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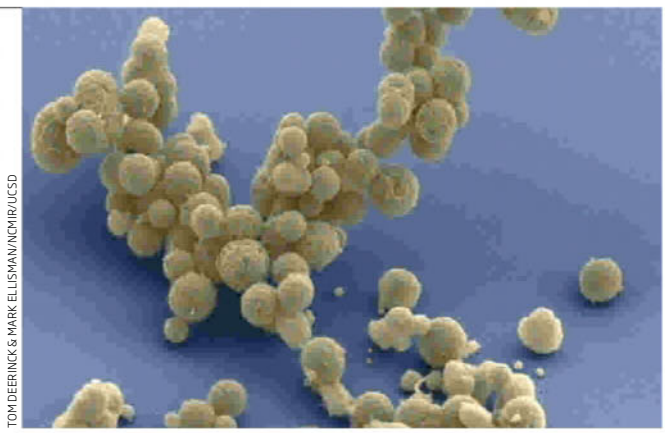

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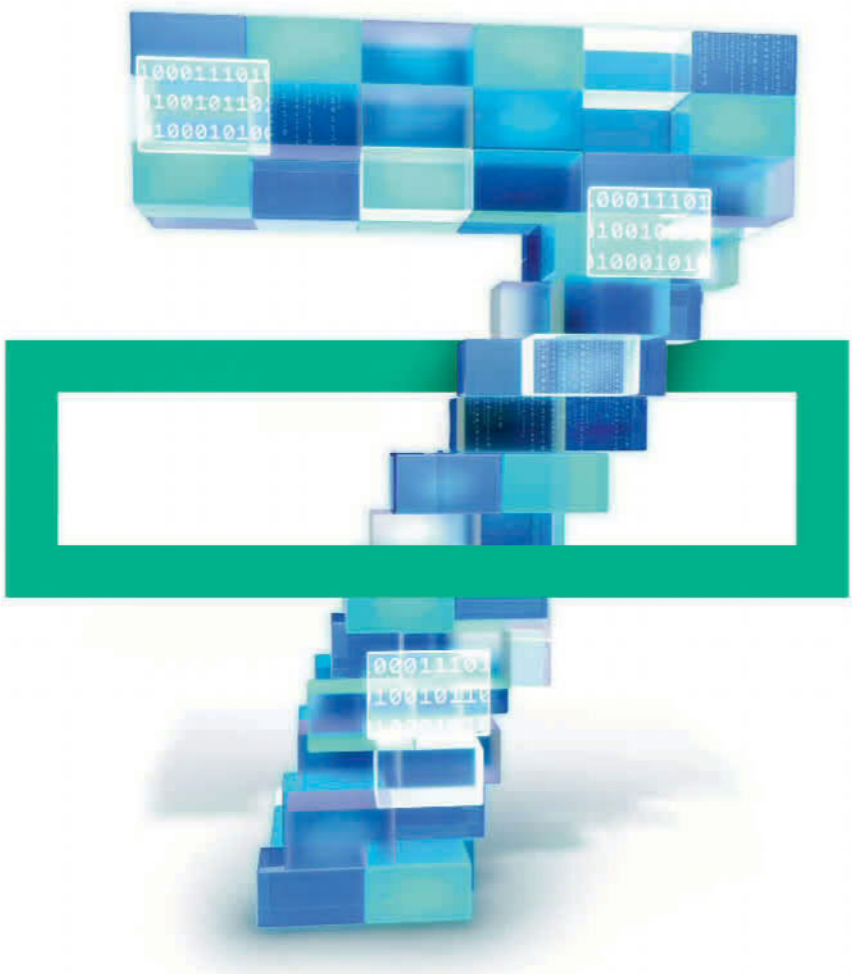

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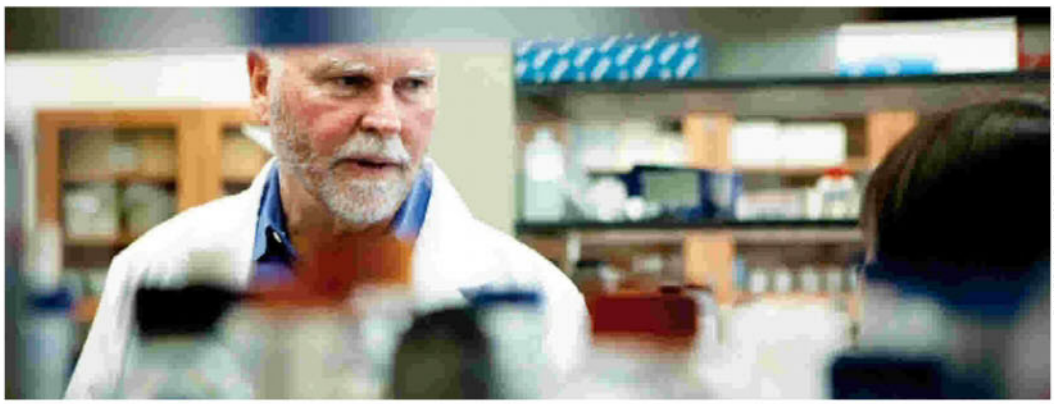


ELI MEIR KAPLAN/FOR THE WASHINGTON POST VIA GETTY

Bare necessities

Exploring the essentials of life isn't about playing God

HAVE we found the essentials of life? A team in the US has reduced the number of genes in a modest bug called *Mycoplasma mycoides* by almost half, creating the tiniest genome that can support vital survival functions (see page 6).

The new strain is called JVCI-syn3.0, the letters coming from the name of the J. Craig Venter Institute in La Jolla, California. The institute is named after the charismatic biotechnologist who is almost as well known for his swagger as for his scientific achievements. The first human genome to be fully sequenced was Venter's own, and he has in the past drawn opprobrium for attempting to patent genes. His apparent grandiosity irks more buttoned-down colleagues. And his ambition prompts those averse to genetic engineering to invoke inchoate risks, frequently buttressed by the claim that it amounts to "playing God". This time, Venter's rhetoric has been reined in a little. The genome of JVCI-syn3.0, while put together on a computer and assembled by DNA sequencers, includes no new or artificial genes. If anything, its creation shows the limits of our power and depth of our ignorance: we have no idea what a third of the genes the team found actually do.

But now we can start figuring out what the essentials of life really are. That will, Venter insists, invigorate synthetic biology, with benefits for all of us: he, and others, want to design organisms that can make biofuels, protein or vaccines more efficiently.

Since Venter made his first synthetic cell in 2010, however, the ease of gene editing has exploded. This allows scientists to tweak genomes far more cheaply than building them from scratch. The CRISPR technique, which has itself generated much ethical controversy, might end up the more practical and widespread method. Either way, far from wilfully taking risks – playing God, if you really must – synthetic biologists are developing the expertise to address very human needs. Venter's bullish approach has brought that a step closer. Let him swagger. ■

To err should be inhuman

NEURAL networks, like the ones grabbing headlines for winning boardgames or driving cars, depend on huge amounts of computing hardware. That in turn means a colossal amount of power: the next wave may consume millions of watts each.

That's one reason why some suggest we rethink what we want computers to be. Reducing the precision with which they analyse problems, and putting up with the odd "error", can cut zeroes off their energy consumption (see page 36). And it has precedent in the human brain – an unrivalled piece of hardware using electrical fluctuations and requiring a million times less power than a computer.

