Massivity, organisers can take control of fans' phones to create spectacular effects. For instance, the camera flashlight on each phone could be activated remotely, turning the crowd into a glittering star field. Or a team's

colours could sweep around the phone and tablet screens in the venue like a Mexican wave. A host of Premier League football clubs in the UK are investigating the technology and it is a strong contender for the in-stadium wireless tech at the 2015 NFL Super Bowl, Mobbra says.

These kinds of applications are possible because Mobbra has found a way to deliver Wi-Fi to

"You can't take a lighter to a gig these days to hold up – we can illuminate camera lights to great effect"

every user in a large crowd.

A typical wireless access point can supply just 50 connections – so unless a venue can afford to run an access point for every 50 or so people, Wi-Fi is not guaranteed. Even then, simple radio interference can destroy any chance of stadium-wide access.

"Some venues are spending millions on conventional Wi-Fi access points and finding it just doesn't work," says Will Walton, Mobbra's founder.

With Massivity, 500 users can log on at each wireless access point. Because Massivity is patent pending, some technical elements of the system are being kept secret. We do know it manages wireless connections in a more intelligent way: such as adding imperceptible delays to each user's internet access, a process known as time sequencing.

In a test, the Mobbra team charged up 1000 Samsung phones and used two Massivity access points to make them all stream and display the same video, vibrate at once and fire their flashes together.

The phone side of the equation is choreographed by an app called Fangage, which tweaks the phone's Wi-Fi settings. It will launch on the Apple and Android app stores later this month. During a game, all phones could vibrate to tell the crowd of a betting opportunity, or a special food and drink offer, says Walton. "You can have four streams of video, which could be replays or goals from other matches that are on at the same time. At gigs you'll get behind-the-scenes news and backstage interviews with the stars."

Health and safety rules mean you can't take a lighter to a concert these days and hold it up, he says. "But we can illuminate all the camera lights to great effect."

"If one seat block has spare hot dogs you can tell just those people they are on offer behind them," Walton says. Mobbra is in negotiations to provide its service to major gig promoter Live Nation, and also to Virgin's V Festival in the UK.

One London-based gig producer, who preferred to remain anonymous, is impressed by the possibilities: "It could turn every phone in the crowd into pixels of a massive screen so you could show pictures too." ■

Let the sun shine in

A device powered by the sun's rays could provide early diagnoses for a range of deadly diseases

Hal Hodson

THE power of the sun could spark a medical revolution. A device can diagnose diseases using little more than a smartphone, sunlight and a tiny DNA sample.

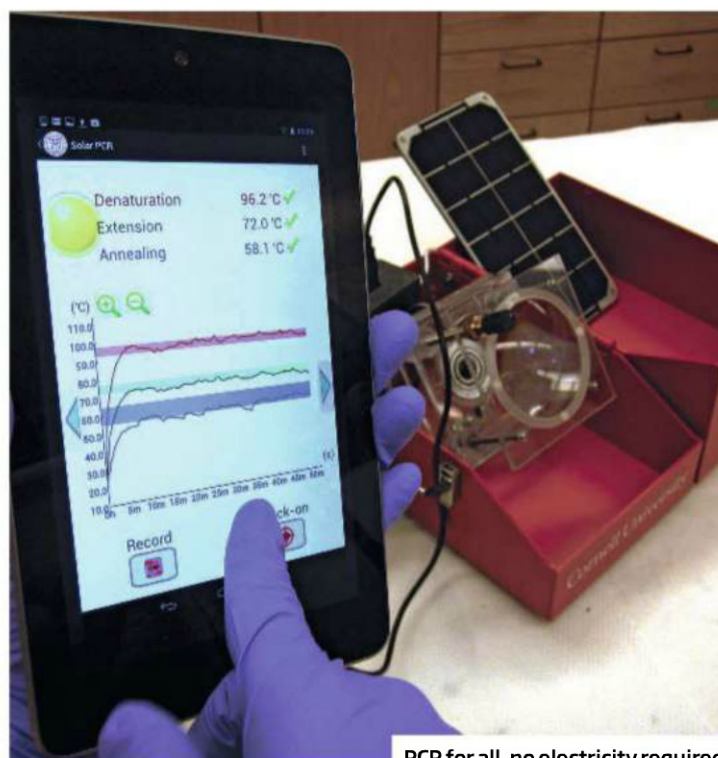
The KS-Detect, built by engineers at Cornell University in New York, will be used to diagnose Kaposi's sarcoma, the AIDS-related cancer that killed Tom Hanks's character in the film *Philadelphia*. Li Jiang and David Erickson, who developed the device, are testing it in Uganda, in partnership with Makerere University in Kampala.

Kaposi's sarcoma is one of the most common forms of cancer across sub-Saharan Africa, caused by a herpes virus that takes advantage of weakened immune systems. It kills between a fifth and a third of those it infects within a year – and up to 70 per cent within three years. Late diagnosis is one of the main

factors contributing to the low survival rate. Cornell's KS-Detect aims to change this.

Testing for the disease typically involves using the polymerase chain reaction (PCR) to amplify traces of the herpes virus DNA in the presence of a primer until there are enough copies to show up in a detector. But you need precision electronics to heat and cool the sample and drive the reaction.

The KS-Detect works without electricity by using a lens to focus the sun's rays into a disc of light where the edges are cooler than the centre. A long microscopic channel is etched onto a chip that is placed under the disc of light. The sample moves along this channel so that its temperature changes in cycles, alternating between the heat at the centre of the light disc, and the cool edges. This drives the PCR. A dye called SYBR Green glows under blue light if amplified DNA from the herpes virus is detected. A smartphone



PCR for all, no electricity required

controlling the chip then reads the results.

"We thought why not go straight to the source and use sunlight directly as heat, skip the electricity?" says Jiang. "That let us skip a lot of the components you need in normal PCR."

Francis Moussy of the World Health Organization in Geneva, Switzerland, is impressed. With such a device people can be tested where they live. "It's really important to bring diagnostics to

the patients instead of making the patients travel," he says.

Moussy, who works on new medical diagnostic technologies for the WHO, says the device can be adapted to detect other diseases. All that's needed is to change the primers so that different kinds of DNA can be amplified. "PCR is used for the detection of TB [and] can be used for many non-communicable diseases. It's a tool that's becoming more and more useful." ■

Turn your phone's Wi-Fi hotspot into a cry for help

AN APP that turns a smartphone into a wireless SOS beacon could one day help rescuers track down people who have been trapped in buildings after natural disasters or bombings.

Because such events often knock out phone and internet networks, trapped people cannot make calls, send texts or email for help. "They are in an island of non-connectivity," says

Amro Al-Akkad, an engineer with the Fraunhofer Institute for Applied Information Technology in St Augustin, Germany.

Then his colleague, Leonardo Ramirez, noticed that if his neighbours changed the name of their home Wi-Fi network, it doubled as an opportunity to send a message, such as "No smoking on the balcony". He realised that you could use an app to insert a short SOS message into the name field of a phone's Wi-Fi hotspot, too, as these can broadcast a radio signal without requiring internet access. Rescuers can then read the

message with their own Wi-Fi app.

The team consulted emergency workers from the Haiti and Fukushima disasters and developed a "victim app" and a "seeker app". "They wanted it simple, unencrypted and smart," says Al-Akkad.

With the victim app a trapped person can write a 27-character message such as "broken leg stuck in bank" or "need help fire on bus" and a

seeker app up to 100 metres away can pick it up. The app found two "trapped" people in a large-scale, simulated terrorist attack at a seaside chemical plant in Stavanger, Norway. The team will present the apps at a computer conference in Toronto, Canada, in April.

They hope the victim app will be incorporated in Android or iOS operating systems, but they are also patenting a way to distribute the app virally at a disaster scene. "We need this as no one expects to be in a disaster and won't download the app," says Al-Akkad. Paul Marks ■

"A trapped person can write a 27-character message such as 'broken leg stuck in a bank'"

A happy oyster is a big-data oyster

IN A pleasant spot on Tasmania's coast, Barilla Bay Oyster Farm has been growing and serving oysters for more than three decades.

But are their oysters as healthy as they can be? The farm is about to find out. Some of the oysters are having sensors the size of credit cards tacked onto their shells.

Farm manager Justin Goc says the information will help him make better decisions. The farm is one of a handful of places that have joined a trial organised by Sense-T, a government-funded project to build a sensor network across Tasmania. The project aims to link up several types of existing sensors, as well as install new ones, to create an agricultural database.

Sensor technology is now sophisticated enough to be able to monitor an oyster's heartbeat. The new sensors will do this, and also track whether the oyster's shell is open, which provides insight into the oyster's feeding habits. It will record how deep in the water the oyster has settled, and what the temperature and light levels are like down there. Meanwhile, separate sensors keep tabs on changes in the water's salinity, and overall temperature and oxygen levels.

All the data can be analysed in real time, so if an oyster's condition

changes, it will be possible to search for corresponding changes in the water. For the last six months, Sense-T physiologists have been analysing the sensors' output in the lab to figure out what combination of factors produce the best oyster.

"If we can start to use the data to predict how oysters have grown, that will be useful," says John McCulloch at CSIRO,

"The sensors will monitor the oyster's heartbeat and track whether its shell is open or closed"

Australia's national research agency and a partner in Sense-T.

For example, farmers must periodically take oysters out of their baskets to see how much they have grown. This process is time-consuming and disruptive. The hope is that a handful of strategically placed sensors could do the job instead.

Other Sense-T projects aim to make similar improvements with abalone, vineyards and cattle. "It's when you put it all together that the exciting stuff happens," says Ros Harvey, Sense-T director. "We can find better ways to use our resources – how to do more with less." **Aviva Rutkin ■**



Getting their own oyster cards

NICK RAINS/ALAMY

ONE PER CENT



Eco-friendly urinal disguised as plants

Is it a planter or a toilet? The PPlanter is both. It uses biofilters to treat urine without the harsh chemicals of portable toilets. Developers Hyphae Design Laboratory of Oakland, California, say it is odour-free as the urine and tap water feed into an air-tight tank; without air, urine doesn't produce smelly ammonia. The liquids are pumped into a biofilter containing bamboo, wood chips, straw and rock. The bamboo takes up the water and nutrients in the urea, while bacteria break down protein and carbohydrates. Last year, a PPlanter was tested in San Francisco and the city wants to install a second this year.

\$25

The cost of a smartphone designed for the developing world by Mozilla, creator of the Firefox web browser, as announced at the Mobile World Congress in Barcelona, Spain, last week

Bespoke ski boots, printed for you

Skiing is miserable if your ski boots don't fit, but being measured for custom insoles is pricey. British start-up Alprint is launching an app that lets you get bespoke 3D printed insoles by taking cellphone photos of your feet while standing on a printable paper calibration mat. The foot's dimensions are calculated from the photos and, with data such as the skier's weight, are used to create an insole that fits perfectly.

Organ-knitting robots

Multi-armed robots could one day knit together different human tissues to mass produce replacement human organs. Ibrahim Ozbolat of the University of Iowa used one robot arm to draw 3D patterns with strength-giving filament-like cells, while another robot arm filled the gaps between the filaments with cartilage progenitor cells (*Robotics and Computer-Integrated Manufacturing*, doi.org/rnh).

ANASTASIA VICTOR

ButtonMasher Multiplayer games

Play with the crowd

Tens of thousands of people are all trying to control the same game. **Jacob Aron** finds out why

LEFT, left, left! I am trying to play a game by typing commands, but my character won't obey. That's because, at the moment, there are 67,000 other people all trying to control the same character. We are part of Twitch Plays Pokémon, in which tens of thousands of people attempt to play a single version of a classic video game. It started as a quirky experiment, but may have revealed a novel way to play.

The popularity of video-streaming site Twitch has soared in the past few years as a way for people to broadcast their game-playing experiences. The software is built into the recently

released PlayStation 4 and will soon be added to the Xbox One.

Viewers are normally passive, restricted to a chatroom beside the video, but one Twitch user has set up a stream taking commands from the chat. Observers enter words like left or right that are then fed into a copy of *Pokémon Red*, a single-player game which involves capturing creatures that fight battles. In the past two weeks, as many as 80,000 players at a time have worked together to advance the game. Progress is very slow – it has been half an hour and we are still stuck in the same battle – and hindered by

some people deliberately inputting unhelpful commands. Even so, players were 75 per cent of the way through as *New Scientist* went to press.

Pokémon Red doesn't require quick reactions, making it well suited to this style of play. Could the stream's popularity lead to a new genre of collaborative games? Copycats using other games have already sprung up on Twitch, but none has seen the success of Twitch Plays Pokémon. "You can put practically any game in and it'll be controllable from chat, but there's a good possibility you'd end up with something that doesn't provide a good experience," says the stream's creator, an Australian programmer who prefers to stay anonymous.

Jeffrey Bigham of Carnegie Mellon University in Pittsburgh, Pennsylvania, who studies how crowds can perform complex, real-time tasks such as video captioning, might have a solution. Last year, Bigham and his colleagues looked at different ways for many people to control a single game. One method gives sole control of the game to the player whose inputs match the majority most often. But, crucially, the player doesn't know they are in charge. "That elected leader can act out the crowd's will in a very consistent and real-time way," says Bigham – and if the crowd's mood

changes, a different leader is picked.

Bigham suggests this scheme could be adapted to create a game within a game, where people watching an expert player's stream could join in. For example, observers could attempt to play the game like the expert and be

"As many as 80,000 players at a time have worked together to advance the game"

scored on how well they match.

Octodad: Dadliest Catch, a game in which players control an octopus pretending to be a human, takes a different approach. Four players each control a limb – to hilarious effect, says Phil Tibitoski of game-developing team Young Horses. Inspired by the success of Twitch Plays Pokémon, the team is now considering its own crowdsourced game in which the audience acts as a "Dungeon Master", deciding what players will experience. Another developer, Sean Hogan, is letting Twitch users collaborate to build levels in his game, *Even the Ocean*, by adding or removing blocks using chat commands. "The larger streaming and YouTubeers become, the more room there is for this to grow," says Tibitoski. "I don't think it's going anywhere soon." ■



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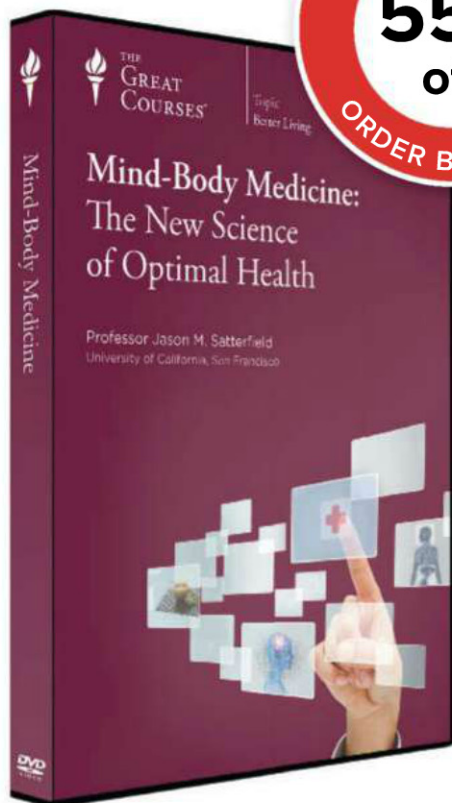


Twitch Plays Pokémon
7d 10h 13m 21s

Anarchy [Progress Bar]

Pietrek1020
Jake40208
T harps
Alexia267
Earth spirit
Thoe kmfse
Unseenline
Supplican
Nikos717
Afrothunder87
Spamaaaaabot4
Mudshroom
Pertsnae
Kadajski
Parlosno
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The king of Svalbard

BEFORE J. R. R. Tolkien was dreaming up hobbits and constructing languages for elves to speak, he worked at the Oxford English Dictionary, where he was assigned words beginning with W. "Walrus", Tolkien proposed, came from the Old Norse *hrossvalr*, meaning "horse-whale".

This is unlikely to be foremost in your mind if you happen across one while swimming off Svalbard in the Arctic Ocean. That's what happened to photographer Paul Nicklen - though Nicklen, who grew up among Inuit in the Canadian Arctic, was in the water with the express aim of finding the beasts.