Introducing error will also make computers better at handling the real world. Neural networks, loosely modelled on the brain, capture some of its problem-solving capacity. AlphaGo surprised opponents and designers alike with Go moves described by some as "intuitive".

Computers that play Go, understand human language and behaviour, spot patterns across databases of genetic information or forecast economic and climate trends do not deal in absolutes. It is their rough guesses that will bring us closest to comprehensive artificial intelligence. ■

ADAM BERRY/GETTY

Can we sniff out bombs?

LAST week, terrorists walked into Brussels' Zaventem airport and detonated bomb-laden luggage in the check-in area. They also bombed a subway station. As *New Scientist* went to press, 35 people had been killed and hundreds wounded.

Can we stop attacks like this? Airport security focuses on keeping explosives off planes. Stopping bombs detonating in crowded check-in areas and transit terminals is a bigger challenge. Security checkpoints work, but they cause delays and create queues that can also be a target. But there are new ways to scan people as they walk.

Cameron Ritchie, head of technology at the US-based security firm Morpho, is working on a "tunnel of truth". Passengers would be scanned by an array of sensors as they walk through the tunnel to get into airports or train stations.

The Lincoln Laboratory at the Massachusetts Institute of Technology has a different approach. A team there has turned to lasers to "sniff" explosives from a distance. The lab says it can scan spaces like check-in areas from 100 metres away by sweeping them with lasers tuned to frequencies that vaporise molecules found in bombs. This material makes a tiny sound as it vaporises, which is amplified and detected.

Lasers are also used in a device called G-Scan, developed by Laser Detect Systems of Ramat Gan in Israel. This fires a green laser at a target then uses Raman spectroscopy to "fingerprint" the molecules that scatter light back. It can identify anything visible, including bottle contents or surface smears.

Detecting explosive material from a distance would enable security services to track down bomb-making supplies – not just finished weapons. By scanning for telltale chemicals on people's bodies and clothes as they move around cities, security services may be able to catch suspects before they have built their device.

One concern is that such sensitive detectors may trigger many false alarms. There is also the question of whether airport and train security staff can respond to a positive signal quickly and effectively enough to neutralise a threat, says Brian Jenkins, a security researcher at the Rand Corporation. "You can't just yell, 'hey you with the bomb'."

Satellite lost

JUNKED? Hitomi, a Japanese astronomy satellite, seems to be tumbling through space, and may have broken up. It was due to come online on 26 March, but failed to communicate with Earth.

A tweet by the US Joint Space Operations Center reported five pieces of debris around the satellite shortly afterwards.

All may not be lost. The Japan Aerospace Exploration Agency heard a brief burst of signal from the craft, and video taken from the ground suggests it is falling through space.

"That indicates the sat was at that point alive, just unable to point its antenna at Earth," says Jonathan McDowell at the Harvard-Smithsonian Center for Astrophysics. He says it might be possible to talk to Hitomi and stop it tumbling. "But if you told me we were never going to hear from the sat again, I would be devastated but not surprised," he says.

"If we never hear from the satellite again, I would be devastated but not surprised"

Hitomi's mission is to observe the universe in X-rays, investigating matters such as the birth of black holes and the origins of cosmic rays.

Space geckos

IN A few years, the exterior of the International Space Station could be crawling with geckos. It's not an alien invasion, or the plot of a low-budget sci-fi movie. The robotic geckos could follow from an experiment NASA launched to the International Space Station last week aboard an uncrewed Cygnus spacecraft.

The Gecko Gripper devices use tiny artificial hairs that replicate the ones geckos use to climb walls. They are designed to help

astronauts keep track of objects in zero gravity, and enable robots to crawl around a spacecraft to inspect and repair it.

The bots have already been tested on parabolic aircraft flights, where they grabbed and manipulated 10-kilogram and 100-kg objects during 20-second periods of microgravity. On the ISS trip, astronauts will test the system by attaching five devices in a range of sizes to 30 surfaces inside the space station at different angles, to check how well they grip. The devices will be left in place for periods of time between two weeks and a year.

Zika's arrival traced

ONE person carried the Zika virus to the Americas a full two years before its detection there last year.

Brazil was the first country in the Americas to report Zika, in May 2015, and the virus has since infected hundreds of thousands of people in 33 countries. The virus is native to Africa but in the last 10 years it jumped to some of the islands of Micronesia and Polynesia in the Pacific.

A genetic analysis suggests the virus in the Americas came from an individual infected in Polynesia, and that it arrived between May and December 2013. "One person with the infection was bitten by a mosquito and that chain of infection persisted," says Oliver Pybus of the University of Oxford (*Science*, doi.org/bdrx).

It isn't surprising it took two years for Zika's presence to come to light. Its symptoms closely resemble those of dengue and chikungunya viruses, which were already circulating.

"Zika in the Americas came from an individual infected in Polynesia, and it arrived in the second half of 2013"

HIV prevention

IT SAVES money and prolongs lives, but who should pay – the UK health service or local councils?

Trials around the world have shown that Truvada, an antiviral drug, helps prevent uninfected, at-risk people from getting HIV. After 18 months of negotiations, it looked certain that NHS England would foot the bill if Truvada was rolled out across England. Instead, on 21 March NHS England announced it would mount a two-year, £2 million pilot study of 500 men at high risk of infection to assess the efficacy and cost. NHS England also backed away from funding the drug, saying that the bill should be met by local authorities, which provide other HIV services.

"After 18 months, it's galling to be told that," says Sarah Radcliffe at the National AIDS Trust charity. She says there is abundant evidence that Truvada is effective and cuts healthcare costs.

Teresa O'Neill of London Councils says the capital has the country's highest rates of HIV so councils there would face a high bill. She points out that it costs £380,000 to treat an HIV-positive person for life, versus £4700 to supply Truvada for a year, so you'd have to take the drug for 80 years before it became more expensive.

Catastrophic Antarctic melting

A MASSIVE rise in sea level is coming, and it will trigger climate chaos around the world. That was the message from a controversial recent paper by climate scientist James Hansen. It was slated by many for assuming – rather than showing – that sea level could rise by between 1 and 5 metres by 2100.

But now, just a week after being formally published, it is being backed up by another study. "He was speculating on massive fresh water discharge to the ocean that I don't think anybody thought was possible before," says Rob DeConto of the University of Massachusetts-Amherst. "Now we're about to publish a paper that says these rates of fresh water input are possible."

DeConto's model includes factors that previous studies omitted. First, floating ice shelves around Antarctica will soon be exposed to above-zero summer air temperatures, speeding their melt, he says. Second, once the shelves are gone, the huge ice cliffs that remain will begin to collapse (*Nature*, DOI: 10.1038/nature17145).

DeConto's findings suggest that even if countries meet the pledges made as part of the Paris agreement, global sea level could still rise 1 metre by 2100. If emissions keep climbing it could go up more than 2 metres.

"Today we're measuring global sea level rise in millimetres per year," DeConto says. "We're talking about the potential for centimetres per year just from Antarctica."