Walrus live for some 30 years in the wild and are huge - males can reach 3.6 metres long and weigh 2000 kilograms. They cluster in their thousands on beaches and have remarkable, metre-long tusks. Both sexes have the monster teeth, used by males for fighting. Walrus have few natural predators; only an orca or a polar bear would even try and take one on. If you did ever get this close, you might smell their breath - notoriously bad, apparently, from a diet composed mainly of clams. Rowan Hooper

Photographer

Paul Nicklen National Geographic Creative
paulnicklen.com





Mercy for all?

Belgium is the first nation to allow euthanasia for children of any age. Other countries should face up to the issue, says **Rachel Nuwer**

EUTHANISING an infant is not technically difficult. Intravenous sedatives are used to silence the brain, followed by a pain medication such as morphine. This is often enough to trigger respiratory arrest and death, but if not, neuromuscular blockers are added, and the child dies. The process takes 5 to 10 minutes.

"This is strange to say, but it happens in a peaceful manner," says Eduard Verhagen, who is head of the Department of Pediatrics at the University Medical Centre in Groningen, the Netherlands, and also a lawyer.

Neighbouring Belgium has just become the first country to legislate in favour of child euthanasia at any age. However, there is a partial precedent. In 2005, the Netherlands recognised the Groningen protocol, a set of criteria outlining the circumstances under which ending the life of an infant under the age of 1 is permissible.

Under those guidelines – which were written by Verhagen – euthanasia can only be undertaken if an infant's diagnosis and prognosis are certain and confirmed by an independent doctor; there is evidence of hopeless and unbearable suffering; both parents give their consent; the procedure follows medical standards; and all details are documented.

Before this, there had been an estimated 10 to 15 cases of infant euthanasia in the Netherlands each year between 1997 and 2004, but only about a fifth were reported. Doctors did not want to risk a murder charge. Now, while



euthanasia remains technically illegal for infants in the Netherlands, doctors are not prosecuted so long as the protocol's criteria are met.

Opponents argued that this would lead to a slippery slope of infant euthanasia. The opposite happened. Since 2005, there have been only two cases in the Netherlands. Both involved babies with lethal epidermolysis bullosa, a disease of the connective tissues.

This decline in euthanasia correlates with an increase in late-term abortions. Previously, most euthanasia cases involved babies born with severe to extreme spina bifida – a congenital disorder in which some of the vertebrae do

not fully form. Doctors found that surgery was not possible and that the child would suffer constantly. In 2007, the Netherlands began offering free ultrasound scans at 20 weeks of pregnancy, at which point spina bifida can be detected. Mothers whose babies are diagnosed with the disease can then decide whether to terminate the pregnancy.

This is not necessarily the best course for everyone in this situation. Only the most extreme cases of spina bifida are deemed

"Rather than draw out the inevitable, would it not be less cruel to swiftly end a child's suffering?"

hopeless, and it is impossible for doctors to precisely gauge severity in utero. Having infant euthanasia as an option allows mothers to be sure that their baby has no chance of survival before ending its life. But, as Verhagen says, in practice most in this situation decide not to take any chances and terminate the pregnancy.

The means of ending a baby's life are subject to debate. Recently, the line between proactive palliative care – applying pain medications that may hasten death – and euthanasia has become more blurred. In some countries, including the US, food and fluid may be withdrawn in some circumstances.

But palliative care practices do not necessarily result in a quick death for a terminally ill infant. Death by dehydration and starvation can take days or weeks and it is impossible to guarantee that the child – even heavily medicated – does not suffer. Moreover, no one doubts that death is the outcome of withholding life-sustaining care and support. Rather than draw out the inevitable, would it not be less cruel to swiftly end that life, alleviating all risk of unnecessary suffering?

Belgium and the Netherlands have chosen to face this dilemma directly. There are anecdotes – stories that come up in quiet, informal conversations between professionals – of infant euthanasia in other countries, but in most places publicly admitting to it is tantamount to admitting murder. Grief-stricken parents faced with the impending death

of their baby and who do not happen to live in the Netherlands or Belgium can do little more than stand by and try to make their child as comfortable as possible as death approaches.

Of course, not every country is as progressive. In the Netherlands, there is a culture of consensus-finding and frank discussion.

"Some of us wish to at least have a vote in how we die." That's how Verhagen puts it. Eventually, the conversation extended to the right of parents to choose how their baby will die.

Even there, though, euthanasia is not an easy subject on which to reach a consensus. The Netherlands debated it for more than 20 years, and there are further debates to be had. Unlike in Belgium, Dutch children aged between 1 and 12 cannot be euthanised under any circumstances, although Verhagen and others are working to change that.

There will always be those who – due to religious or personal beliefs – oppose ending a human life. In the US, for example, reaching a federal consensus on the subject of infant euthanasia seems unlikely. On the other hand, progressive states such as Oregon might someday implement their own laws on it, much as they have for assisted suicide in adults. Whether this will ever come to pass remains to be seen. As Verhagen wrote in *The New England Journal of Medicine*, "This approach suits our legal and social culture, but it is unclear to what extent it would be transferable to other countries."

For most parts of the world, a refusal to even discuss the subject dominates. As unpleasant as it is, parents, physicians, hospitals and nations need to confront this issue as a matter of responsibility towards both infants born into hopeless circumstances and their families. ■

Rachel Nuwer is a science writer based in New York

ONE MINUTE INTERVIEW

War against sexual violence

In the war zone of DR Congo, sexual violence is shockingly common. Surgeon **Jo Lusi** is fighting to change that



PROFILE

Kasereka "Jo" Lusi is an orthopaedic surgeon. With his wife Lyn, he co-founded HEAL Africa, a hospital in the Democratic Republic of Congo that provides reconstructive surgery for women who have been raped, as well as other medical care

At your HEAL Africa hospital, you treat women who have been raped. What made you open it?

In the early 2000s, my wife Lyn and I became concerned with the plight of women during the two civil wars and continued armed conflict in eastern Congo. Women pay the highest price during such violence. We couldn't stand by and do nothing, so we did something.

What types of injuries can rape cause?

A common injury is a tear, or vaginal fistula, which can leave women unable to have children or control their bladders. As well as the physical toll, there is a social and emotional impact. Many women are rejected by their families and communities – even their husbands.

Has the recent end of the M23 rebellion in DR Congo meant a decrease in sexual violence?

It has provided a window to see deeper into forest villages, where we find even worse atrocities. And although the war of the M23 rebels has ended, there are still 20 other militias terrorising people

in the jungles of eastern Congo. Women are also being raped by soldiers of the Congolese army.

What drives this violence against women?

In our culture, when one tribe invaded another's villages, rape was used as a method of humiliation and provocation, to victimise the other tribe. It was a way to insult the vanquished; to show them you are more powerful than they are.

How are you working to fight this practice?

We have to change the negative attitude of our men. Many believe that in order to prove that you're a man you have to rape a girl. In the rural areas we have 150 trained community counsellors working to change this.

We also provide safe houses and treat the physical injuries of those who have been raped. We offer legal counselling and opportunities for women to learn to read, write and acquire other important skills they can use to generate an income. And we give micro-grants to help the women and their families start businesses. Africa can't develop without women.

Has this work ever endangered your life?

Yes, every day we need protection. When the civil war was going on, I heard about threats to my life. I have even confronted those who want to kill me.

What motivates you to keep going?

In 2002, Lyn and I met a woman called Sakina whose husband had been killed. She ran away to a neighbouring village with her three children. There she was brutally raped by five men – who used the barrel of a gun. I could not imagine a human being doing something so inhumane and brutal to another. So I decided to do something. She was my first fistula patient. I find myself with tears in my eyes treating women. It is a labour of love.

My other motivation is my wife Lyn. She died of cancer recently, but I do this work in her memory. She was the driving force behind the hospital. And she is the one who told me, "nobody is fit to live until they've discovered what is worth dying for".

Interview by Curtis Abraham

Grow your power source

Biological engineer **Angela Belcher** is using viruses to help create batteries that are better for the environment. She tells **Katia Moskvitch** how she's harnessing evolution to solve modern problems

You're making batteries using viruses - don't they normally make us sick?

When people think of viruses, the flu often comes to mind. But there are also viruses everywhere, from in the ocean to inside the gut, that infect bacteria. Those are not harmful to humans. Viruses are basically genetic material with a protein coat. They need a host so they can use its molecular machinery to make copies of themselves.

The main virus I work with has a single strand of DNA in a protein coat and it is completely benign. It only infects a particular bacterial host – and doesn't kill it, just slows it down as it uses the host to replicate itself.

How did the idea to use viruses to grow materials for batteries first occur to you?

I was inspired by how the abalone marine snail makes its hard shell using minimal organic material. It uses proteins to guide the incremental development of calcium carbonate in a geometric pattern. That gave me the idea to try to use biology to work with more than just the usual materials. A virus is a beautiful example of self-assembly of an ordered protein structure, and it's also easy to manipulate genetically.

Why do we need new types of batteries?

Most of us use rechargeable batteries in our everyday lives – in cellphones, computers, hybrid cars and more. The main type on the market are lithium-ion batteries, which require highly reactive compounds to manufacture and take an environmental toll.

As we try to increase the amount of energy that can be stored and make batteries rechargeable for more cycles, not just any material will do: we need ones that are more abundant and more environmentally friendly. As you know, you can't just throw a traditional battery away because many of the materials

currently used, including cadmium and lead, can be toxic to the environment. That's why we are focusing on rechargeable bio-batteries.

How do you actually make these bio-batteries?

To test if it would be possible to use a virus to grow materials for electrodes, I started with a tiny virus called the M13 bacteriophage, which has a long, tubular shape.

By inserting a specific gene, we spurred the virus to produce a protein coat that binds with compounds such as cobalt oxides and iron phosphates. The virus is long and tubular, so we were able to grow nanowires with these compounds, which we used in an electrode for a prototype lithium-ion bio-battery.

Once you proved it was possible, how did you improve on these bio-batteries?

We improved the power performance of electrodes made from iron phosphate nanowires by finding a genetic sequence for a virus that favourably binds to carbon nanotubes (CNTs), which are highly conducting (*Science*, vol 324, p 1051). To do this, we started with a billion different viruses and forced them to interact chemically with the CNTs – simply by mixing them in a test tube.

How did you narrow it down from a billion?

We selected the viruses that attached to CNTs, maybe a thousand of them, and washed the rest away. We then isolated those viruses and made copies of them by putting them into a bacterial host through infection – the normal virus-bacteria interaction. Next, we repeated the CNT-binding process with our selected viruses and chose the ones that bonded best to the CNTs.

What distinguished the most useful virus?

We were looking for the survival of the fittest, the one virus out of a billion that could develop a strong and specific interaction

PROFILE

Angela Belcher is a biological engineer and materials scientist at the Massachusetts Institute of Technology. She is developing bio-batteries using viruses to shape the growth of inorganic conductive materials



to not only coax iron phosphate nanowires to grow into a particular shape, but also to serve as a type of glue to bond those nanowires and CNTs, resulting in a more conductive composite.

Once we found the specific virus to bind the conducting material strongly, we again created copies and coated them with the nanowire compound – in this case, iron phosphate. Then we dried these composite nanowires, which incorporate iron phosphate and CNTs, and put them into a battery. The end result looks like a regular rechargeable



We have recently been working on lithium-air batteries, which are powered by reactions with oxygen in the air. We have demonstrated that we can greatly improve a lithium-air battery's charge-storage capacity by using our genetically modified viruses to build nanowires to use in the battery's cathode (*Nature Communications*, doi.org/rkr). This is because the virus-built nanowires have a spiky surface. Compared with wires made using traditional chemical methods, our spiky ones have a bigger surface area across which the electrochemical activity happens as you use or charge a battery.

How well do your different types of batteries work, compared to what's now available?

Our bio-batteries are still experimental. We have been able to demonstrate really great performance but at the moment they don't have the lifetimes to compete with commercially available batteries. We can only

"We hope to use viruses to power everyday electronics - and the cars of the future"

power small devices such as flashlights, laser pointers, watches and LED lights. For devices like cars and computers, which require significantly more energy and longer usage time, we would need to improve the power performance first.

We also want to make them rechargeable for thousands of cycles. Currently, we have batteries that are rechargeable for hundreds of cycles. Our eventual aim is to use viruses to not only power our everyday electronics but also the electric cars of the future.

How do you dispose of bio-batteries when they can no longer hold a charge?

The ultimate goal is to make them completely biodegradable. Our batteries are already greener because the materials we use to make the electrodes, including iron or manganese-based materials, are benign to the environment, unlike many of the materials currently used, such as cadmium and lead.

What other types of problems might viruses help us to solve?

Biology is very good at solving problems through selection and evolution, so there is great potential when we apply biology to problems that are not normally seen as biological problems. Why not try to use evolution to come up with new solutions? ■

battery, but either one or both of the electrodes are grown biologically.

Can you explain the advantages of building batteries from viruses?

A great thing about using viruses is that we can work with them at low temperatures, even at room temperature in some cases.

Another big advantage is that viruses are pliable. By changing the genetic code, we can make the same virus bind to different materials at once, and in this way make nanocomposites with a variety of properties.

It can be really hard to control things on the nano scale, but at that level you have the advantage of being able to introduce new properties not available with larger materials.

You've been making these prototypes for some time. What's the latest?

A typical battery has a cathode, an anode, an electrolyte that charged ions flow through and a separator to keep the two electrodes apart. When the positively charged lithium ions move from the anode to the cathode during cell discharge, an electric current is produced.

BOB O'CONNOR

Robot love

From John Brown

Your leader on getting hitched to robots was quite right: "The love for a robot may become a love that dare not speak its name" (15 February, p 5). But first we need a name to avoid mentioning. How about "automating"? The robot itself (herself? himself?) could then be an automate. And presumably give you a lovebyte. *Long Buckby, Northamptonshire, UK*

From Ellis Pritchard

In your Cure for Love special, the juxtaposition of having a religion grappling with robot ethics



(15 February, p 24), drugs to help cope with break-ups (p 26), and people marrying computers (p 29) poses a question. Will we need to develop an equivalent to the anti-love pill for android companions to take when they are inevitably dumped for the latest model? *London, UK*

Not so fast

From David Whitehouse

China has had considerable success in its crewed space programme. However, in your article on the rise of China as a space superpower you quote Richard Holdaway, the Rutherford Appleton Laboratory Space division director, as saying that the country is "progressing a lot faster than the US did with theirs

in the sixties" (15 February, p 42). This is disputable.

China launched a crew of two and then three about a year earlier than the US did, following their respective one-man orbital missions. However, the US was substantially faster in achieving its first space docking, with Gemini 8, taking only four years and one month after its first crewed orbital flight, whereas China took nine years.

The US landed a man on the moon seven years and five months after John Glenn became the first American to orbit Earth in 1962. If China had moved as fast, it would have put someone on the moon in March 2011. *Farnborough, Hampshire, UK*

Rare meat

From Paul Henson

The best way to save an endangered species – such as the black rhino, which was the subject of your story on permitted trophy hunting to raise conservation cash (18 January, p 4) – is to farm it.

This also removes the dangers associated with the trade in rare animal parts, provides breeding stock to release into the wild for conservation and sustainable hunting, and helps emerging economies. Pygmy elephant burger, anyone?

Taupo, New Zealand

Dangerous minds?

From Jonathan Fanning

In his letter (1 February, p 32) about Michael Brooks's call to create agile minds rather than ever more science graduates in the UK (21/28 December 2013, p 38), Derek Williams points to the teaching of "thinking" in schools in Venezuela and wonders what we can learn from this. Free-thinking Venezuela has led the revolt against international capitalism, and has advocated wealth redistribution and enhanced government service

provisions. It is extremely unlikely that Conservative MP and education minister Michael Gove will be proposing the introduction of the same sort of education in the UK.

York, UK

The drugs do work

From Geoff Searle, consultant psychiatrist

Clare Wilson's article highlighted the usefulness of talking therapies in treating schizophrenia (8 February, p 32). I fully support the UK's National Institute for Health and Clinical Excellence guidelines in offering psychological treatment to those with a psychotic illness such as schizophrenia. However, Wilson's article portrays psychiatrists as uncaring brutes forcing ineffective drugs on vulnerable patients. Not only is this stigmatising, it is also untrue and the quoted evidence is weak.