COLIN MONTEATH/HEDGEHOG HOUSE/MINDEN

Still there... for now

60 SECONDS

Bleach bum

It's a white-out for the Great Barrier Reef. An aerial survey last week showed that at least 95 per cent of the reef's northern 1000 kilometres has been severely bleached. It's the worst case in history, says the National Coral Bleaching Taskforce, which carried out the survey. Bleaching is caused by high sea temperatures and can kill coral.

Apple vs FBI

The stand-off is over, for now. The FBI has successfully broken into the iPhone belonging to San Bernardino gunman Syed Rizwan Farook, bringing to a halt its legal battle with Apple. In court documents filed on Monday, the FBI said it no longer required Apple's assistance to access files on the phone, although it hasn't made public how it did it.

Stroke protection

Giving mice antibiotics can protect them from brain damage caused by stroke. Antibiotics change the make-up of the mice's gut bacteria, which in turn alters the immune cells that travel to the brain and would normally cause inflammation. The treatment appears to reduce cell destruction by around 60 per cent (*Nature Medicine*, doi.org/bdrw).

Green boom

More than twice as much was spent on new capacity to generate electricity from renewables like solar and wind than on power stations that burn fossil fuels last year. China was responsible for two-thirds of the renewables investment in the developing world, and 36 per cent of the global total.

Permafrost pups

Two puppies that lived 12,460 years ago have been discovered perfectly preserved in permafrost in the northern Russian region of Yakutia. Last week, one of them underwent an autopsy so that its organs can be compared with those of modern dogs and wolves.

Smallest ever genome comes to life

Humans built it, but we don't know what a third of its genes actually do

Andy Coghlan

WE HAVE even further to go to understand life than we thought. In creating the latest landmark synthetic organism – the world's first minimal genome – Craig Venter and his team have discovered that we don't know the functions of almost a third of the genes that are vital for life.

"Finding so many genes without a known function is unsettling, but it's exciting because it's left us with much still to learn," says Alistair Elfick, a bioengineer at the University of Edinburgh, UK. "It's like the 'dark matter' of biology."

Venter, founder of the J. Craig Venter Institute in La Jolla, California, has long hoped to unravel life's essential toolkit.

Now his team has created the first minimal genome – the tiniest possible stash of DNA capable of supporting life. With 473 genes, the new cell, JCVI-syn3.0, has at least 50 fewer genes than nature's record-holder for the shortest genome in a self-sustaining living organism, *Mycoplasma genitalium* (*Science*, doi.org/bdrz).

The feat builds on JCVI-syn1.0, the first living bacterium reliant on a synthetic copy of an existing genome, unveiled by Venter in 2010. That genome was designed in a computer, before assembly and insertion into cells.

Since then, Venter and his colleagues, co-led by Clyde Hutchison, have been whittling down the 901 genes of JCVI-syn1.0 to the minimum for supporting life. With the help of transposons – "jumping genes" that insert themselves into sections of DNA and disrupt individual genes – the team tested which genes a bacterium can do without. They then designed a stripped-down genome, and inserted it into an existing cell that had had its own genome removed.

But their first attempts at a minimalist cell didn't succeed. "Every one of our designs failed because we based these on our existing knowledge base," says Venter.

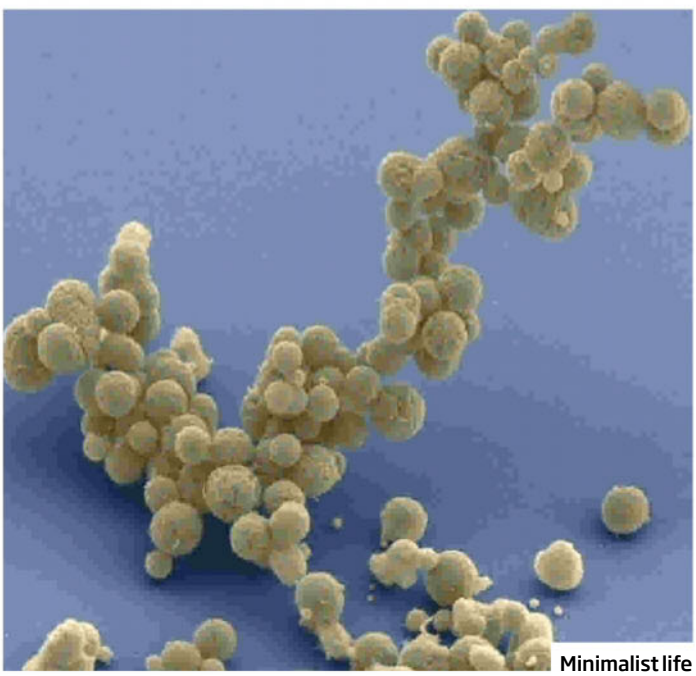
Their breakthrough came when they realised that some genes they thought were expendable were actually crucial. "To get a viable cell, the researchers needed to make discoveries about many essential and semi-essential genes that we did not know about," says Steven Benner of the Foundation for Applied Molecular Evolution in Alachua, Florida.

Surprisingly, some 31 per cent of the vital genes have no known function, suggesting we may still have much to learn about the cellular processes crucial to maintaining life. "It means we know about two-thirds of essential biology," says Venter.

Hutchison says it is an "exciting possibility" that some of these genes perform key functions we don't know of yet.

It's unclear how genes of such universal importance have ducked under the radar for so long. One possibility is that the mystery genes do actually code for known functions, but their sequences are so different from their equivalents in other organisms that we have not been able to spot and identify them.

Once these mysterious extra genes were included, the minimal cells were found to live, grow and divide, forming clumps of cells in a dish of nutrients.



TOM DEERINCK & MARK ELLISMAN/NCMIR/UNIVERSITY OF CALIFORNIA AT SAN DIEGO

Minimalist life

Bacterial Eden

Of the genes with known functions, most make proteins vital for survival, or check the fidelity of genome duplication when the cell divides. Other essential genes include ones that code for cell-membrane proteins and those that enable the organism to turn nutrients into energy.

But Venter's organism was produced in a bacterial Eden with every comfort provided, including a plentiful energy supply of easy-to-process glucose. In a harsher environment, such as soil or water, it would need extra genes to compete with rivals for resources, and to survive and

LIFE FROM SCRATCH? NOT YET

The design of the first synthetic minimal genome hints at new ways to build life. So can we do this from scratch? Not quite.

For a start, the genome is based on a slimline version of one from a naturally occurring bacterium. The genes were not dreamed up by people, but had already evolved in nature. Also, to make the minimal genome, researchers didn't create any new genes or biological functions, but simply dumped those not essential for keeping the cell alive.

Then there was the cell itself. Once the genome was designed from code on a computer, it had to be put inside a living cell stripped of its own, native genome. That cell also came from a living natural bacterium that had all the intricate cellular machinery already in place. And the process revealed we have no clue what a third of those vital genes do. So the ability to create life from scratch without nature's help is still way beyond our capabilities.

grow using scarcer sources of nutrients. "It is likely that their degree of 'essential-ness' will be environment-specific," says Elfick.

Next, the team plans to work out the functions of the mystery genes. What they find out could yield insights into how genes can be repurposed for synthetic biology, or enable us to design entirely new genomes for the first time (see "Life from scratch?", below left).

"What we've done is important because it is a step towards completely understanding how a living cell works," says Hutchison. "If we can really understand this, then we will be able to design cells efficiently for the production of pharmaceutical and other useful products."