I am very aware of the benefits and side effects of antipsychotic medication and work tirelessly to improve the balance between the two, but many people with psychosis cannot manage without pharmacological intervention, and such articles make it harder to persuade them to accept helpful medication. Psychological treatment is a useful tool but not the whole answer.

Bournemouth, Dorset, UK

From David Rigby

Wilson's article does point out some interesting initial evidence against the long-term use of antipsychotics in schizophrenia. However, I rather feel that it overstates the benefit of avatar-based therapy to reduce distressing voices. She says the "approach helped 15 out of 16 people in the study". It is important to note that 26 people were recruited for the study, but 10 dropped out because they found the approach too distressing. Although avatar



therapy may be useful, it is still in its infancy, and will only be suitable for certain patients. *London, UK*

Glorious mud

From Scott Baker

Instead of Australia dumping millions of tonnes of sludge onto their Great Barrier Reef so they can export more coal to be burned (8 February, p 7), why don't they send it to an island country that needs it because of rising sea levels caused by climate change, such as Tuvalu in Polynesia? If the sludge is as harmless as they say, the Tuvaluans should appreciate this gift. Australia might even get the world community to help sponsor it to preserve the islands. *New York, US*

Green umbrella

From Hugh Thorpe

Stephen Battersby attributes increased boggiess in Europe to the removal of forests thousands of years ago (11 January, p 46). He argues that reduced evapotranspiration, whereby trees take water from the ground and return it to the air via their leaves, led to wetter soils and bogs.

This is a well-recognised phenomenon, but may be only part of the reason. Another process at work is interception, when rain sticks to foliage and evaporates. Remove the trees and the soil gets wetter.

This is happening in parts of semi-arid Australia. Removal of natural scrub over many decades has allowed more water into the soil, raising the water table. Unfortunately, the subsoil is heavily saline so the rising water brings salt to the surface and remaining vegetation dies.
Christchurch, New Zealand

Eats, shoots

From Subramaniam Divakaran
In her discussion of excrement-eating pitcher plants in Borneo (1 February, p 43) Stephanie Pain suspects the many species of *Nepenthes* may still have a few surprises in store. Here's one possibility: I wonder if the juices they produce have a laxative effect to promote output?
Euless, Texas, US

Blighted lives

From Claire Manson
Your leader highlighted that deaths caused by medical errors, adverse drug reactions or hospital-acquired infections are the third leading cause of mortality worldwide (25 January, p 5). To these "iatrogenic" deaths we can add many people whose lives have been blighted by non-fatal iatrogenic impacts.

For example, I have been profoundly affected by the drug DES – diethylstilbestrol, a synthetic oestrogen given to many millions of women during pregnancy from the 1940s to 1970s to reduce risk of miscarriage, but which turned out to cause health problems in many children of those who took it. The problems caused by DES took 20 years to come to light. Some called it "the silent thalidomide".

You could say I got off lightly – I was rendered infertile but have not had the vaginal and breast cancer it has caused in some DES daughters. DES has been a scourge through my life and threatens still

with further unknown health difficulties. My DNA has been changed by vested commercial and political interests.

In addition, DES did harm in people through its use in livestock as a growth promoter. Although DES is no longer used for this, oestrogens in our food chain remain a concern, an issue summed up well by US environmental historian Nancy Langston (*Environmental History*, vol 13, p 41).
London, UK

Batting for bats

From Alan Wellings
As a former bat ecologist I thought your article on diseases carried by bats (8 February, p 44) unnecessarily demonised these animals, which already get a bad press. What next? "Humans: nasty



carriers of millions of diseases, avoid", or "birds: flying bags of flu virus: don't touch"? All animals are disease vectors and many diseases carried by other animals are transferable to humans.
Mount Albert, Ontario, Canada

Back to Africa

From Don Martin
With hindsight, it seems obvious that there might be Eurasian genes in populations in the south of Africa once thought to be genetically isolated (8 February, p 10). The idea of these people being totally isolated before

European contact was too parochial. Three thousand years ago, advanced civilisations had been flourishing in the Middle East for millennia, and although the Atlantic was not accessible to them, coastal travel along the east of Africa seems likely.

Certainly by 900 years ago, with the Crusades under way and spices being traded from India, there must have been a lot of travel down the east coast of Africa, and it is not surprising that Middle Eastern genes might be found throughout.
Toronto, Canada

From Nick Hilliard
There is some historical evidence to support the theory that European DNA made its way into southern African tribes at the time of the Roman Empire. Around 450 BC, ancient Greek historian Herodotus wrote in the *Histories* that King Necho of Egypt ordered a ship to sail around Africa, and that it returned two years later.

Herodotus was sceptical about the story's claim that when the ship was off the southern tip of Africa, the sun shone from the north. Inadvertently, this scepticism provided strong supporting evidence that the full two-year voyage did happen. It would strain credulity to suggest the sailors remained celibate for the duration.
Dublin, Ireland

Going cheep

From Bob Masta
Kate Douglas looks at how a bird that was bred for its plumage came to sing intricate melodies composed of many phrases (8 February, p 36). For me, the most plausible explanation is that, intentionally or not, the Bengalese finch was bred for song as well.

Breeders probably weren't selecting for plumage alone, but for overall aesthetics. This would

involve subjective judgement of multiple traits. Even if a breeder intended to select solely on plumage, better singers would still have an advantage over birds with comparable visual appeal. And note that unlike selection for weight, which might plausibly be done in hatchlings, selection for plumage would involve "breeding plumage", by which time the birds would also be singing.
Ann Arbor, Michigan, US

Sup this

From Kit Devine
If you are struggling to find a non-alcoholic drink for adults to savour (1 February, p 32), I highly recommend soda, lime and bitters. Tasty and not too sweet.
Bronte, New South Wales, Australia

For the record

■ **Sugar-free.** Researchers at the Indian Institute of Science used a labelled amino acid, not a sugar, to study the relationship between ants and the *Humboldtia brunonis* tree (15 February, p 18).

■ **In our look at robot romance, we wove in an inaccuracy.** Dan O'Hara at Birmingham City University, UK, was a consultant for a company that designed the online bot Weavr, rather than its designer (15 February, p 29).

■ **Double ouch in our pain genetics story** (8 February, p 12). It was the *TRPA1* promoter gene, not *TrypA1*, and this was also the only one of the nine genes identified that showed the correlation between higher pain sensitivity and higher methylation level.

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The story in the stones

How did a simple ape become the smartest creature on Earth? **David Robson** chips away at the truth

SPARKS fly as stone meets stone, and shards of rock ricochet off the furniture around me. Each strike makes me flinch, but Bruce Bradley is the picture of cool concentration as he chips away at his axe head. It is, after all, a skill he has been honing since before he can remember. "I was a natural born flint-knapper. Laugh at that if you want, but I've got video to prove it." As a baby, he says, he was often seen banging two rocks together in his parents' garden. Then, when his family moved to Arizona, he developed his talents by copying the Native American arrowheads scattered across the desert.

Decades later, Bradley makes stone tools spanning the breadth of human history. His workshop at the University of Exeter, UK, is full of this handiwork. Piles of rocks line the walls, and to one side a deerskin with a dark stain hangs on a wooden frame. It was butchered using some of his team's handmade tools, he tells me. "We've got a freezer out there full of dead parts – you could eat them if you wanted."

My interests lie elsewhere. The stone tools on the table in front of me are not just useful, they tell the story of our journey from simple ape to thinking human. Previous attempts to trace the history of the mind have relied on speculation as much as hard evidence but, over the past three years, Bradley's Learning to be Human project has taken a more precise approach to looking inside the heads of the people who made these tools. Combining findings about stone-tool construction with neuroscience, psychology and archaeology, we can now estimate the origins of distinctly human mental abilities, such as when we first began to order our thoughts and actions, when our visual imagination blossomed, when we

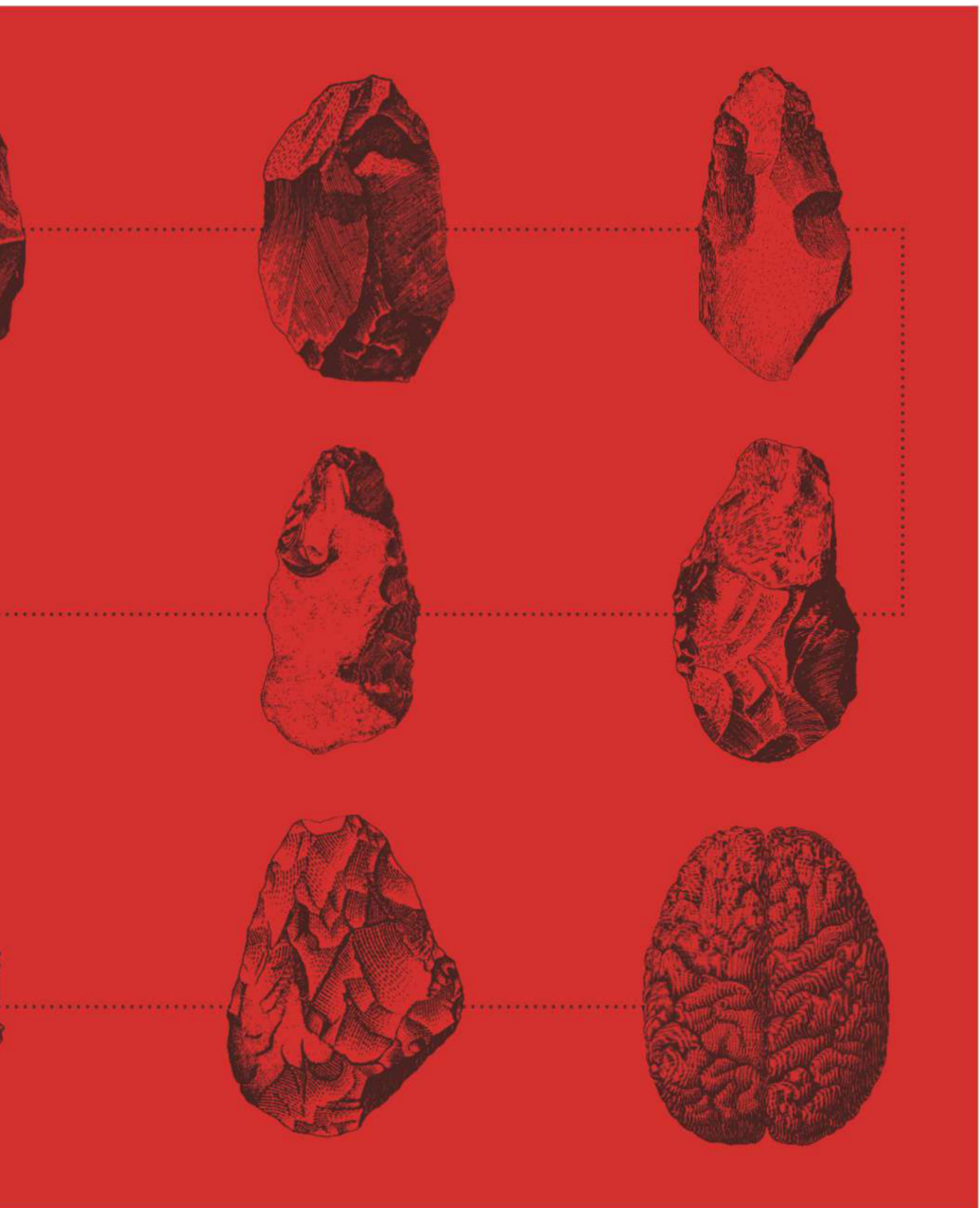
started to think about the past and future, and when we first played make-believe. There are even hints about the emergence of our capacity for patience, shame and suspicion – and the nature of our ancestors' dreams.

People have long sought a "secret ingredient" unique to human intelligence that could explain our extraordinary cognitive abilities. Most recently, the spotlight has fallen on size – the idea that a big brain is the key. However, it is becoming increasingly clear that there is no secret ingredient. Instead, our peculiar way of thinking results from a reorganisation of the different brain regions, as much as from their expansion (see "Size isn't everything", p 38). What's more, this began long before we diverged from chimps, around 6 million years ago. Indeed, comparable but more modest changes can be seen in many of our nearest relatives. "In a way we're just an extreme great ape," says Jeroen Smaers at Stony Brook University, New York, who last year compared the brain evolution of 17 species of primates.

So what accelerated this evolution in our ancestral line beyond what was happening in other apes – and how did this give rise to new ways of thinking? Only by re-examining the archaeological record can we map out that path. And that's why I am in Bradley's workshop.

He pauses in his work to show me three stone tools. The first and crudest of them is a jagged rock that signals perhaps the first landmark moment in that journey. Aside from walking on two legs, our earlier ancestors were distinctly ape-like, and like chimps and other primates, they probably had limited tool use, picking pebbles off the ground to crush nuts. But things change about 2.6 million years ago, with *Australopithecus garhi*. Rather than just using nature as they found it around them, ➤





2.6 MILLION YEARS AGO

OLDOWAN TOOLS

Australopithecus garhi

- Dexterity
- Motor control
- Modification of nature

"I'm willing to bet there would be no consciousness on this planet if we didn't have flakable rocks"

2mya

1.6 MILLION YEARS AGO

ACHEULEAN TOOLS

Homo erectus

- Hierarchical thinking
- Planning
- Complex emotions

Skills used to produce stone tools reveal the minds of their creators

Sweet dreams

Until about 2 million years ago, human ancestors probably settled for the night in trees. Some psychologists have proposed that the sensation of falling that we sometimes feel when we drop off is a remnant of an early warning system that stopped us descending so deeply into sleep that we ended up on the forest floor. Dozing on branches is likely to have ended with *Homo erectus*. "At 6 feet and 140 pounds, it was way too tall and heavy," says Frederick Coolidge at the University of Colorado in Colorado Springs. Instead, *H. erectus* slept on the ground, and this, Coolidge suggests, resulted in a great leap in cognition.

A more peaceful night's slumbers, without the constant risk of falling from a branch, would have allowed *H. erectus* to spend longer in rapid-eye-movement sleep and slow wave sleep, says Coolidge. These stages are known to be crucial for the consolidation of memories and associative thinking, and that's not

Our ancestors stopped napping in trees when they became too big

all. "It probably allowed many more creative dreams," he says. These could have had an impact on waking life.

Coolidge even speculates that the idea of the leaf-shaped Acheulean hand axe - a complex tool that signals a new way of thinking (see main story) - might have come to a *H. erectus* knapper in one of those dreams.



they began to modify it, wielding one stone to chip the end off another and using the resulting sharp edge to butcher meat.

The idea of using one tool to create a more useful implement is itself a conceptual leap. But just as important is Bradley's discovery that it takes a dexterity and motor control not seen in other apes to create the jagged Oldowan-style tool in front of me. This includes coordinating your limbs so that one hand is doing a different job from the other. "You need one hand for support, one for striking," says Nada Khreisheh, Bradley's colleague - movements that chimps struggle to master even with training. If such bodily control seems like more of a hop than a leap, consider all the new opportunities it opened up - including the creation of better tools - that would reward increased intelligence, accelerating our evolution compared with the other apes. "I'm willing to bet there would be no consciousness on this planet if we didn't have flakable rocks," says Bradley.

Even with that trigger, our ancestors were slow to progress. Things didn't begin to take off until *Homo erectus*, about a million years later. *H. erectus* is significant for many reasons. As well as having broadly similar bodies to modern humans, they lived in

600,000 YEARS AGO

AXES, CLEAVERS, SPEARS

Homo heidelbergensis

- Language
- Sense of self
- Visual imagination
- Emotional control
- Symbolism

200,000 YEARS AGO

Homo sapiens

- Awareness of past and future
- Creativity
- Hypothetical thinking
- Improved memory

300,000 YEARS AGO

LEVALLOIS TOOLS

Neanderthals

- Advanced hierarchical thinking
- Tuition
- Patience

bigger social groups than their predecessors. Successful communal living requires cooperation and the ability to detect and punish cheats who try to get something for nothing. According to Eva Jablonka at Tel Aviv University in Israel, those challenges may have spurred the evolution of complex emotions such as shame and embarrassment, which would help individuals toe the party line. “We became emotionally modern before we became cognitively modern,” she says. But what really marks out the thinking of *H. erectus* is encapsulated in the second tool of the three in front of me, an exquisite leaf-shaped object known as an Acheulean hand axe.