"Finding so many genes without a known function is exciting. It's like the 'dark matter' of biology"

Bioengineers have applauded the feat, but some are sceptical about the commercial potential. Some believe it is cheaper and more effective to tweak existing natural genomes, using techniques such as gene editing, than it is to build new genomes from the bottom up. "It's a milestone," says George Church of Harvard Medical School, who is a pioneer of CRISPR gene editing. "But the market will tell you if it's valuable."

Such efforts to design synthetic life forms are often referred to as playing God, and frequently raise fears about their possible impact on the environment and human health. "If we're already playing God, we're not doing a particularly good job of it," Elfick says. "Simply streamlining what's already in nature doesn't seem very God-like and, if anything, is a very humbling exercise."

He says we should not worry about this synthetic cell: "There are plenty of bugs already out there we should be much more worried about." ■

ONE MINUTE INTERVIEW

Tiny but mighty

A bacterium that can thrive with the smallest feasible string of synthetic genes is no vanity project, says **Richard Kitney**

FEDERICO DE LUCA

PROFILE

Richard Kitney is a professor of biomedical systems engineering at Imperial College London, and co-director of the Centre for Synthetic Biology and Innovation. He was not involved in Craig Venter's research

What is the main advance with the creation of the smallest synthetic genome, JCVI-syn3.0?
What Craig Venter's team has done in making this minimal genome is to identify clear gaps in our knowledge about what makes a cell survive. They have essentially removed sections of the genome one by one to see what happens – in other words, to see if it dies and to try and understand why.

What new insights has the bacterium given about life's minimum requirements?
The failure of a predecessor organism with even fewer genes led to the refinement of the rules for designing a genome, and identified a group of indispensable genes with functions we now need to investigate.

What do you make of the fact that almost a third of the genes in syn3.0 have no known function, yet seem essential to life? What might they be doing?
This is partially because of the incomplete state of knowledge within the field. As Venter's team also points out, the tools used to match genes in syn3.0's genome to comparable ones with known functions in other organisms may have failed to identify some genes because their sequences differ too much. It is of course an intriguing question as to what any unidentified genes do.

Does the fact that Venter borrowed the "shell" of a different organism as a host and provided a perfect environment for growth detract from his achievement?
Borrowing the shell of a naturally occurring bacterium is of course a major simplification of the technical challenge of making a synthetic organism. But it did allow the team to concentrate on the problem of genome minimisation – a very large endeavour on its own. Because the researchers chose a rich growth medium, they could snip out many functions from the original host, as these are not needed when food is plentiful. What all this highlights is that there is in fact no universal minimal cell, only a minimal cell for a given set of conditions.

Does the work offer clues about how life began?
No, it tells us nothing about how life started naturally.

There has been criticism that such work is a vanity project with no real scientific worth. Do you agree?
Venter and his colleagues are serious researchers who are pursuing an important goal, so this is absolutely not a vanity project. It is an important step towards meeting synthetic biology's need for stable, well-understood host cells that make and do useful things for us.

Does it take us closer towards creating living organisms from scratch?
This is not really a step forward in that sense.

And where will the work go next?
What is clear is that the host genome as presented has quite a way to go in terms of extending the catalogue of usable organisms available for synthetic biology.

Interview by Andy Coghlan

Did a cosmic cloud kill off the dinos?

Shannon Hall

A NEBULAR winter could have doomed the dinosaurs. The clue is a thick layer of an extraterrestrial element on the ocean floor, now claimed to be the result of Earth colliding with a galactic cloud.

The most-heard explanation for the dinosaurs' demise is an asteroid impact, which left a crater off the coast of Mexico and a worldwide 30-centimetre-thick layer of iridium, an element otherwise rare on Earth.

But every so often, astronomers suspect, the solar system ploughs into a giant nebula of molecular gas and dust much denser than typical interstellar space. The resulting galactic fog would have darkened skies and cooled the ground until a harsh winter set in. It would also have destroyed the ozone layer and halted photosynthesis.

Now Tokuhiro Nimura of the Japan Spaceguard Association in Ibara and colleagues claim such a collision could have ended the dinosaurs' 150-million-year reign. At a site in the Pacific Ocean, the team found an iridium-rich sediment layer 5 metres thick, too thick for a sudden event like an asteroid strike to account for it.

They argue that a collision with a giant molecular cloud – which could take Earth at least a million years to pass through, picking up iridium steadily as it does so – fits the discovery much better. "Such an encounter and related perturbation in global climate [is] a more plausible explanation for the mass extinction than a single impact event," they write (arxiv.org/abs/1603.06136).

Adrian Melott at the University of Kansas in Lawrence says the idea is wacky but not impossible. "We know that these clouds exist," he says. "We know that we're likely to run into one sooner or later. And they have some evidence from the ocean floor in favour of their idea."

Others question that evidence. David Kring at the Lunar and Planetary Institute in Houston, Texas, argues that the deposit could have been disturbed by currents, organisms and drilling, broadening the layer locally.

"There have been several studies specifically designed to determine the thickness of the iridium anomaly," he says. "They all indicate the anomaly is sharp, not broad," which would favour the impact hypothesis.

Even so, a collision with a cloud could have dislodged rocks from the fringes of the solar system and sent them hurtling toward Earth – perhaps explaining the crater and leaving a thin iridium layer intact.

We could test this idea by searching the ocean floor for radioactive elements likely to be replenished from space, like uranium and plutonium, says Alexander Pavlov at NASA's Goddard Space Flight Center in Maryland. Most uranium isotopes aren't even found in the solar system, so finding them along with iridium would prove that something interstellar, like a vast nebula, was the true culprit. ■

LYNN HILTON/ALAMY STOCK PHOTO

No escaping this winter

Asteroid shower brought a sea to young, dry Mars

MARS may once have had an ocean – but only for a geological eye blink. This puts a dampener on ideas that there is or was life on the Red Planet.

That's according to a theory from Tim Parker of NASA's Jet Propulsion Laboratory in Pasadena, California. Speaking at the Lunar and Planetary Science Conference in The Woodlands, Texas, in March, he argued that a sustained barrage of asteroids hitting the young Mars could have delivered short-lived water to the surface.

Signs that Mars was once rife with water litter the surface. These include polygonal cracks seen by NASA's Opportunity rover. On Earth, these require evaporation to form, so Parker sees them as an indication that the rover is traversing what was once the edge of an ocean. "The uniformity of the surface is much easier to explain in a shallow marine setting," he says.

But models of the ancient Mars climate require a thicker atmosphere to keep water liquid on the surface. This atmosphere must have somehow been rapidly lost to leave Mars as dry as we see it today.

Now Parker and his colleagues say a tumultuous time in the solar system's history known as the late heavy bombardment could provide the water with no need for a major change in the atmosphere. During this period about 4 billion years ago, a barrage of asteroids is thought to have collided with the inner planets. Such asteroids could have brought water to an initially dry Mars, says Parker.

"This ocean would have frozen and disappeared – leaving very little time for life to evolve"

Because Mars's atmosphere was so thin, this ocean would have frozen and disappeared after just a few hundred million years – allowing very little time for life to evolve.

"Tim is always thinking outside of the box," says Devon Burr of the University of Tennessee, Knoxville. "There are a variety of ways of warming Mars and getting liquid water, I don't know if the late heavy bombardment, for me, is conclusive."

Jacob Aron ■

Prairie dogs are serial killers of ground squirrel

IT WAS thought to be just a small, furry grass-nibbler, but the white-tailed prairie dog has another life – as a serial killer. Some prairie dogs bite their ground squirrel neighbours to death on a regular basis, the first time that a mammalian herbivore has been seen killing other herbivores.

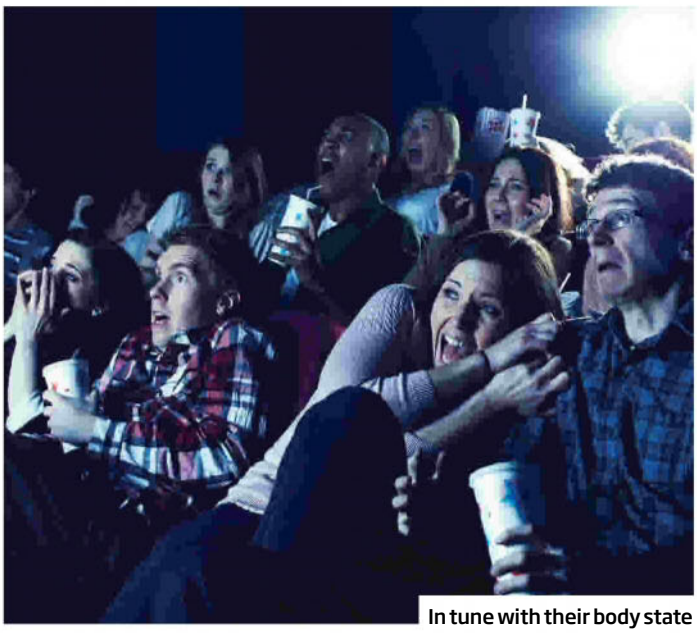
What's more, those who kill go on to produce more surviving offspring, improving their evolutionary fitness, say John Hoogland, a biologist at the University of Maryland Center for Environmental Science, and Charles Brown of the University of Tulsa, Oklahoma. The duo recorded 163 killings of the squirrels over six years in the Arapaho National Wildlife Refuge in Colorado.

Hoogland describes the killings as quick, subtle and unanticipated. While some prairie dogs chased the squirrels, others stalked them, waited outside their burrows or even dug babies out of their holes. They bit them to death, then abandoned the carcass and resumed foraging on nearby vegetation. "The killer supreme killed seven babies from the same litter in one day," says Hoogland.

Over the six years, about 47 prairie dogs killed squirrels, and 19 of them were serial slayers, including one female who dispatched nine squirrels over four years (*Proceedings of the Royal Society B*, doi.org/bdpv). For squirrels a competitor species can be as much of a risk as a predator. Aisling Irwin ■

JOHN HOOGLAND

Not going to eat that...



BRAND NEW IMAGES/GETTY

In tune with their body state

'Fearless' twins show body affects emotions

IS FEAR all in the mind – or body? Experiments on twins who can't feel fear are suggesting that some emotions rely on us becoming aware of changes to our body.

Many studies have shown that the amygdalae, two almond-shaped structures in our brain, are crucial for feeling fear. People who have lost them through injury or disease also lose the ability to feel most kinds of fear.

In 2013, Justin Feinstein, then at the University of Iowa in Iowa City, and his colleagues managed to scare three "fearless" people – two female identical twins and a woman known as S. M., all of whom had had their amygdalae destroyed by illness. Feinstein made them inhale carbon dioxide, giving them the sensation of choking. This was the first time that S. M. had experienced fear since she was a child. It showed that the amygdalae are not essential for all kinds of fear.

One theory of emotion suggests that feelings are not generated directly by the brain, but through an awareness of our body. When we see a spider, for example, the theory says we feel fear not because emotional centres of the brain are activated, but because the brain evaluates the situation and releases hormones such as adrenaline that increase our heart rate and give us sweaty palms. It is our awareness of these changes to our body that we interpret as fear.

"This seems to be evidence that extreme panic has different circuitry from normal fear"

Now Feinstein's colleague Sahib Khalsa, at the University of Tulsa, Oklahoma, and his team have given the fearless twins a drug that mimics the action of adrenaline. High levels of this drug can cause temporary breathing difficulties and rapid heart palpitations. The team asked the twins and a group of volunteers with intact amygdalae to rate their experience of these changes on a scale from 0 to 10.

Both twins had the same physical reaction as the other volunteers – their heart and breathing rates increased. But only one twin said she was aware of both these changes, rating her breathing problems as a 10 on the scale. She also reported a choking sensation and had a panic attack.

The volunteers also noted breathing difficulties and a quarter had panic attacks. The other twin noted a slight awareness of her heart rate changing, but she rated her physical symptoms as close to zero and did not panic.

The results indicate that there are mechanisms beyond the amygdalae that are involved in fear and anxiety, and support the theory that an awareness of physiological changes may be necessary to experience some kinds of emotion (*The Journal of Neuroscience*, doi.org/bdpz).

However, the fact that the twins – who both have damaged amygdalae because of a rare genetic condition – had different responses suggests there may be environmental factors at play, too.

"This seems to be more evidence that extreme panic has its own underlying circuitry that is different from normal fear," says Nick Medford, who studies consciousness and emotion at the Sackler Centre for Consciousness Science in Brighton, UK.

Further experiments involving scanning the twins' brains while they experience fear would help us identify mechanisms of emotion in the brain, says Khalsa.

Such studies could also lead to alternative treatments for anxiety disorders. There is some evidence to suggest that people who have abnormal awareness of their bodily functions are more prone to anxiety and depression.

"If you could pinpoint neural regions responsible for our awareness of our body state and the different mechanisms that generate fearful feelings, you might have new targets to modulate or reduce anxiety," says Khalsa. **Helen Thomson** ■

Emissions reveal a constructive side

Richard Schiffman

TAKING carbon dioxide out of the atmosphere is crucial to slowing the progress of climate change. But rather than lock all that CO_2 away underground, what if we could use it to make things? That's the aim of a pilot plant at the University of Newcastle near Sydney, Australia.

Launched last week, the plant will test the commercial potential of mineral carbonation, a process that forms stable materials by chemically binding CO_2 to minerals containing calcium or magnesium. The plant will bind the gas into crushed serpentinite rocks to create magnesium carbonate, which can be used to produce cement, paving stones and plasterboard.

It could be a way of "permanently and safely disposing of CO_2 and making useful products in the process", says Klaus Lackner of Arizona State University in Tempe, who pioneered the technique in the lab.

The process happens naturally when rocks are gradually weathered by exposure to CO_2 in the air. This helped cut the proportion of the gas in the ancient atmosphere to levels low enough for life to flourish, says Geoff Brent, senior scientist at Orica, an explosives manufacturer based in Melbourne. His firm is supplying the plant with CO_2 – a by-product of making ammonium nitrate.

But we can't afford to wait millions of years for geology to rid the atmosphere of our greenhouse emissions. "It's about turning the natural process into a large-scale industrial process on our required timescale – which is extremely urgent," says Brent.