Better by design

We do not know what inspired this revolutionary design – it may even have come in a dream (see “Sweet dreams”, left). The first attempts, which date from around 1.5 million years ago, were fairly crude, but over the following 1 million years Acheulean axes became thinner and more symmetrical as they began to embody a more systematic style of working. Bradley’s demonstrations show that to achieve the more sophisticated designs, you need to prepare the surface of the

rock – working away smaller chips to create an angle before striking off the larger, flatter flakes. “They take a lot more planning and understanding of force,” he says as he chips away at his own rock. Breaking down a goal into a series of smaller actions in this way shows the beginnings of hierarchical thinking. Chunking and sequencing our actions seems so central to the way we operate today – whether we are making a cup of tea or running a bath – that it’s almost impossible to imagine our minds working in any other way. But the refined Acheulean axes offer some of the first signs that our ancestors were beginning to develop the ability to organise their thoughts in these more complicated ways.

This innovation in axe design has been linked to another milestone in human cognition: language. It is such a complex system, dependent on many different thought processes, that its origins are sometimes described as evolution’s biggest mystery, but there is some evidence suggesting that tool-making could have been a catalyst. Bradley’s collaborator, Dietrich Stout at Emory University in Atlanta, Georgia, points out that articulate vocalisation requires precise movement of the lips and tongue. Chimps and other primates are unable to achieve these,

but in our ancestors tool-making drove the development of the brain areas involved in motor control that could later be co-opted for speech. Stout also notes that the sequential thinking needed to create the leaf-shaped hand axes is similar to the thinking that allows us to understand and construct sentences.

To test the theory, Stout used brain scans to try to pick apart the cognitive skills used in each type of tool-making. As predicted, they show that people making replicas of the Oldowan tools have greatest activity in areas associated with the motor control needed to speak, while brain activity in those making the Late Acheulean tools shows an overlap with that normally associated with linguistic grammar. That includes the inferior frontal gyrus along the bottom of the frontal lobe – an area that expanded rapidly in the human line compared with other apes.

Language is, arguably, our only unique feature, and its emergence set us on a road that led away from every other animal. Unfortunately, this turning point in our journey is virtually invisible in the archaeological record: Bradley can show me no tools that definitively signify the first words. But there are hints that our ancestors had begun speaking by the time of *Homo* ➤

“Time spent playing may have helped develop ‘counter-factual thinking’”

heidelbergensis, thought to have evolved from *H. erectus* at least 600,000 years ago.

H. heidelbergensis was certainly more human in other respects. Its brain, at about 1200 cubic centimetres, was just a shade smaller than ours, providing a cognitive power that is evident in the variety of tools it used, including refined hand axes, cleavers and spearheads. To envisage an amorphous lump of rock transformed into these different shapes and styles would have required good spatial cognition, perhaps signalling the birth of the visual imagination. *H. heidelbergensis* also revisited certain places again and again, sometimes scattering hand axes across the ground. Some read this apparently inexplicable waste of good handiwork as an early attempt to signpost sites of significance. That is skirting close to the mindset needed for symbolism. Crucially, *H. heidelbergensis* also possessed refinements in its vocal anatomy. For instance, traces in bones indicate they had more nerves linking the brain and tongue than their predecessors, and their voice boxes seem to lack a balloon-like appendage that constrains vocalisations in other apes. Both of these changes would be needed to produce eloquent sounds.

Whenever it emerged, language brought a whole new set of mental challenges. “When I tell you a story, I can frighten you very easily,” says Jablonka. “And you have to control this fear.” It’s easy to take that ability for granted, but chimps fail to make a good distinction between symbols and real things – they go wild when they see a picture of a banana, for instance. In a similar way, our ancestors may have struggled at first to understand the mental images conjured up by language. To deal with their immediate visceral reactions, Jablonka says, they must have developed greater control over their emotions – and they would have learned to be more sceptical and suspicious of others in the process. They also needed a better verbal memory, so that they could remember what others had told them, to differentiate it from what happened in their own lives. Out of that emerged the ability “to tell my own story, the autobiography”, she says. If Jablonka is right, language contributed to our sense of self.

Beautifully crafted

Our ancestors were probably still navigating these difficulties as the human mind approached the last stretch of its journey. To demonstrate this final mental leap, Bradley draws my attention to the third object on the

table in front of us. The beautiful Levallois tool is carved from shiny black stone. With dimples lining its edge, it looks a little like an oyster shell. Bradley tells me the tool is little more use for cutting and scraping meat than the cruder hand-axes – its value was probably aesthetic, rather than practical. To make it, a base stone had to be fashioned into a circle before the “lid” was removed with one strike. That craftsmanship takes great skill and patience, as Bradley and Khreisheh’s modern apprentices discovered. “People like making hand axes,” says Khreisheh, “but they hate making Levallois tools.” Since the process comprises many different stages, and the apprentices often need specific instruction, the mind that originally created this tool was probably capable of advanced hierarchical thinking and complex communication for tuition. These intricate objects first appear at least 300,000 years ago, but although they

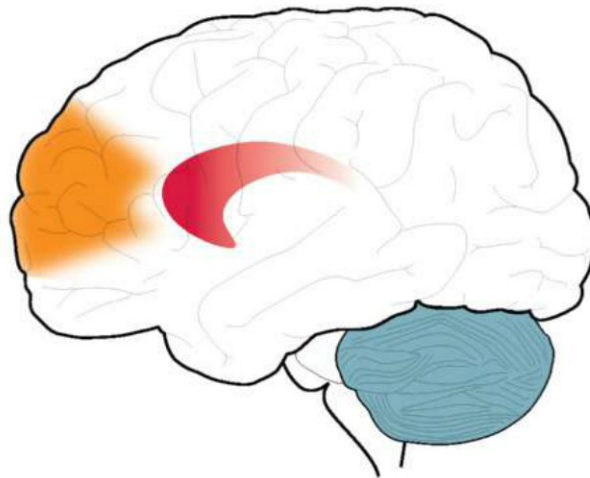
are found among the remains of our own species, they are most commonly associated with the Neanderthals.

Levallois tools provide some of the best evidence that Neanderthals shared much of the cognitive toolkit possessed by humans living at the same time. And herein lies the mystery. “Whatever the Neanderthals’ cognitive leap was, it stopped; it didn’t continue,” says Bradley. So why did we develop more ambitious inventions and rich artistic cultures, while they hit a dead end? Answer that question, and you get a glimpse of the final stage in the evolution of the human mind.

Some think the solution is child’s play – literally. Since our ancestors first diverged from the other primates, childhood has continued to get longer, giving the brain more time to develop outside the womb. From the remains of bones and teeth, it seems that early human children took longer to develop

Size isn’t everything

Human intelligence has more to do with the organisation of brain regions than it does with overall size. Tools may have played a key role in shaping parts of this complex organ



● PREFRONTAL CORTEX

Self-control, introspection, social cognition

Lots of signal-transmitting “white matter” reflects this area’s role in combining data from the senses and the rest of the brain. That could help with precise tool-making actions and with the insight needed for complex social relationships

● FRONTOSTRIATAL SYSTEM

Incremental learning of skills

As our ancestors evolved there was a rapid increase in the size of this area relative to other brain regions. This would have improved their capacity for learning, allowing for the production of more complex tools

● CEREBELLUM

Sequential thinking

High connectivity between here and the frontal motor areas enables fine control of movement. This area may have grown as the tool-making and language skills of our ancestors developed

than Neanderthal ones. Child psychologist Alison Gopnik at the University of California, Berkeley, argues that the extra time spent playing may have helped them develop “counter-factual thinking” – the ability to consider how things might be, not just how they are. That allowed them to imagine the environment in more creative ways, giving them greater control over their surroundings, she says. As a result, they could do things that might not have occurred to earlier humans, like inventing new tools and building shelters.

Frederick Coolidge and Thomas Wynn at the University of Colorado in Colorado Springs see a more dramatic trigger. They argue that our last cognitive leap was down to a chance mutation that increased our ability to hold several ideas in mind and manipulate them. Even in modern humans, this “working memory” is limited to about seven items. However, a small increase would have had huge consequences. An improved ability to remember what had just been said would have increased the sophistication of conversation, allowing more complex grammar with many different clauses. That means you can think and plan more hypothetically, using “what if” and “if, then” statements, for instance.

Working memory is also associated with creativity and innovation, because it allows you to mentally explore different solutions to a problem. Wynn and Coolidge also point to research suggesting that enhanced working memory could have improved our long-term memory and future planning because it provides a bigger mental “blackboard” on which we can assemble the details of our past experiences, and draw on them to work out the best way to proceed with the task ahead.

A recipe for success

This hypothesis has been strengthened in recent years by a wave of circumstantial evidence. For example, Lyn Wadley at the University of the Witwatersrand in Johannesburg, South Africa, has looked at the steps involved in making glues used to stick spearheads to poles. Earlier humans had simple adhesives such as plant gum, but she has found that in Sibudu cave, South Africa, about 70,000 years ago, they began to cook up the tree sap with red ochre and beeswax to produce a superior glue that doesn’t break on impact or dissolve in water.

When Wadley tried to replicate the complex recipes, she found that she had to pay attention to many different factors, including the temperature of the fire, the moisture



PHILIPPE PSAILA/SCIENCE PHOTO LIBRARY

Recreating stone tools opens a window into the minds of those who invented them

and different proportions of ingredients depending on the quality of the tree gum. “It took a lot of coordination to ensure success,” she says. That’s only possible with an enhanced working memory to keep all the different elements in mind at once.

Further clues come from the food these people ate. Around this time, early modern humans began to hunt small game, such as small deer species and rodents. Former army survival expert Klint Janulis, now at the University of Oxford, tried the methods they used and found he needed to place 10 to 15 traps to capture enough food to make it worthwhile. “Within a couple of hours you can set enough traps to feed yourself, and maybe another person, for a day,” he says. But that requires forethought, and keeping track of their locations needs just the kind of advanced cognition that Wynn and Coolidge suggest.

The timing of these advances at 70,000 years ago is particularly significant because they come just after the eruption of the Toba supervolcano in Indonesia, which plunged the world into a mini ice age and caused a human population crash in Africa. Any beneficial mutations within the small remaining population could spread quickly, leaving a permanent mark on their descendants. “All extant humans are ancestors of those 2000 or so humans,” says Coolidge. If he and Wynn are right, then the explosion at Toba marked the beginning of the home stretch to modern thinking. Armed with this slightly superior thinking, we left Africa and took over the

globe, while the Neanderthals and our other evolutionary cousins became extinct.

Of course, our journey isn’t over and it is tempting to speculate how the human mind will evolve in the future. Wynn wonders if we will see further changes in working memory. “It’s variable within populations,” he says. “We suspect it may still be under evolutionary change.” And it is possible that advances in technology could substantially change the mental challenges we face, just as stone tools did in the past. Claims that the internet is making us stupid have so far proven to be unfounded but the way we interact with one another is certainly changing and so are the mental skills associated with success.

Bradley is more interested in the past than the future. The air is now thick with flint dust as he hands me the finished axe. There are still many questions left to answer, he says, as we try to fill in the gaps between the known landmarks of cognitive evolution. “From our point of view it’s just scratching the surface of what could be done.” But he has already achieved one of his goals – he wanted to teach a new generation of flint-knappers the skills he has been refining since childhood.

There’s also a chance that his handiwork will find a place next to the artefacts he so admires. The Smithsonian Institution in Washington DC, he says, is interested in collecting his life’s work to demonstrate the progression of a modern day flint-knapper. “My body could even be a permanent exhibit there too, when I shift off this mortal coil,” he jokes. It would be a fitting place of rest for the “natural born knapper” who has spent his life trying to understand how we learned to be human. ■

David Robson is a features editor at *New Scientist*

Return of the wild

A radical way of reviving ecosystems is beginning to catch on, finds Sara Reardon

THE sky is purple and the wind is fierce on top of the cliff. David Burney has to shout as he explains what we're looking at. Below us is the Makauwahi Cave, which contains the remains of plants and animals going back thousands of years. It is revealing what the Hawaiian island of Kauai was like before people arrived. Here you can find the bones of moa-nalo, the giant flightless ducks that once ruled Hawaii.

For millions of years, these plant-eating fowl roamed the islands, taking their pick of the lush vegetation. There were no large predators to threaten them. Then came the Polynesians. They probably started feasting on the plump, defenceless birds as soon as they had jumped out of their canoes. "It was an instant luau" – a feast – says Burney.

The ducks were soon wiped out, and the onslaught was only just beginning. European settlers introduced rabbits and goats to Hawaii, and the defences that native plants had evolved against the ducks' thick beaks were little use against sharp teeth. Today, many of the original plant species of Kauai are extinct, replaced by invasive weeds. "For years, I documented extinction," says Burney, who has spent much of the past two decades unearthing fossils here with his wife Lida Pigott Burney. "I felt like the county coroner."

Then, a few years ago, the Burneys decided to go beyond studying the past, to recreating it. They searched for surviving native plants

and began to plant them on disused farmland near the cave. The Makauwahi Cave Reserve was born. Here, endangered yellow hibiscus flowers called ma'o hau hele, brought from nearby islands and from Kew Gardens in London, stand out starkly against the dark sky. Burney points out a lone loulu palm tree, one of the last of its kind, which he planted after finding it in the cave's fossil record.

But even on this small site of just a few acres, keeping weeds in check is a major battle. What if, Burney wondered, the giant ducks were still around. They might feast on the weeds in preference to the beak-resistant native plants. So he decided to try a little experiment. As we arrive at an enclosure, one of his surrogate ducks comes to meet us. It is a giant tortoise named Cal. Burney says Cal and his fellow duck impersonators are doing what he hoped. They prefer to eat non-native plants, and they are thriving and laying eggs.

The Makauwahi Cave Reserve is a tiny example of what's come to be known as "rewilding". The term means different things to different people, and in the widest sense of putting aside land for wildlife, it has been going on for more than a century. But the rewilding movement now springing up around the world is a bit different. Its supporters almost all agree on two things. First, that many supposedly wild areas are actually a mere shadow of what they were before our ancestors arrived on the scene. Second, that we

Top predators like wolves can shape entire ecosystems

cannot restore these ruined ecosystems to their former glory without restoring the animals that shaped them – especially the big animals at the top of the food chain.

This is where it gets controversial. In Britain, for instance, there has been opposition to reintroducing the beaver, never mind the wolves and bears that once roamed the island. What's more, most of the world's large animals have gone the way of the moa-nalo over the past 10,000 years or so. Undeterred, rewilding enthusiasts want to replace them with substitutes just as Burney is doing – which in North America might mean letting African cheetahs, lions and elephants loose on the

JOEL SARTORE/NGS CREATIVE



great plains. Is this madness or genius?

Surprisingly, one of the most densely populated continents has taken the lead on rewilding. An initiative called Rewilding Europe has set aside ten areas of 1000 hectares that it aims to rewild by 2020. Some of these projects are well under way – red deer and ibex roam sites near the border of Portugal and Spain, for example. Director Wouter Helmer envisions these reserves becoming Europe's version of the national parks in North America and Africa. "We are not looking backward, we are looking forward," he says. "It's the future harmony between man and nature in which we are interested."

*"The moa-nalo were
giant flightless ducks
that once ruled the
Hawaiian islands"*

Yet it is easy to forget that nature is red in tooth and claw. Since the 1980s, researchers in the Netherlands have been slowly introducing large grazing animals to a reclaimed marshland, about 40 kilometres from Amsterdam, called the Oostvaardersplassen. But in a particularly harsh winter in 2005, many animals died of starvation, prompting protests from the public and debate in the Dutch parliament over whether this constituted animal cruelty. But feeding the animals, the rewilders argued, would change their behaviour.

As a compromise, the site's managers now shoot any starving animals they see and leave

“Surprisingly, Europe has taken the lead in rewilding, setting aside ten areas”

the bodies for scavengers, although many are not spotted. Drawn to the carrion, white-tailed eagles have returned to the Netherlands for the first time in the modern era. The site now contains thousands of red deer, miniature horses and Heck cattle, a species bred to resemble the 1500-kilogram aurochs that once roamed the area. Sooner or later, wolves are bound to move in.