There are several challenges. Mining for serpentinite is energy-intensive and damaging to the environment, for one thing. But Brent says the rock is one of the most common on Earth, and that carbonation plants could be built near mining areas to reduce transport emissions.

Another objection is that mineral carbonation costs too much compared with storing CO_2 underground. However, underground storage has its own problems: suitable repositories are hard to find and there is a risk that the gas may one day escape.

"Carbonation is more secure in the long term, because there is no danger of leakage and no need to maintain long gas pipelines and transportation infrastructure to move the CO_2, since we will be obtaining it on-site," says Brent.

"The whole point of the project is to get the price down low enough," says Marcus Dawe, CEO of Mineral Carbonation International, the firm coordinating the effort. "It is all about how we can make this economical."

Dawe and his team are optimistic that they will make progress by the end of the 18-month pilot project. But for mineral carbonation to take off, there will need to be a higher price on carbon, says Dawe, because right now "nothing is more economical than putting CO_2 in the air". ■

MINERAL CARBONATION INTERNATIONAL

Made with greenhouse gases

Is calcium boost behind brain zap effects?

WE MAY finally be figuring out how an increasingly popular therapy that uses electricity to boost the brain's functioning has its effects – by pushing up levels of calcium in cells.

Transcranial direct current stimulation (tDCS) has been linked to effects such as accelerated learning and improving the symptoms of depression. It involves using electrodes to send a weak current across the brain, which proponents think changes the electrical properties of neurons, leading to changes in their connectivity.

But the cellular mechanisms that lead to such broad neurological changes are not clear and some are doubtful that tDCS has any effect on the brain. Despite this, devices are being developed to sell to people keen to influence their own brains.

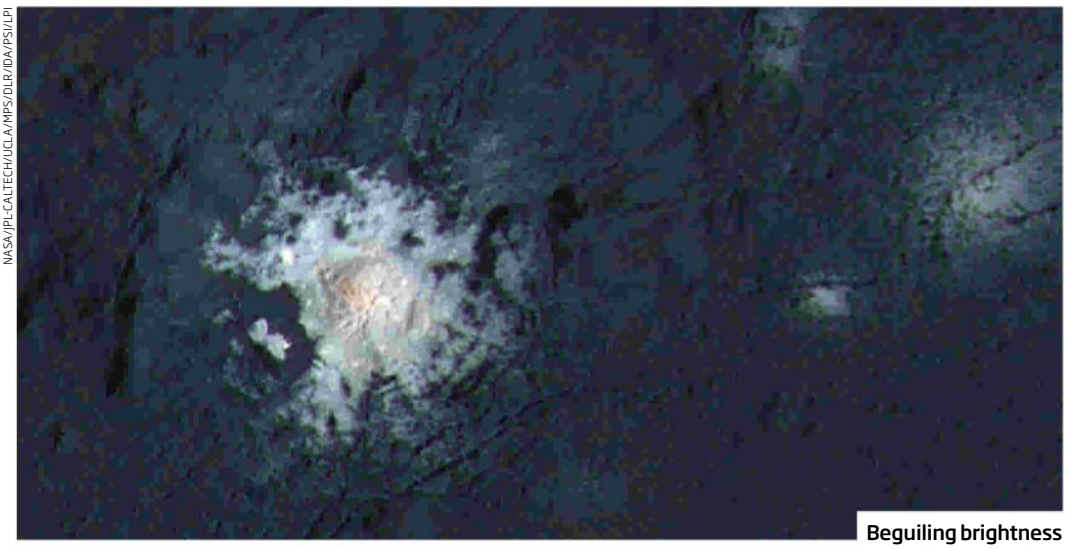
Now Hajime Hirase at the RIKEN Brain Science Institute in Tokyo, Japan, and his colleagues have an answer. They have identified sudden surges in calcium flow in the brains of mice seconds after they receive low doses of tDCS. The surges start in star-shaped cells called astrocytes that strengthen connections between neurons and regulate the electrical signals that pass between them.

The team used mice that had been engineered to show depression-like symptoms, such as struggling less against restraints. After they had received tDCS, the mice struggled for longer. The same effect didn't happen in mice whose calcium signalling had been disabled (*Nature Communications*, doi.org/bdr2).

"By triggering calcium surges, tDCS may be interfering with neuron connectivity"

Astrocytes use calcium to manage the flow of information between neurons, and these findings suggest that tDCS artificially boosts the process. Hirase thinks calcium signalling may also be behind other suggested effects of tDCS, such as improved memory.

Understanding the link between tDCS and calcium could dispel doubts about the technique. "Scepticism is not so much about tDCS itself as it is about inflated expectations," says Walter Paulus of the University of Göttingen in Germany. Sally Adee ■



NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA/PSI/LPI

Beguiling brightness

Bright spots and ice dazzle on Ceres

Jacob Aron, The Woodlands, Texas

LET'S take a look inside. The latest from NASA's Dawn probe, which has been in orbit around the dwarf planet Ceres since April last year, suggests this tiny world has water ice on the surface and craters that provide a window on its interior.

A spectacular view of the beguiling bright spots at the heart of the 92-kilometre-wide Occator crater from just 375 kilometres up, shown above, was just one of the latest findings unveiled by the mission team at the Lunar and Planetary Science Conference in The Woodlands, Texas, on 22 March.

These spots have perplexed researchers since Dawn first reached Ceres, the largest object in the asteroid belt. Probing their nature could give clues to Ceres's interior. In the new image, Dawn has seen colour variations across the surface of the bright regions. These wouldn't be visible to the human eye, but reflect possible differences in the composition of the material seen by Dawn.

This close-in view reveals that the central bright spot actually sits within a 10-kilometre-wide depression inside the crater. At the centre of that is a small mound. "We're starting to see how complex the distribution of the bright material is," said Carol Raymond of NASA's Jet Propulsion Laboratory in California.

How this arrangement formed is still a mystery. Timothy Bowling at the University of Chicago presented a possible explanation, in which a meteorite smacked into Ceres, exposing icy material from as much as 40 kilometres below the surface and heating it up. As this material settled into the Occator crater we see today, the water would evaporate, leaving bright salt and minerals behind.

"Seeing water ice anywhere on Ceres is a surprise – it is warm enough at the surface for it to evaporate"

The floor of Occator is also riddled with fractures that seem to be older than the crater itself. These could have provided an escape route for material beneath the surface.

The team behind Dawn has also made an unexpected discovery: water ice hiding in a crater. The 10-kilometre-wide Oxo crater seems to have formed relatively recently. The find comes from spectral data taken during Dawn's higher orbit in June last year.

Seeing water ice anywhere on Ceres is a surprise as it is warm enough at the surface for any ice to evaporate into space. That means it must have been exposed recently, said Jean-Philippe Combe of the Bear Fight Institute in Winthrop, Washington. "This area is possibly a cold trap where H_2O-rich materials could be preserved for at least some time," he said.

So where has this water come from? Models of Ceres's formation, along with the sightings of bright spots like the ones at Occator, suggest the dwarf planet has an icy sub-surface layer that is mixed up with salt and rock. The ice at Oxo could have been exposed by a landslide, or dug up by a meteorite.

Dawn will continue to gather data about Ceres until August at least, and possibly into next year. But some questions about this enigmatic world may not be answered until a repeat visit. "It would be nice to land there, wouldn't it?" said Raymond. ■

How to stack oranges in 24 dimensions

IT'S a tight squeeze. Mathematicians have proved that they know the best way to pack spheres in eight and 24 dimensions – the first time this problem has been solved in a new dimension for almost 20 years.

"I think they're fantastic results. I'm excited that this has been done at last," says Thomas Hales at the University of Pittsburgh, Pennsylvania.

The sphere-packing problem asks a deceptively simple question: what arrangement crams the most spheres into a limited volume? It is easy to describe, but difficult to prove.

In 1611, Johannes Kepler suggested that the best arrangement for 3-dimensional spheres like oranges is a pyramid. But it took until 1998 for Hales to publish a proof – and another 16 years to formally verify it.

Meanwhile, mathematicians have been gunning for higher dimensions. Now, Maryna Viazovska at Humboldt University of Berlin has proved that a grid called the E8 lattice is the best packing in eight dimensions (arxiv.org/abs/1603.04246v1). Almost immediately after, she teamed up with other researchers to prove that a related arrangement called the Leech lattice is best in 24 dimensions (arxiv.org/abs/1603.06518v1).

The fact that these dimensions were next to fall is no coincidence. For reasons we don't understand, such lattices don't show up in other dimensions. But they were suspected to be the most efficient arrangements in the dimensions they apply to.

"These are unbelievably good packings," says Henry Cohn at Microsoft Research New England in Cambridge, Massachusetts. "The spheres in these dimensions fit perfectly, in ways that don't happen in other dimensions."

Packing spheres in 24 dimensions isn't just a mathematical game. The problem has applications in wireless communication, and has been used to communicate with spacecraft in the distant solar system. Lisa Grossman ■

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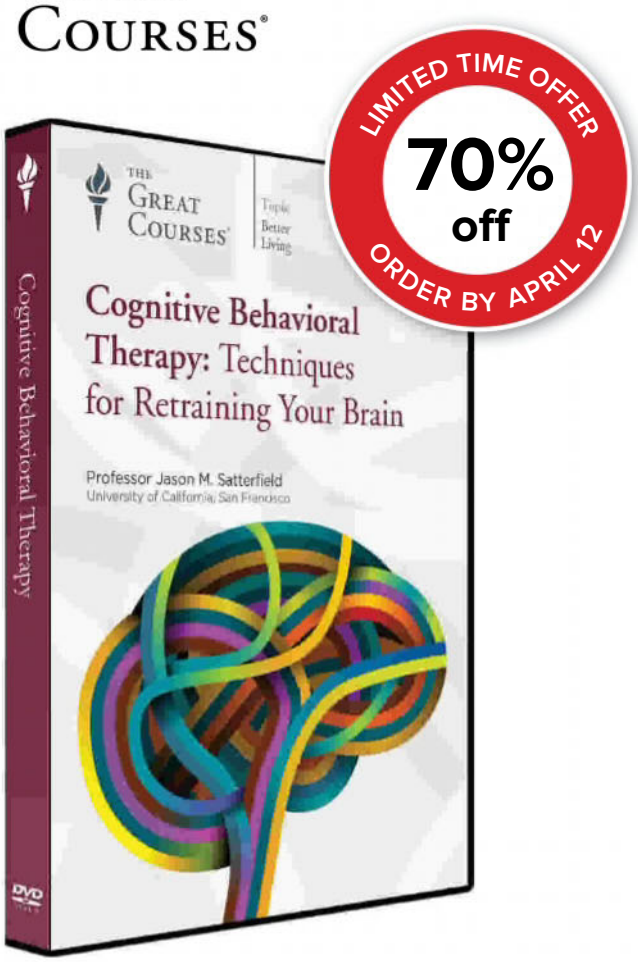

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JOHN WATKINS/FLPA/CORBIS

Migrating birds arrive in the UK earlier and leave later

SOME common migrating birds – including the blackcap, (pictured above) – are staying in the UK for two weeks or more longer than half a century ago. "We knew that birds were arriving earlier in spring, but this is the first study I know of in Europe that has also tracked when they leave in autumn," says Stuart Newson of the British Trust for Ornithology.

Newson has tapped into amateur observations of bird migrations collected over more than 50 years, starting with paper files in the 1960s and ending with 800,000 records from BirdTrack, an internet-based volunteer observation network, to study 14 common migrating birds. He found that 11 species arrive earlier and four leave later (*Ibis*, doi.org/bdpr).

Amateur data is best, he says. Professional ornithologists have mostly counted birds arriving at a handful of coastal observation points. And many previous studies concentrated on dating the first birds to arrive. Observations from citizen scientists avoid such biases, and cover leaving times too.

One reason for late leaving could be that females are laying more than one clutch of eggs thanks to the longer breeding season, says Tim Sparks of Coventry University, UK. Indeed, the study also shows that birds taking most advantage of earlier springs and balmy late autumns, such as the blackcap, are increasing in number.

Ghost galaxies are full of dark matter

THERE'S more than meets the eye. A so-called ultra-diffuse galaxy has been found to consist of over 99.96 per cent dark matter.

An ultra-diffuse galaxy is a huge galaxy with relatively few stars widely spread out, so it looks ghostly and is hard to study.

The fact that they hold their shape makes researchers think such galaxies must consist of at least 98 per cent dark matter – the stuff thought to make up about 80 per cent of the mass in the universe overall. But no one had directly measured it.

Now Michael Beasley at the Institute of Astrophysics of the Canary Islands, Spain, and his colleagues have "weighed" an ultra-diffuse galaxy in the Virgo cluster named VCC 1287.

The team measured the speeds of seven globular star clusters orbiting the galaxy, a clue to how much mass it contains, and found that it must have about 80 billion times more mass than the sun and 3000 times more dark matter than stellar mass (*Astrophysical Journal Letters*, doi.org/bdpb).

VCC 1287 was probably born with both dark matter and gas but lost the latter as it fell into the Virgo cluster. Without gas, it couldn't create new stars, so it ended up with lots of dark matter but little light.

Exercise keeps your brain younger

YOUNG in body, young in mind. Older people who are physically active seem to stave off memory loss – but only if they start early.

Clinton Wright at the University of Miami in Florida and his colleagues followed 876 people, starting at an average age of 71, over five years. At the end, the brains of non-exercisers looked 10 years older than those who did moderate exercise. Those who exercised also showed less memory loss (*Neurology*, doi.org/bdpw).

These effects are associated with better vascular health, suggesting that exercise helps the brain by keeping down blood pressure and preventing strokes.

But the team's results showed that physical activity can only delay memory loss if a person begins exercising before the onset of symptoms. "Once there's damage, you can't really reverse it," says Wright.

Why we have really big noses…

IT'S an evolutionary mystery that's literally as plain as the nose on your face. Why did our ancestors develop a prominent protruding nose when most primates have flat nasal openings?

A new study suggests that our unusual nose may simply be a by-product of other, more important changes in the structure of our face as our brains enlarged.

Takeshi Nishimura at Kyoto University, Japan, and his team modelled the flow of inhaled air through the nasal passages of humans, chimpanzees and macaques. It turns out that our noses, unlike those of other primates, are poor at warming or cooling air that goes to the lungs (*PLoS Computational Biology*, DOI: 10.1371/journal.pcbi.1004807).