Wolves were the key to one of the best known examples of rewilding. In 1995, nearly 70 years after hunters had wiped them out, wolves were reintroduced to Yellowstone National Park in the US. In the absence of large predators, deer populations had burgeoned out of control and begun to venture into nearby areas. Overabundant elk ate trees down to their nubs, leaving beavers with no lumber for their dams, which, in turn, changed the flow of rivers. Once the wolves were restored to the park, however, deer and elk numbers decreased and they became less bold.

Examples like this show that restoring the animals at the top of the food chain can reshape entire ecosystems. Conservationists say this demonstrates that rewilding can have practical benefits.

To sceptics, though, such complex effects are exactly what is worrisome. “Inserting species into ecosystems with the hope they will play a specified role is incredible science hubris,” says Justin Brashares of the University of California in Berkeley. In some cases, he says, when species have been driven out of an area by people, returning them is not a problem. But history is full of examples of well-meaning introductions of species that got out of control, from cane toads in Australia to the kudzu vine in the US. So there is a lot of caution about the idea of substitute species.

But enthusiasts can point to a few small success stories. On Ile aux Aigrettes, a little island off the coast of Mauritius, 20 Aldabra giant tortoises were introduced by the Mauritian Wildlife Foundation in 2000 as a substitute for the extinct native tortoises. The restoration wasn’t motivated by nostalgia, says Christine Griffiths of the University of Bristol, UK, who leads the project. It was done to help save native plants, such as a kind of ebony tree found only on this island.

Although logging stopped in the 1980s, the

trees were not recovering. Since the tortoises arrived, however, seedlings have sprung up everywhere (*Current Biology*, vol 2, p 762). The tortoises eat the trees’ fruits and disperse the seeds about the island in their faeces. The seeds are also more likely to germinate after passing through a tortoise, the team has discovered. “Tortoises would be a wonderful tool for most islands,” Griffiths enthuses.

In 2007, her group introduced Aldabra and Madagascan radiated tortoises to Round Island, also near Mauritius. Its native tortoises are extinct, too, and the island is overrun with weeds, as Kauai is. As hoped, the tortoises are feasting on the weeds and mostly leaving native plants alone, the team reported last year (*Conservation Biology*, vol 27, p 690).

Substituting one tortoise for another on a small island is a fairly safe bet. “It’s hard to imagine a runaway tortoise population,” says rewilding advocate Josh Donlan of Advanced Conservation Strategies, an environmental consultancy based near Salt Lake City, Utah. “We killed them once, we can do it again.” But Donlan wants to go much further to rewild North America.

In a 2005 article in *Nature*, Donlan, Burney and 10 other biologists pointed out that, while most conservationists think of the time before European settlers arrived as the continent’s wild state, they really should look further back. They should focus on the late Pleistocene around 13,000 years ago, before humans wiped out most of the large animals.



“History is the best guide we have for creating a roadmap for biodiversity and conservation in the future,” Donlan says.

The group proposed rewilding a large swathe of North America to recreate an ecosystem as rich as the ancient one. The Bolson giant tortoise, now found only in Mexico, could be returned to its former range. Bactrian camels could stand in for North America’s extinct native camelids. African and Asian elephants, the researchers proposed, could replace the lost mammoths, mastodons and gomphotheres that helped maintain grasslands by feeding on trees. African lions could replace the extinct American lion.

The backlash was immediate. Persuading



Rewilding led to controversy in the Netherlands when animals starved



Large herbivores shape the vegetation of the land where they roam

the public that dangerous creatures should be allowed to run wild near inhabited areas, many researchers pointed out, would be nearly as mammoth a task as restoring the mammoths themselves. Scant conservation funds would be better spent preserving the top predators that still survive, such as wolves.

Even with public support and funding, there would still be practical problems. For instance, an analysis by Brashares suggests that the climate in most of North America is not suitable for lions and cheetahs (*PLoS ONE*, e12899). “It’s a fun and interesting philosophical idea, but when the rubber hits the road, we can’t move things around and expect them to do well,” says Brashares.

Climate complicates things in more than one way. In Europe, for instance, one would need to go back at least 50,000 years to determine the continent’s virgin state, but this was the middle of the last ice age, so it is no surprise that the fauna and flora were very different. Go further back to the last interglacial period, 100,000 years ago, when Europe’s climate was similar to the present, and the wildlife was, well, wild. Hippopotamuses and hyenas roamed Britain, for instance. Is this what we should regard as the natural state?

Any serious rewilding effort would also need to consider why a species went extinct. In the New World, the loss of large animals was relatively recent and coincided with the spread of people. But in the Old World, there has been

much debate about whether it was warming after the last ice age or ancient hunters that wiped out big animals.

Spain, for instance, had both reindeer and lions 20,000 years ago. It is thought the lions were hunted to extinction, whereas the reindeer couldn’t deal with the warming climate. If so, lions might thrive if reintroduced but reindeer might not.

Pleistocene Park

In western Siberia, Sergey Zimov of the Russian Academy of Sciences is turning this argument on its head. Instead of studying the causes of past extinctions to determine whether rewilding is feasible, he is rewilding to see what caused the extinctions.

Zimov has built a 125-hectare “Pleistocene Park” complete with horses, reindeer, musk ox, elk and moose. These large herbivores thrived on the Siberian steppe for a million years before disappearing along with the

mammoths around 10,000 years ago. The vegetation of the steppe changed too, with grasses giving way to mosses and forests. Zimov suspects hunters triggered this change by killing large numbers of the herbivores. And he hopes to prove it by showing that high densities of herbivores can thrive on the steppe even in a warm climate, and that their presence will restore the original vegetation.

As part of this, Zimov and his colleagues are developing a second park in a warmer area 250 kilometres south of Moscow, containing even more large herbivores as well as, eventually, cheetahs and lions. Tourists will be able to visit this fenced “Wild Field” as if on an African safari, Zimov says.

Rewilding could have other environmental benefits, too, such as helping to slow the melting of permafrost. Undisturbed snow traps ground heat accumulated over the summer, whereas land under trampled snow cools much faster. As a result, the permafrost at Pleistocene Park, is 4 °C cooler than elsewhere, Zimov says. Grasslands also reflect more of the sun’s heat than dark forests. What’s more, Zimov thinks converting the tundra back to grassland will capture carbon from the air.

Besides combating climate change directly, rewilding could also help ameliorate some of the consequences. For instance, the UK has been suffering from severe flooding in recent years. George Monbiot, author of the rewilding manifesto *Feral*, points out that there is strong evidence that reforesting upland areas denuded by Britain’s ancient farmers will reduce water run-off.

In many places the land is deliberately kept tree-free, but in some parts the burgeoning deer population is thwarting reforestation efforts by destroying saplings. So introducing wolves could help, as in Yellowstone.

For its enthusiasts, though, rewilding is about more than practical benefits. In a world where we are bombarded by dismal news about the environment, it offers inspiration rather than gloom. “It’s a new kind of ecotourism that captures the imagination,” says Joe Bull of Imperial College London, who runs a rewilding consultancy.

Even critics such as Tim Caro of the University of California in Davis, who dismisses the idea of Pleistocene rewilding with exotic animals such as elephants as “a stupid idea”, concede this point. “It’s a more positive view of conservation rather than just talking about what went wrong,” he says. ■

“Rewilding is a new kind of ecotourism that captures the imagination”

Sara Reardon writes for *Nature* in Washington DC

Could the heat of certain spices solve some of medicine's biggest problems? Moheb Costandi tackles a burning question



Catching fire

IT STARTS out as a pleasant tingle, before growing into a burning sensation that feels like your whole mouth is ablaze. You sweat, you cry, and your nose streams. You gasp for water, but it feels like nothing can douse the flames. Once the pain has subsided, however, you suspect you'll seek out an even more extreme fix the next time around.

Anyone who enjoys a curry knows this feeling – and chefs have been using the sensation of chillies and other peppers to spice up their culinary experiments for centuries. But it is only in the last decade or so that scientists have begun to understand how we taste piquant foods. Now they have found the mechanism that not only explains the heat of chillies and wasabi, but also the soothing cooling of flavours like menthol.

The implications of this discovery extend far beyond cuisine. The same mechanisms build the body's internal thermometer, and some animals even use them to see in the dark. Understand these pathways, and the humble chilli may open new avenues of research for conditions as diverse as chronic pain, obesity and cancer.





The story begins in earnest in 1997, with David Julius at the University of California, San Francisco. Although people had long speculated about the source of the chilli's fire, his team was the first to discover how its key component, capsaicin, sets our mouth aflame. Most of our sensory perception depends on specific "channels" on the surface of certain cells, each responding to a different kind of stimulation. When the channel is activated, its pores open up, allowing electrical charge in the form of ions – charged particles – to flow in. These ion channels are often found on nerves, where this influx of ions triggers an electrical impulse.

There were many candidates for the channel that responds to capsaicin, but with some nifty genetics work, Julius was able to pin it down. It is called TRPV1. Crucially, he then showed that the channel also responds to uncomfortably hot temperatures – about 43 °C or higher – that would be enough to damage tissue. This neatly explains why chillies feel like they are burning the mouth.

Other TRP (pronounced "trip") channels had previously been implicated in different kinds of sensory perception, but this was the first to represent our internal thermometer (see diagram, page 47). It didn't take long for other, related protein channels to emerge that explain our sensitivity to other temperatures and food ingredients. In 2002, for instance, Julius discovered the TRPM8 channel, which is activated by relatively cool temperatures, between about 10 and 30 °C. This channel is also triggered by menthol, giving it that cooling sensation.

Just chillin'

Having identified the TRPM8 channel, Julius and his colleagues went on to create a strain of genetically engineered mice that carried two defective copies of the gene that normally codes for its protein. They then tested the animals' sensitivity to cold by placing them in a box containing two chambers, each with a different ambient temperature, and compared their behaviour with that of their littermates.

The normal mice showed a strong preference for the chamber kept at 30 °C, but the genetically engineered animals happily stayed in the colder chamber for long periods of time, preferring the warmer one only when the temperature dropped to below 15 °C. They were also far less able than their littermates to distinguish between cool and warm surfaces.

The researchers are now filling in the other gaps in our understanding of the body's

SPENCER WILSON

thermostat. As they do so, it is becoming clear that in some animals these mechanisms have evolved in surprising ways. For instance, in pit vipers and vampire bats, a super-sensitive variant of the TRPA1 channel, which responds to temperatures of around 10 °C, has been co-opted for infrared-based thermal imaging.

A new understanding of the senses was only half the cause for excitement, however, as it soon emerged that these channels' responsibilities are wide-ranging, potentially implicating them in a range of disorders. Of particular interest is the fact that they are found on nerves that respond to painful stimuli – and that they can act as a kind of switch that amplifies or damps down the nerve's sensitivity. When that mechanism backfires, thanks to certain mutations, even the slightest changes in temperature can produce devastating pain (see "Worse than childbirth", below). But the flip side is that

these channels open promising avenues of research for new kinds of analgesics that could potentially use the pathway as an entry point.

Initially, most research focused on TRPV1 – the first channel that Julius discovered. Unfortunately, finding ways to alter pain perception through this route was much more difficult than it first seemed, since the potential drugs were quickly found to have unwanted and potentially dangerous side effects. Because TRPV1 is involved in detecting hot temperatures, anything that blocked its function made people less sensitive to painful heat. That meant they were more prone to injury, by scalding themselves in a hot shower for instance. And, due to its involvement in regulating the core body temperature, drugs that block the channel can cause a dangerously high fever. "Every major pharmaceutical company piled in," says pain researcher John Wood at University College London, "and something like \$60 billion was spent trying to make drugs based on TRPV1. We made hundreds and characterised them really carefully, but none were any good."

Such problems have discouraged many researchers, but there may be a way around them if we better understand the way the channels react to their immediate environment. In 2013, Peter McNaughton, then at the University of Cambridge, and his colleagues found a protein that modulates TRPV1 function during inflammation. The protein, called AKAP79, seems to shift the cell's molecules into specific formations. "It localises some of the components of signalling pathways to the right regions inside the cell, so that they're ready to go when the pathway is switched on," says Joan Btesh, also at Cambridge, who led the work. The result is that when this protein is present in excess, the TRPV1 channel has a lower threshold for generating nervous impulses. That means that normally innocuous temperatures feel painful – a serious problem in chronic pain conditions, including fibromyalgia, migraine and certain injuries.

Drooling at the dentist

Luckily, there may be a way to reverse the effect. McNaughton and Btesh's team has found a chemical that stops the AKAP79 protein from binding to the TRPV1 protein channel, reducing the pain associated with the inflammation. And, crucially, it works without reducing sensitivity to heat. "By blocking the interaction between the two proteins, we're reducing the number of TRPV1 channels that are available to respond to stimuli, and preventing the modification of channels that are already in the cell membrane," says Btesh. So far, experiments with mice have been positive.

Others are looking at ways to apply



CULTURA RM/JOSEPH GACOMINI/GETTY

these drugs in small regions of the body, for better local anaesthetics. At the moment, an unpleasant effect of having a local anaesthetic at the dentist is that the drugs knock out all your nerve cells, including those involved in moving the muscles, leaving your face temporarily paralysed. One solution is to use the capsaicin in chilli, or related molecules, as a kind of key to preferentially unlock pain nerves: by temporarily opening the heat channel, it creates an entry for an analgesic to then work its way into the cell. Since the nerves involved in moving muscles don't have the same receptor, they would be left unaffected, so the recipient is not turned into a drooling mess.

Given the many thermal channels on nerve cells, there may also be many other targets. For example, it's well known that cooling has analgesic effects in some painful conditions, such as osteoarthritis, and that it has a soothing effect in inflammation. This is likely to involve TRPM8, but other TRP channels probably play a role, too, which could complicate the picture. And since too much activity in these pathways could also induce an unpleasant hypersensitivity to cold, it could be tricky to find a drug that achieves a comfortable medium.

WORSE THAN CHILDBIRTH

Extreme heat or cold can cause pain for all of us – but for some people even small shifts in temperature can be agony. In 2010, John Wood at University College London and his colleagues identified a condition called familial episodic pain syndrome in a Colombian family who had been reporting symptoms of severe pain.

"When these people get cold or tired, they have excruciating chest pain which knocks them out," Wood says. "They come out of it, exhausted, after about 2 hours. The women say that the pain they feel is worse than childbirth."

After Wood's team sequenced the genomes of the family members, they identified a mutation in the TRPA1 gene that seemed to lie behind the family's condition. This gene coded for a cell-surface receptor protein, or channel, that had previously been found to respond to very cold temperatures. Rather than deactivating TRPA1, the mutation identified by Wood and his colleagues sensitises the channel, so that the TRPA1 protein becomes active when it should be resting.

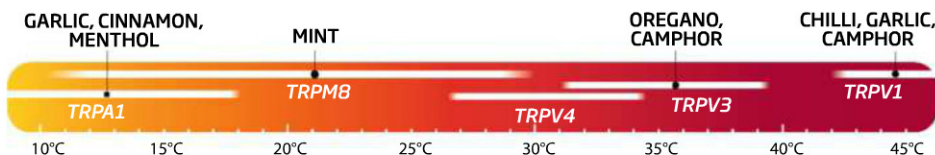
Wood adds that this pain syndrome is probably unique to the Colombian family in which the mutation was identified. So while this research provides useful insight about the involvement of TRP channels in pain states, it is unlikely that drug companies will spend any money to develop a way of relieving this family's acute discomfort.



Our bodies' heat sensors do a whole lot more besides

The thermostat within

Our internal thermometer is made from a series of TRP proteins each of which reacts to a different temperature range. They can also be activated by food ingredients to induce a burning or cooling sensation



In the meantime, other researchers are looking at the possibility of using these channels to fight fat. One idea could be to use the channels to fiddle with the body's thermostat to control energy expenditure so that it burns those excess pounds. Clearly, it is something that would need to be done with care – besides the dangers seen in the pain relief studies, the benefits can be unpredictable too. For instance, you might think that knocking out the heat sensing mechanism would have the same response as a cold temperature, triggering automatic mechanisms to burn more heat to compensate. Yet the animal studies have been conflicting: although in some studies, mice lacking the TRPV1 receptor have been shown to lose weight, in others they gain it.

There are hints that gently stimulating TRPV1 receptors could be the answer instead.

For instance, activation of the TRPV1 channel seems to suppress the production of adipocytes – cells that are specialised to store energy as fat. Other studies have suggested that stimulating the channel can cause the body to burn fat it has already built up. And since it is involved in taste, it may contribute to the feeling of being full after eating a meal, which prevents us from overeating.

Although the exact reason for this response is still under discussion, human trials so far have been promising. Subjects asked to take a regular dose of capsaicin every day, for instance, showed a modest increase in the calories they burn – enough for a steady weight loss over the course of months.

Perhaps most surprising is the discovery that these channels might also be involved in tumour growth. TRPM8, which allows us to taste mint, is known to be present at abnormally high levels in prostate cancer, for example. The more severe the cancer, the higher the levels of this protein in the cancerous cells. Animal research suggests that here, the channel may have been co-opted in a cellular signalling pathway that sets off cell division. Since these channels are also found in the epithelial cells that line blood vessels, they might also contribute to the spread of cancer by promoting the formation of blood vessels that feed tumours.

Targeting the TRPM8 pathway may therefore provide a way to control growth of cancer. In one experiment, chemicals that inhibit TRPM8 activity were shown to reduce the proliferation of prostate cancer cells growing in a Petri dish. Such experiments could eventually lead to drugs that prevent the spread of the disease. Indeed, one clinical trial is already under way.

These prospects are a world away from Julius's first work on the fiery mystery of chilli. What once seemed like a curiosity for curry lovers now looks set to carve out its own corner in healthcare.

For the time being, we can at least say one thing with certainty: in the field of medicine, few areas of research are as hot right now. ■

Moheb Costandi is a journalist based in London. His book *50 Human Brain Ideas You Really Need to Know* was published by Quercus last year

THEY CALL HIM THE ICEMAN...

...And for good reason. Wim Hof, a 59-year-old Dutchman, has a remarkable ability to withstand extremely cold temperatures for long periods of time. This ability has garnered him no less than 20 world records. In 2009, Hof reached the summit of Mount Kilimanjaro in two days, wearing nothing but a pair of shorts. Later in the same year, he ran a full marathon above the Arctic circle in Finland, in temperatures of about -20°C – again, wearing only shorts. And in 2011, he broke his own world record for ice endurance, by staying immersed in freezing water for just under 2 hours.

Hof puts this down to an ability to take conscious control over his bodily functions. "It's mind over matter," he says. "I've learned through breathing exercises to take control of my nervous, cardiovascular and immune systems. It makes me able to stay in the cold for longer, and to endure a lot of pain."

Hof's claims are backed by scientific

evidence. A 2012 case study by researchers from Radboud University in Nijmegen, the Netherlands, showed that his meditation technique appears to produce a controlled stress response, reducing the unpleasant feelings that normally come with freezing weather.

Genetics is likely to play a role, too, with one particular gene that may produce individual differences in sensitivity to cold. The gene encodes a receptor protein, or channel, called TRPM8, which is normally found in a subset of pain-sensing nerve fibres. Certain TRPM8 variants might make people more or less sensitive to painfully cold temperatures, and there may even be mutations that make people completely insensitive to them.

"I'm not aware of any mutations that have been identified in the human TRPM8 gene," says physiologist David Julius at the University of California, San Francisco, "but someone like Hof sounds like a good candidate for DNA sequencing."

A long-dismissed form of clean energy is
resurgent, thanks to some unexpected allies.
Helen Knight reports



IF ANY energy source is worthy of the name “steampunk”, it is surely ocean thermal energy conversion. Victorian-era science fiction? Check: Jules Verne mused about its potential in *Twenty Thousand Leagues Under the Sea* in 1870. Mechanical, vaguely 19th-century technology? Check. Compelling candidate for renewable energy in a post-apocalyptic future? Tick that box as well.

Claims for it have certainly been grandiose. In theory, ocean thermal energy conversion (OTEC) could provide 4000 times the world’s energy needs in any given year, with neither pollution nor greenhouse gases to show for it. In the real world, however,

it has long been written off as impractical.

This year, a surprising number of projects are getting under way around the world, helmed not by quixotic visionaries but by hard-nosed pragmatists such as those at aerospace giant Lockheed Martin. So what’s changed?

It’s possible that Verne dreamed up the idea for OTEC to help out Captain Nemo, the protagonist of Verne’s deep-sea yarn who needed electricity to power his submarine, the Nautilus – it is the first written mention of the idea. “By establishing a circuit between two wires plunged to different depths, [it should be possible] to obtain electricity by the difference of temperature to which they would have been exposed,” Nemo told his shipmate. Eleven years after the book was published, French physicist Jacques-Arsène d’Arsonval proposed the first practical design for a power plant that does exactly that. Instead of using wires, he used pipes to exploit the temperature difference between the cold deep ocean and the warm surface waters to generate steam energy.

The idea is brilliant. The ocean is a massive and constantly replenished storage medium for solar energy. Most of that heat is stored in the top 100 metres of the ocean, while the water 1000 metres below – fed by the polar regions – remains at a fairly constant 4 to 5 °C.

To make energy from that heat difference, modern-day systems pump warm surface water past pipes containing a liquid with a low boiling point, such as ammonia. The ammonia boils and the steam is used to power a turbine, generating electricity. Cold deep-ocean water is then piped through the steam, causing the ammonia to condense back into a liquid, ready to begin the cycle again (see diagram, page 51). Steam-powered turbines drive nearly every coal and nuclear power plant in the world, but their steam is produced by burning polluting coal or generating long-lived nuclear waste. OTEC, by contrast, provides steam in a clean and theoretically limitless way.

Electric ocean

That’s in an ideal world. In reality, what the ocean’s thermal gradient gives, the equipment takes away. The main problem is accessing the cold deep water: pumping the vast amounts of water needed requires 1000-metre-long pipes that are wide enough and strong enough to handle several cubic metres of seawater per second for every megawatt of electricity produced. Tally all the inefficiencies in the process and the theoretical efficiency of an OTEC plant drops to a dismal 4 to 6 per cent.

Thanks to this and other factors, the process needs a temperature difference of at least 20 °C between the surface and deep water to work. Such conditions exist in a relatively narrow band around Earth’s equator that

includes the tropics and subtropics (see map, page 50).

Despite these constraints, the 20th century was filled with fitful efforts to make OTEC work. The most ambitious of these, in the 1970s, was sparked by an oil crisis, after which the US president Jimmy Carter signed into law the production of 10,000 megawatts of electricity using the technology by 1999. However, the price of oil then fell again, and alternatives to petroleum sank once more to the bottom of the to-do list.

So when Lockheed Martin last year announced that it would begin construction on a 10-megawatt plant off the coast of

“Jules Verne mused about getting energy from stored heat in the ocean in 1870”

southern China, the news was met with a marked lack of interest. We had been here before.

A closer look, however, reveals that the project may signal a sea change for OTEC. The time may finally have come for this 19th-century technology to become part of the 21st century’s renewable energy mix, thanks to a strange partnership of other renewables, the oil industry – and perhaps even climate change.

Many calculations are changing. OTEC’s efficiency may be low, but since it uses seawater, which is abundant and free, it still makes economic sense if done on a large-enough scale. Oil prices are unstable and climate change is becoming an increasingly urgent driver of alternative energy sources. The shortcomings of intermittent renewables such as wind and solar energy, which only produce electricity when the sun is shining or the wind is blowing, are still keeping these on the margins. By contrast, OTEC plants can operate 24 hours a day, says Ted Johnson of Ocean Thermal Energy Corporation, which plans to commercialise the technology. Round-the-clock power means an OTEC plant could simply be plugged directly into a municipal grid to replace fossil fuel power plants, without the adjustments and balances necessary to integrate unpredictable solar and wind power.

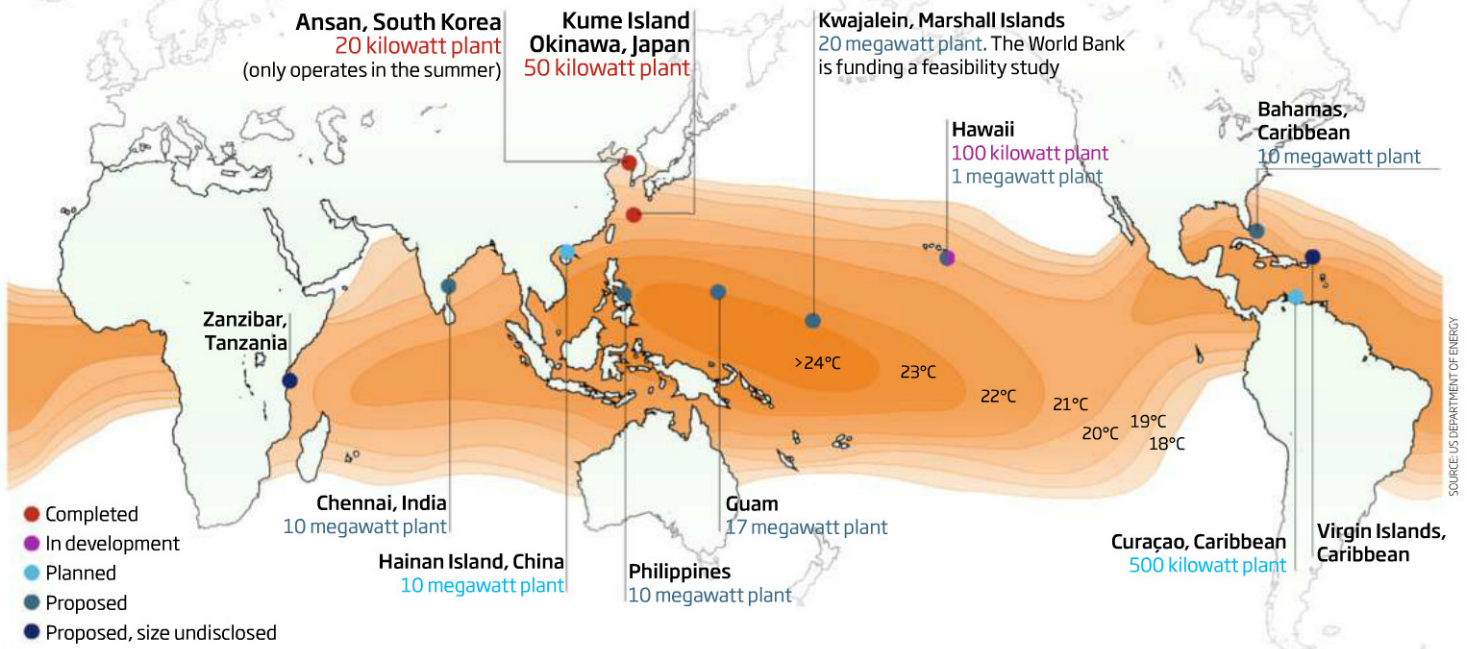
But what use is that power if the equipment needed to harness it costs more than the electricity it provides? Here, too, advances have been made. Lockheed Martin borrowed techniques from bridge and wind-turbine manufacturing – both of which use advanced fibreglass and resin composites to make their ultra-light, ultra-strong materials – to design a cheap pipe that is strong and flexible enough to withstand the stresses and strains of ➤



NIELS BUSCH/GALLERYSTOCK

Oceans of power

To create an ocean thermal energy conversion (OTEC) power plant, the **temperature difference** between the ocean's surface and deep waters must be at least 20°C. That means the world's existing and planned stand-alone OTEC plants all sit within the planet's warm "equatorial waistband"



ocean currents. Even better, it can be assembled on the ocean-surface platform of the OTEC plant itself and gradually lowered in as it is made, eliminating the risk of transporting the huge structure into position – and dropping it. A promising OTEC project in the Bay of Bengal had to be scrapped in 2003, after engineers building a 1-megawatt plant lost not only their first pipe but also its replacement.

Then there are myriad lessons from the offshore oil and gas industry, where it has become commonplace to operate in ocean depths greater than 1000 metres. These have made equipment available for commercial purchase that just 20 years ago would have needed to be designed from scratch.

Thanks to such developments, a 100-megawatt plant would cost about \$790 million to build, says Luis Vega, who researches OTEC at the Hawaii Natural Energy Institute at the University of Hawaii at Manoa. Taking the costs of building and running an OTEC plant into account, Vega reckons the price of the electricity produced would come in at around 18 US cents per kilowatt hour, not far from US Department of Energy estimates of 14 cents for coal with carbon capture and storage, and 14 to 26 cents for solar energy.

In this changed landscape, OTEC projects have begun to pop up all over the world. Last year, a 50-kilowatt pilot OTEC plant began operating on Kume Island in Okinawa, Japan. Meanwhile in Hawaii, Makai Ocean Engineering is building a 100-kilowatt plant at its Ocean Energy Research Center in Kailua-

Kona on the Big Island. This year, Bluerise, a spin-out from Delft University of Technology in the Netherlands, is planning to start building a 500-kilowatt OTEC plant close to Curaçao International Airport in the Caribbean. "These smaller islands are likely to be the first market, as they are all suffering from a dependency on expensive imported fuels," says Remi Blokker, CEO of Bluerise.

But they won't be the last. Recent advances promise to bring OTEC into the mainstream.

Various research groups have investigated

"Tropical islands will be the first market, as they rely on costly imported fuels"

the possibility of combining OTEC with solar power. Paola Bombarda at the Polytechnic University of Milan in Italy has modelled the output of an OTEC plant that uses solar power to increase the temperature of the warm ocean water before it is used to boil the ammonia. She found that even a low-cost solar collector – a simple device that traps heat in lenses or tubes – could triple a plant's daytime electricity output (*Journal of Engineering for Gas Turbines and Power*, vol 135, p 42302).

Similar techniques could help plants in countries that lie a bit too far north to rely on OTEC all year round, such as South Korea. In the summer months, the temperature

difference between the surface and deep water around South Korea exceeds the all-important 20°C minimum, but that isn't the case in winter. So to make it work year-round, engineers at the Korea Ocean Research & Development Institute (KORDI) in Goseong-gun are beginning to modify a 20-kilowatt demonstration plant so that heat from solar power, wind farms and waste incineration plants can pre-heat the incoming surface water before it meets the ammonia.

An even better idea would be to combine OTEC with another 24-hour power source. Hyeon-Ju Kim and his colleagues at KORDI are looking to geothermal energy, which taps heat deep underground, to boost the temperature of the seawater that boils the ammonia in a combined "GeOTEC" plant. Such tweaks could expand the "equatorial waistband" for productive OTEC plants by a factor of two.

In light of these rapid developments, OTEC has become promising enough that the prospect of its expansion has begun to ring alarm bells among environmentalists. Concerns have been raised by the US National Oceanic and Atmospheric Administration, among others, about the risk of algal blooms forming as nutrient-rich, bacteria-free water from the sunless depths is introduced to the hungry algae in warmer, sunlit waters. But computer modelling suggests that as long as the cold water is returned to the ocean at depths lower than 60 metres, the risk of algal blooms should be minimal, says Vega.

To eliminate even this modest risk, London-

based Energy Island has patented a design for an OTEC plant in which the ammonia vapour is no longer condensed into liquid at the surface but at depth. This means nutrient-rich water would never need to be pumped up to the surface, says founder Dominic Michaelis.

Another question being posed echoes previous concerns about the large-scale take up of other renewables: does OTEC have local and global effects on the environment, such as changing global temperatures?

Happily, research suggests we can ramp up OTEC production without affecting the ocean. Researchers at the University of Hawaii's Ocean and Resources Engineering department in Honolulu modelled the effect of widespread, commercial-scale OTEC production on the seas, including the global thermohaline circulation – the network of slow currents that transport deep water throughout the oceans. They found that OTEC plants could safely extract the equivalent of 7 terawatts of electricity, or nearly 50 per cent of global energy consumption, before they would have any noticeable effect on ocean temperatures (*Journal of Energy Resources Technology*, vol 135, p 41202). However, the authors acknowledge the difficulties of drawing strong conclusions about the environmental effects of OTEC.

It is certainly a good time to add a new form of renewable-energy generation to the mix, since climate change may have unforeseen circumstances for some existing clean technologies. In July, the US Department of Energy released a report on the energy sector's vulnerability to climate change, which found that higher temperatures could reduce the amount of fresh water available for both hydropower generation and concentrated solar power plants, whose superheated equipment requires water cooling.

By comparison, OTEC sweet spots don't



This power plant will feed ocean energy into Hawaii's electrical grid

appear to be vulnerable to climate change, says Robert Thresher, a research fellow at the National Renewable Energy Laboratory in Golden, Colorado. "Most of the OTEC resources are along the equator, and you wouldn't expect the sea surface temperature to dramatically change there," he says.

Out of the blue

Indeed, climate change might even increase the global output for OTEC by expanding the OTEC-friendly zone: "As the oceans warm with climate change, you might find warmer [surface] water further north and south from the equator," he says. Though the idea has also been proposed elsewhere, he hastens to add that this is "an intuitive notion" that would need to be confirmed by rigorous modelling.

More problematic is the suggestion that the deep oceans may have absorbed a great deal of the heat of climate change, which could reduce the all-important temperature difference of surface and deep water (*New Scientist*,

7 December 2013, p 34). However, according to research published last year by Magdalena Balmaseda and colleagues at the European Centre for Medium Range Weather Forecasts in Reading, UK, it is far from clear where exactly that heat is going. "The heat absorption is not uniform in space, depth and time," says Balmaseda (*Geophysical Research Letters*, vol 40, p 1754).

Whether or not the warm equatorial waistband OTEC relies on expands, the technology might not be limited to countries in the tropics for much longer. At the Offshore Symposium in Houston, Texas, in February 2013, SBM Offshore, which develops technology for oil exploration and drilling, revealed that it has been investigating designs for a 10-megawatt OTEC ship as a means of providing power to remote oil wells. OTEC plants become more expensive the further they are built from shore, but ships, which are cheaper to build, have no such constraints. OTEC ships could roam the seas in search of spots with the best temperature ratios, tethering to submarine cables to return power to shore.

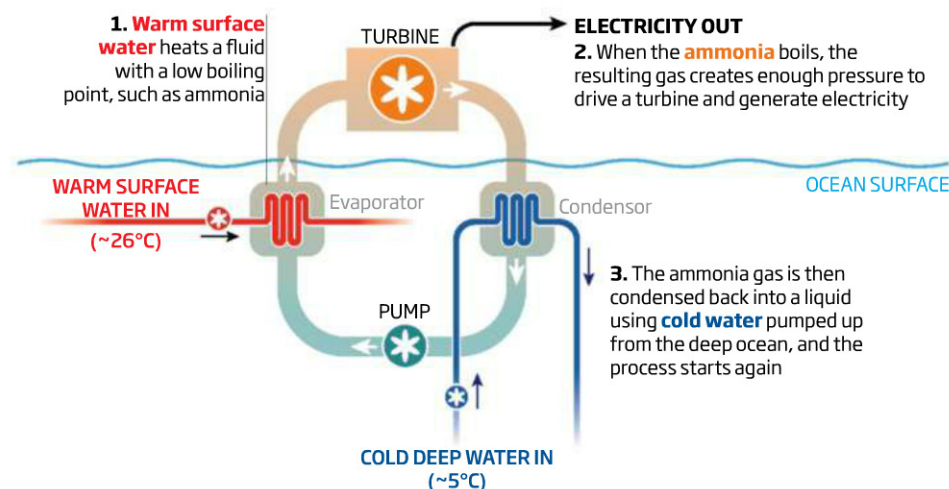
Indeed, proponents of the technology believe the future lies in OTEC ships that "graze" the oceans for electricity. To get around the problem of delivering it to shore by submarine cables, the electricity generated could be used in situ to split seawater into hydrogen and oxygen, with the hydrogen stored in fuel cells before being transported for use around the world. A 100-megawatt OTEC ship could produce 1.3 tonnes of liquid hydrogen per hour, says Vega, albeit at a present cost of about three times what a barrel of oil costs today. The hydrogen economy, after all, is still finding its feet.

Nonetheless, it appears, after all this time, that Jules Verne may have been onto something. If anything, he was thinking too small. Instead of a ship powered by the ocean, a fleet of ships may bring the ocean's energy to the world. Steampunk indeed. ■

Helen Knight is a writer based in London

Electricity from the sea

The temperature difference between deep and shallow ocean layers can be used to create a green source of electricity



The best I can be

Does a new generation of self help books work, asks **Kate Douglas**

Mindwise: How we understand what others think, believe, feel and want by Nicholas Epley, Allen Lane, £16.99

The Tell: The little clues that reveal big truths about who we are by Matthew Hertenstein, Basic Books, £17.99

Smarter: The new science of building brain power by Dan Hurley, Viking, £16.99

SELF help. Now try to keep an open mind. This is the world's bestselling genre, with around 45,000 titles in print. What's more, it has intellectual credibility. Today's cutting-edge titles are written by respected scientists and journalists, and include a sophisticated blend of neuroscience, psychology and philosophy.

It's only human to want to better oneself, if just to outsmart the competition. So we should applaud the trend to bring the latest insights from the human sciences to a wider audience. But, having read a fair few of these titles, I can't help noticing a distinct lack of personal growth. Sure, I know more about my brain, mind and behaviour, but am I a better person?

Nobody could doubt the credentials of my three recent guides. Nicholas Epley is a behavioural scientist at the University of Chicago Booth School of Business and apparently a "professor to watch". If you want to know what other people really think about you, he's your man, and in *Mindwise* he aims to improve your capacity for reading the minds of others. Then there's Matthew Hertenstein, a

psychologist at DePauw University in Greencastle, Indiana, who researches non-verbal behavioural cues. He promises to reveal all in *The Tell*. Finally, "award-winning science journalist" Dan Hurley justifies this accolade in *Smarter*, his exploration of the "new science of building brain power".

Mind-reading, prediction and intelligence; three books, three superpowers. How exciting! As I crack open my copies and rummage around in the blurbs, my inner cynic is overwhelmed by the promise of a new and better me.

First up, *Mindwise*. Epley begins by lauding the amazing human capacity to intuit what others are thinking. But pretty soon he is detailing its failings: we are overconfident in our mind-

reading abilities; we use our own mind as a template for others, yet confabulate wildly to make sense of ourselves; by stereotyping people we overemphasise differences; we are woefully poor at reading body language; and we constantly misapply our mind-

"Mind-reading, prediction and intelligence - three books, three superpowers. How exciting!"

reading talents, dehumanising others while imbuing inanimate objects with human traits.

It's compelling stuff. But as I read on, it becomes apparent that *Mindwise* isn't in fact about me. Despite Epley's convictions to the contrary, I will complete this

book review on time, and I already know that I shouldn't worry too much about what other people think of me, because they seldom do. At best, his protagonist is the average person, at worst, the American undergraduate who is the subject of most psychological research. That's not me. And while it is useful to understand the limitations of my mind-reading ability, what I really want to know is how to overcome them. In the last chapter, we finally get there: the best way to find out what someone else is thinking is... to ask them.

Disappointed, I move on to *The Tell*. Hertenstein promises to reveal my skill for making "reliably good predictions across many spheres of life". This sounds more promising. But a "tell" turns out to be just a hyped-up non-verbal cue, and much of the research is familiar. The real problem, however, lies in presenting this as news I can use - to spot a liar or a lover, for instance, or to predict whether someone is nice or will make a



Use it or lose it? Some activities may increase general intelligence

good leader. The trouble is that social science reveals general patterns, whereas I deal with individuals, and my judgements of them have consequences. Admittedly, Hertenstein advocates caution in using non-verbal cues, but then what good are they to me? Epley's prescription – just talk to people – is starting to look quite wise.

While I could consider the implications of Hertenstein's research for myself, I would much rather a fellow journalist and self-professed "skeptical bastard" does it for me. At the core of Hurley's *Smarter* is a dispute over whether intelligence can be increased. Hurley speaks to the main players, weighs up the evidence, and picks seven activities or treatments that promise the most. These include two types of short-term memory training, physical exercise, mindfulness meditation, learning a musical instrument, wearing a nicotine patch and a form of electrical stimulation of the brain. Then he puts them to the test.

His journey is very entertaining. Who will win the battle of minds? Will Hurley overcome the tribulations of the 6 am boot camp, the fiendishly difficult "N-back" cognitive test and the intricate fingering required to play the Renaissance lute, and reach the holy grail of increased intelligence? It is also thought-provoking, raising questions about what intelligence is, how it changes as we grow older, and whether we should try to improve it if we can.

I won't steal Hurley's thunder by revealing whether his personal experiment worked. Either way, remember, he is just one data point. And so is each of us. Which is why, if I want to be a better person, it's going to take more than a few self help books, no matter how statistically significant their content. ■

Kate Douglas is a feature writer for *New Scientist*



Complex systems like the internet might not be robust enough

Sumner, who worries about what happens when synthetic biology gets out of the lab. "Our children's children could be getting Bio-Lego for Christmas to build their own synthetic pets!" she says, warning that we cannot control how evolution might rewire synthetic life, or predict how such beings might change the ecosystem.

And futurist Melanie Swan foresees concerns over privacy rights for neural data as streams from sleep-monitoring devices expand to include data from eye-tracking glasses, wearable EEGs and portable MRIs.

As for ditching worries, cognitive scientist Benjamin Bergen nicely debunks the notion that children can be harmed by certain taboo words, for instance.

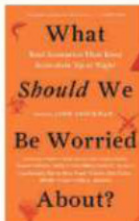
But this is where Brockman's game can both confuse and entertain, as different essays put forward, dismiss and reinstate fears. One of the most striking examples is the "singularity" – when artificial superintelligence outpaces humans. Tegmark has "little doubt that this can happen". But futurist Bruce Sterling says "the AI Rapture... [is] no more to be fretted about than a landing of Martian tripods", and philosopher Andy Clark claims "we should not fear that our Artificial Intelligences will soon match and then rapidly outpace human understanding, turning us into their slaves, toys, pets or puppets".

At the end of the exercise, Brockman's crew has left us with a net balance of new fears. But they also introduce us to some big ideas. As psychologist Daniel Goleman puts it: "Effective worrying focuses our attention on a genuine threat and leads to anticipating solutions." Or perhaps biologist Craig Venter is onto something when he writes, hopefully tongue in cheek: "As a scientist, an optimist, an atheist, and an alpha male, I don't worry." ■

Future shock

AI masters, synthetic life running riot...
It'll be a nightmare, says **Eleanor Harris**

What Should We Be Worried About?
Real scenarios that keep scientists up at night edited by John Brockman,
Harper Perennial, \$15.99



WARNING: read the subtitle of this book first. Its editor, cultural impresario John Brockman, may well have you

struggling to get your shut-eye as he sets out to keep us on our toes.

The trick this time lies in the tone of a book of answers to questions that Brockman poses annually to science's great and good on his Edge website. It's really not all good news.

In 2007, Edge asked what we were optimistic about. Six years later, the tone sounds like a pessimistic rejoinder: what should we be worried about? But with Brockman it's rarely simple. He invited people to share a scientific worry that might not be on the popular radar, or one they think should drop off the radar.

Some concerns read like dystopia mixed with moral panic,

and they surface time and again. There's the emergence of machines with superhuman intelligence (from physicist Max Tegmark and others), the dangers of relying on such fragile, complex systems as the internet (psychologist Randolph Nesse and others), and the impact of new tech on children (social scientist Sherry Turkle and others).

Other concerns seem more surprising, some expressed by rising stars who may live to do something about them. Take environmental economist Jennifer Jacquet. She fears that framing humans as the main drivers of environmental change –

"At the end of the exercise, Brockman's crew has left us with a net balance of new fears"

even though this is the case – will lead to further negative change, an idea she calls "the anthropocelebo effect". This psychological condition involves "a certain pessimism that makes us accept human destruction as inevitable".

Then there is biologist Seirian

ALAN POWELL/GETTY

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The candidate will possess a first degree in life sciences, significant post-graduate experience to a post-doctoral level and have good literacy, IT and mathematical skills. Experience with genetic techniques and / or understanding of next generation sequencing and a familiarity with quality management systems (the laboratory is accredited to CPA(UK)Ltd standards) would be useful. Clinical Scientist state registration would be a great advantage. A solid scientific knowledge combined with a logical approach is essential. The company has a considerable research portfolio.

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The IOSH Research Committee is developing a long term research strategy. This year we are inviting researchers to submit proposals (written in English only please) for high quality research that will support us, and our stakeholders, in providing an evidence base for effective OSH (occupational safety and health) research.

We will always consider any proposal that aims to support IOSH's strategic vision of a world of work which is safe, healthy and sustainable. However this year we are particularly interested in the following:

- Knowledge Mapping – proposals are welcomed that map out the OSH research landscape. This may include, funding schemes, funding bodies, gaps in research that IOSH may choose to fill and areas of synergy where IOSH may want to work in partnership with others. In this case we would encourage smaller, short time projects that last approximately 12 months.
- OSH Practitioner demonstrations – this year IOSH is particularly keen to receive bids from academics that intend to engage OSH practitioners as part of their field work. We would like to see practical high quality links between research and practice. Making use of working professionals to address real world problems.
- Non UK projects. IOSH would welcome applications where the study topic is not UK based. For example any project focusing on the needs of practitioners across the globe. Or that addresses emerging problems internationally.

Who can apply for funding?

Researchers who have a proven track record in high quality research can apply for funding. Applicants don't need to have a background in occupational safety and health research but should be able to demonstrate how their experience will bring fresh thinking to the development of occupational safety and health policy and practice. They should also have the research and project management skills to lead a successful proposal to completion.

Interested in applying?

If you're interested in applying for IOSH funding for a research project, and meet the eligibility criteria above, send in your application by the closing date **Wednesday 26 March 2014, 9:00am (GMT)**. For more information, visit: www.iosh.co.uk/researchcomp

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Microbiologist/Epidemiologist MRI 01-02-14 - The successful candidate will be an established leader in the field of microbiology/epidemiology, of relevance to veterinary target species (ruminants, pigs or poultry) The individual will lead on outcome driven projects which will relate to Moredun Research Institute's Strategy to improve the health and welfare of farmed animals through the prevention and control of infectious disease. The successful applicant will be a senior scientist of national/international standing. A proven ability to develop and lead innovative research projects in microbiology/epidemiology is essential, as well as a clear track record in securing substantial levels of external funding to support research.

APPLICATION FORMS AND FURTHER PARTICULARS:
CLOSING DATE: noon 17 March 2014

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Immunocore Limited, just south of Oxford, U.K., is an innovative and dynamic biotechnology company developing T Cell antigen receptors-based therapeutics as a novel class of treatments for cancer and other diseases. Having recently entered into three major partnerships with Genentech, GlaxoSmithKline and MedImmune, and with our first drug candidate in Phase IIa clinical trials and a pipeline of TCRs to follow, we are now looking for a Head of Development to oversee the transfer of partnered and in-house pre-clinical programmes into development.

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The Head of Development is a key position within the company, responsible for driving the strategic direction of the company's scientific work. The successful applicant will be required to:

- Transfer pre-clinical programmes into clinical development
- Oversee the technology transfer and outsourcing of GMP manufacture of Immunocore's projects
- Oversee the pre-clinical testing of Immunocore products, both externally and internally
- Be responsible for the selection of appropriate partners for the clinical testing of Immunocore's development candidates including the evaluation and selection of clinical trial sites and investigators
- Oversee all the clinical activities of the company
- Be responsible for the clinical project management, pharmacovigilance, data management, immunomonitoring, immunogenicity testing, pharmacokinetic analysis and medical monitoring
- Contribute towards the development of the Immunocore partnerships.

Suitable candidates will have a PhD in immunology, cellular biology or a related discipline and several years' experience in a similar role. Experience in development of oncology drugs from industry is desirable.

Excellent verbal and written skills are essential.



If you would like to join a growing, dynamic biotech company with a unique technology for novel cancer treatments and play an essential part in its future development please send your application (C.V. and covering letter) to Mrs Corin Canuto, Immunocore Limited, 57 Jubilee Avenue, Milton Park, Abingdon, Oxon OX14 4RX, or e-mail hr@immunocore.com

Closing date for applications: **7th March 2014**



Sustaining Innovation Postdoctoral Fellowships

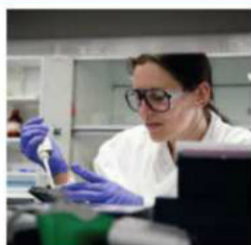
Astex Pharmaceuticals, a world leader in innovative drug discovery, has launched a new Postdoctoral training programme that aims to maintain and further enhance the Company's excellent scientific culture.

This is an opportunity to join a diverse and dynamic team exploring new ideas that are relevant to drug discovery.



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... AND UNLOCK YOUR POTENTIAL



Astex scientists have pioneered Fragment-Based Drug Discovery, generating multiple new drug candidates that are progressing through clinical development.



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Key features of the Sustaining Innovation programme include:

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- ***Opportunities to pursue cutting-edge research in a well-resourced, highly driven industry environment***
- ***Regular meetings to foster scientific rigour, creative thinking and critical reasoning***
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For further information visit our website **www.astx.com/about/careers**

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CDT in Healthcare Innovation

Applications Now Open for the Centre For Doctoral Training in Healthcare Innovation - Up to 7 Fully Funded Doctoral Studentships - start date October 2014

The Centre for Doctoral Training in Healthcare Innovation concerns healthcare innovation and, specifically, training the next generation of biomedical engineering (BME) researchers. These researchers need not only to be well-equipped with a knowledge of modern BME principles and techniques, but also need to be well-versed in the principles and application of translational research skills (i.e. have an appreciation of the potential healthcare impact of technology advances, principles of clinical trials and commercialization of research). Such training will lead to higher quality research, explored in more depth, and we expect graduates from our programme to go on become leaders in the BME field in academia or the healthcare industry.

This is a 4-year PhD programme. The Research Councils UK (RCUK) Digital Economy Programme is supporting the cost of running the CDT for six intakes of students, and is funding 6 studentships for an October 2014 start. Funding by the RCUK is bound by the standard eligibility regulations i.e. Full studentships are available to UK candidates and Partial studentships (fees only) are available for EU candidates.

Further details of the programme may be found online at:
www.ibme.ox.ac.uk/training/cdt

Application deadlines for October 2014 entry: **14 March 2014**



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Tel: +44 (0)20 7942 5998

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Opportunities for POSTDOCTORAL RESEARCHERS in Biomedical Research

at the Spanish National Centre
for Cardiovascular Research CNIC,
Madrid - Spain

The CNIC is dedicated to excellence in cardiovascular research and to translating new knowledge into real improvements in clinical practice.

The scientific project of the centre has been structured in three areas:

- Cardiovascular Development and Repair Department (CDR)
- Vascular Biology and Inflammation Department (VBI)
- Epidemiology, Atherothrombosis and Imaging Department (EAI)

To be eligible, candidates must:

- Hold a PhD degree that must have been awarded no more than five years ago (exceptions will be made for documented career breaks and candidates with children)
- Have, at least, one publication as first author in an international peer reviewed journal
- Candidates must not have resided or carried out their main activity in Spain for more than twelve months in the last three years

The CNIC can offer you:

- A 3-year contract
- An internationally competitive salary
- State of the art infrastructure and latest generation of technological equipment
- Scientific-technical support and complementary training

Deadline for submission of proposals: 4 April 2014

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For further information and applications, please, visit www.cnic.es



Opportunities for YOUNG GROUP LEADERS in Biomedical Research at the Spanish National Centre for Cardiovascular Research CNIC, Madrid - Spain

The CNIC is dedicated to excellence in cardiovascular research and to translating new knowledge into real improvements in clinical practice.

The scientific project of the centre has been structured in three areas:

- Cardiovascular Development and Repair Department (CDR)
- Vascular Biology and Inflammation Department (VBI)
- Epidemiology, Atherothrombosis and Imaging Department (EAI)

To be eligible, candidates must:

- Hold a PhD/ MD degree
- Demonstrate a minimum of three years' postdoctoral/post MD experience in centres of international reference
- Candidates must not have resided or carried out their main activity in Spain for more than twelve months in the last three years

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- Scientific-technical support and complementary training

Deadline for submission of proposals: 21 April 2014

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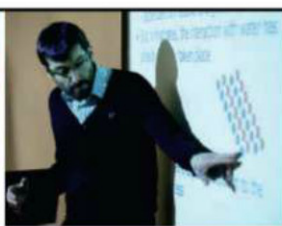
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Lecturer in Physics

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The Stephenson Institute (www.liv.ac.uk/stephenson-institute) has expanding interests in physics, chemistry and engineering for renewable energy, and the Department of Physics (www.liv.ac.uk/physics) has a strong presence in the fields of PV materials and devices, nanoscale and surface physics of materials. It has won leadership of a Centre for Doctoral Training in New and Sustainable Photovoltaics.

We are seeking to appoint an individual with research interests relevant to the Institute. Your research work will have an experimental focus and should be aligned to photovoltaic materials, advanced characterisation, or devices and you will be expected to contribute to the objectives of the new CDT in PV. Strong applicants in other energy science fields will be considered, for example in nanotechnology, new energy sources and storage or conversion. You will demonstrate a capacity to work in an energy-related field and join a new collaborative team of 11 academics. The post is available from October 2014 or as soon as possible thereafter.

Job Ref: A-573791/NS

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Closing date for both posts: 21 March 2014

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We are looking for a motivated candidate who is willing to learn and acquire new techniques of bone cell biology.

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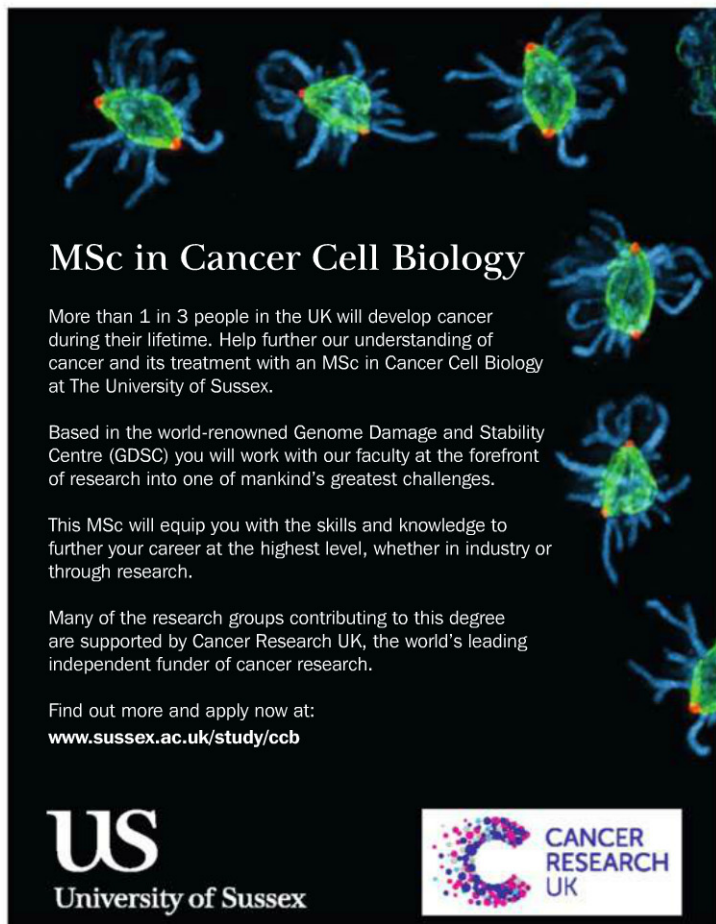
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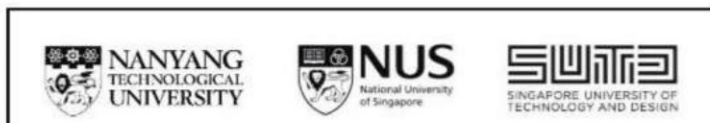
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- Cyber Security
- Machine Intelligence – Software Architecture as Autonomy Enabler

For more information and application procedure, please visit:

NTU – http://www3.ntu.edu.sg/trf/index_trf.html
NUS – <http://www.nus.edu.sg/dpr/funding/trf.html>
SUTD – <http://www.sutd.edu.sg/trf>

Closing date: 21 April 2014 (Monday)

Shortlisted candidates will be invited to Singapore to present their research plans, meet local researchers and identify potential collaborators in July / August 2014.



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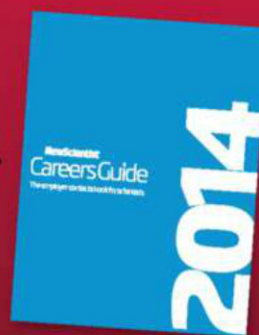


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NewScientist Jobs



PAUL McDEVITT

SUCCUMBING, as we expected, to temptation and seeking entertaining mis-predictions in *New Scientist's* 1964 vision of *The World in 1984* (25 January), Feedback starts with the low-hanging fruit.

In 1964, Wernher von Braun was Director of the George C. Marshall Space Flight Center in Huntsville, Alabama. He was self-assured about the glorious future of this post. "Man may have landed on the surface of Mars by 1984," he began. "Manned 'fly-bys' of Venus will have been made... Astronauts will be shuttling back and forth on regular schedules from the Earth to a small base of permanent operations on the moon."

Then he went more sci-fi, proposing nuclear-powered upper stages of rockets. He naturally presumed that, as a result, "the existence of a low order of life on Mars will probably have been proven" by 1984 and, quite remarkably, "the significance

of the seasonal changes of the Martian canals established."

And then he announced the Grand Mission: "Gradually, space exploration has become a kind of standard behind which dynamic men with their courage, fighting instincts and talents have begun to rely for their advancement. Wars, which had somewhat similar 'rallying' effects, are no longer feasible..." For historical depth, he offered the view that "the Crusades saved Europe much bloodshed by diverting the energies of its fighting men to a far-away objective".

IT WAS Wernher von Braun, of course, who enthusiastically co-opted the work of the pre-war rocket research club the *Verein für Raumschiffahrt* - portrayed as naive amateurs in Thomas Pynchon's novel *Gravity's Rainbow* - into the development of the V2 rocket for the Nazis. Von Braun guided its production by concentration-camp labour, though

he denied visiting the Mittelbau-Dora camp. In the US, he enthusiastically shifted to developing the V2 into intercontinental ballistic missiles. Thus 17 of the 98 other contributors to *The World in 1984* wondered whether there would be a civilisation in 1984, given the threat of those nuclear-tipped missiles (11 January).

A SIGN on the inside of the door leading into the kitchen area at the research institution where geneticist Jon White works says: "This is a fire door. Please keep closed at all times."

Jon says he is currently unable to check whether there is a similar sign on the outside of the door: "I'm in here now and my family are beginning to worry."

SEQUENCING the DNA of a 3-year-old who died 12,600 years ago in the foothills of the Rocky Mountains created much excitement last month (15 February, p 8). This may explain the title of a report in *Science* on 14 February: "Ancient Infant Was Ancestor of Today's Native Americans". Will Howard asks: "What's wrong with this headline?" Feedback confesses it took us several deep thinks to get it. Hint: he was 3...

PROSAIC justice - that was the name we suggested for the risk we run by pointing out other publications' errors, as above. Elizabeth Spiegel and Ian Boehm point us to a lovely note from the Canberra Society of Editors in 2003, suggesting that we, in fact, risk falling foul of "Muphry's Law" - named by John Bangsund of the Victorian Society of Editors as "the editorial application of the better-known Murphy's Law," which holds that if it can go wrong, it will. Read the piece in full at bit.ly/muphry-law.

MUPHRY was indeed at work: while this page was in production, we spotted that *New Scientist* itself said that the 3-year-old boy "turns out to be a direct ancestor of most tribes in Central and South America" (15 February, p 8). Whoops...

FEEDBACK's request for help checking a translation of a sign on Arriva Trains Wales elicited a generous response. In English, it reads "Failure to adhere to this notice may result in prosecution" (1 February).

The company declares in Welsh: "*Gallwch gael eich erlyn am beidio ag ufuddhau'r hysbysiad hwn.*"

A famous web search engine rendered this as: "You can be sued for failing to obey this notice." Five readers wrote in: three pointed out that if it knew the difference between criminal and civil legal action, it would have given "prosecuted", not "sued".

Regarding Arriva's Welsh, John Rowlands suggested that "*ufuddhau'r arwydd hwn*" strictly means "make the sign obey", which could be time-consuming



enough to make you miss your station as effectively as if you had adhered yourself to it. Daphne Watkins admonished herself for missing that, but agreed with John that only a purist could object. As if Feedback would ever entertain the notion of purism.

FINALLY, John Gee in Aberystwyth writes that "a legitimate meaning of 'adhere to' is 'to behave according to' [and that] 'notice' as a noun refers to intelligence, warning or instruction to do (or not do) something". We can only respond: if thou wilt, John.

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

One of the products offered by John West in Australia is "naturally smoked oysters": David Prichard would like to know where in the world you find them - volcanic vents, perhaps?

Chaotic kip

Last night I slept really well but today I have spent the whole day feeling tired. On the other hand, I sometimes have a poor night's sleep and I am just fine the next day. How can this be?

■ Your brain may have slept well last night, but did your body get adequate rest, especially if you went to bed tense with worry? In her book *Stress and Relaxation*, Jane Madders talks of people who go to sleep so keyed up, with their jaws and fists clenched tightly, that it's no wonder they wake up exhausted.

Studies looking at the electrical conduction system of the heart during physical workouts have shown that muscles have plenty of reserve for continued contraction even after a person feels they have reached their limit. And it's common for athletes to experience a "deep tiredness" after very intensive training – even at times in the circadian rhythm when the brain is set for wakefulness.

It transpires that feelings of tiredness are a brain construct, which is separate from the hard-wired daily sleep cycle. Indeed we might make some sense of the chaos we sometimes feel by thinking of sleep as a means of refreshing the brain itself, and tiredness as a separate function that protects the body and organs from genuine overwork by forcing us to rest.

A related factor behind feeling drained the next day is low

overnight blood sugar. This is more likely after a physically active day because the muscles will take more sugar from the blood to replenish their glycogen store. Alcohol consumption earlier in the evening can cause overnight lows through its delayed effect on glucose release by the liver. To combat this have a light carbohydrate snack or non-

"Insomniacs who complained of lying awake were actually observed to have spells of sleep"

stimulant milk drink before bed to trigger an insulin surge, but make sure you avoid sugar.

On the other hand, did you really sleep poorly when you felt fine the next day? In one study,

insomniacs who had complained of lying awake all night were actually observed to have had several spells of sleep.

Nothing has caused more sleep loss than fretting over whether you are getting enough, but it has been shown that bright awakenings depend more on the phase in the sleep cycle you wake from than on the total amount of sleep you get.

You will emerge fresh from the lightest phase of sleep, called type 1, and from the light dreaming sleep that intersperses successive sleep cycles. A night dotted with catnaps each shorter than 15 minutes (ending before you enter deeper sleep), or a single stretch of one-and-three-quarter hours (thus ensuring you have returned to type 1, having gone

through the deeper and restorative types 2, 3 and 4), may provide all the sleep and bodily rest you need. But an alarm clock that wakes you during type 4 sleep could see you groggy and grouchy all morning.

Waking with the feeling you need more and more sleep – known as "sleep fat" – can sometimes result from too much sleep. In these ways, sleep and rest, and shortfalls thereof, can act either for or against us.

*Len Winokur
Leeds, UK*

This week's questions

DREAM ON

Why do I have recurring dreams, years after I left university, of being about to sit an exam but knowing nothing of the subject matter? I'm not alone, lots of people I speak to have the same.

*Guy Jones
Altrincham, Cheshire, UK*

FINGERS OF SOL

Can anyone explain the pattern seen here in the sky (left)? It was spotted in the Pyrenees at about 8 am. We were heading east and although it gradually faded, it lasted for some time. The mountain pass over which the light is shining is at an altitude of 2000 metres and there is nothing in the next valley or mountain that could explain the pattern.

*Simon Houghton
San Sebastian, Spain*



The writers of answers published in the magazine will receive a cheque for £25 (or US\$ equivalent). Answers should be concise. We reserve the right to edit items for clarity and style. Include a daytime telephone number and email address if you have one. We are pleased to acknowledge financial support from Statoil in producing The Last Word. New Scientist retains total editorial control over the content.

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THE DARK SIDE OF THE MOON

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