Leaded ink opens up ancient scrolls

LEAD often gets a bad press. But its discovery in ancient Graeco-Roman ink could make it easier to read an early form of publishing – precious scrolls buried by the eruption of Mount Vesuvius in AD 79.

Some 800 scrolls, part of the classical world's best-surviving library, have tantalised scholars since they were unearthed in a villa in the ancient Roman city of Herculaneum in 1752. About 200 are in such a delicate state that they have never been read. Unrolling the charred scrolls could destroy them, so people have been X-raying the bundles in the hopes of decoding the writing inside. But progress has been slow – it is difficult to detect the difference between the letters and the papyrus they are written on.

Now physicist Vito Mocella of the Italian National Research Council and his colleagues have discovered lead in the ink on two Herculaneum papyri fragments held in the Institute of France in Paris. The presence of lead means that imaging techniques could be recalibrated to pick up the metal, something X-rays excel at (*PNAS*, doi.org/bdn5).

"This really opens up the possibility of being able to read these scrolls," says Graham Davis, at Queen Mary University of London. "If this is typical of this scroll or other scrolls, than that is very good news."

E BRUN

Violent pirouette spun off the moon's water

BALLET doesn't suit everyone. Molten rock flowing beneath the moon's crust billions of years ago shifted its spin axis by about six degrees. The pirouette could have cost the moon most of its water.

We saw the first direct evidence of water on the moon in 2009, when a deliberately crashed satellite found hydrogen – a proxy for water – in a southern crater. There was more there than at the actual pole, a little more than five degrees away, says Matthew Siegler of the Planetary Science Institute in Tucson, Arizona.

While scrutinising maps of the lunar composition, Siegler noticed that the highest concentration of hydrogen at the north pole is also a few degrees away from the true pole, but in the opposite direction.

"They are on exact opposite sides of the moon from each other. It's as if you drew a line through the centre of the moon from those two points," he says.

This indicates that the moon's polar axis used to follow that line, but shifted. Based on its direction, Siegler and his colleagues think the shift was caused when lava flowing up from the lunar interior formed the Procellarum region. The volcanism would have changed the distribution of the moon's mass, spinning it around (*Nature*, doi.org/bdn9).

That pirouette could have cost the moon much of its water. When the poles shifted, frozen water would have been exposed to the sun and evaporated. That helps to explain why the moon is so dry, and suggests that much of the lunar water is leftover from early in its life.

Fungi may help woodpeckers drill

IF A red-cockaded woodpecker wants a home, it does more than just knock on wood – it takes some tiny helpers with it. It seems to carry spores of wood-rotting fungi to each new hole.

Red-cockaded woodpeckers live in the pine forests of the south-eastern US, where they dig tree cavities to live in. Each family has cavities at different stages of construction. It's no quick bodge job – a hole can take years to craft.

Michelle Jusino of the US Forest Service Center for Forest Mycology Research in Wisconsin and her colleagues have found a wide range of fungal spores on the birds, including many that cause wood decay and are found in cavities that woodpeckers dig.

To see whether the birds bring the fungi to the cavities, the team drilled holes in 60 trees, covering half with screens the woodpeckers can't get through. After 26 months, accessible holes had fungal communities that were more similar to those found in natural woodpecker cavities than to inaccessible holes. This suggests the birds do disperse fungi, although any benefit to them is still unproven (*Proceedings of the Royal Society B*, doi.org/bdn7).

NATALIE SHUTTLEWORTH/GETTY

Parasites, mew give me road rage

CATS can make us angry. Scratching our furniture, waking us up – and giving us parasites that may cause explosive rage.

Toxoplasma gondii is a parasite carried by cats that lives in the brains of as many as a third of all people worldwide. Now the parasite has been linked to a psychiatric condition involving disproportionate outbursts of aggression, like road rage.

Emil Coccaro at the University of Chicago and his colleagues compared 110 people with intermittent explosive disorder (IED) with people who have no psychiatric diagnosis.

They found that people with IED were more than twice as likely to test positive for exposure to *T. gondii*. In both groups, those who tested positive tended to rank more highly in tests for aggression (*Journal of Clinical Psychiatry*, doi.org/bdpq).

Coccaro thinks the parasite may be altering neurotransmitters in the brain. However, the correlation doesn't necessarily mean that *T. gondii* is causing the explosive rage. Aggressive people may be less likely to wash their hands, making them more likely to catch the parasite, for example.

Get deep in the game

After years of hype, the moment is finally here. **Douglas Heaven** introduces the games that will kick-start the VR revolution

WHEN a small company called Oculus announced that it was building a virtual reality headset in 2012, it sent expectations soaring. The hope was for a device that might finally deliver on the promise of VR – which had become the butt of jokes after a run of false starts in the 1980s and 90s. The moment of truth will arrive this week, when the Oculus Rift launches – along with a few dozen games that aim to kick-start the VR gaming revolution.

The line-up includes games that let you conquer Everest, repair an orbiting space station and even take part in a ballet. One, *Job Simulator*, even puts you in a world where robots have replaced human workers and simulations are the only way to experience a life of nine-to-five employment.

The Rift, which launches on 28 March, will be joined on 5 April by the Vive, made by HTC and Valve. Sony's Playstation VR system is due in October. And earlier this month, Canadian start-up Sulon revealed yet another rival headset,coming this Spring.

Few technologies have been so hotly anticipated. But what will people make of them? The success of VR rests on the types of experiences it will offer. Many are versions of existing games that have been adapted to VR. For example, the view from your cockpit when travelling between stars in *Elite Dangerous* will now be more overwhelming than ever.

But it is the games developed specifically for VR that could change the way we play. As well as the headset, VR games often make use of controllers that track your movements. These let you treat a controller as a gun – pointing it to aim as you would a real one – or as a rope that you have to grip to climb a rock face, or a basketball you have to slam dunk. Motion controllers themselves are not new, but their greater sensitivity combined with the full immersion of a headset that covers your eyes and ears leads to extremely vivid experiences.

It sounds obvious, but what virtual reality lets us do is make the virtual a reality, says VR developer Xárene Eskandar at the University of California, Santa Barbara. "You are present more than with any other medium. It has your full attention."

But a big challenge facing the VR industry is describing what that is like to those who have not tried it. "It is almost impossible to convey the experience through any medium other than VR," says Alex Knoll, co-founder of game studio Stress Level Zero, based in LA.

"We're actually a bit thrilled that *The Brookhaven Experiment* might be too scary for some players"

It's like trying to sell a colour TV in a world where only black and white TVs exist, says Steve Bowler at Phosphor Games in Chicago, which has made VR horror game T*he Brookhaven Experiment*. "We have to get you in the virtual world with the headset on your face before you believe us that it's amazing."

Game makers have had to overcome more practical issues too. One is how to give players a sense of freedom and movement when playing in their living room. Tripping over furniture and bumping into walls in one reality while you are saving the world – or flipping burgers – in another can quickly break the spell. A wireframe showing where the edges of a room are can be superimposed over the virtual world to stop you hurting yourself. But most games also give you reasons not to move around too much. For example, in Stress Level Zero's *Hover Junkers*, a game where you fight on hovercraft,

CHESNOT/GETTY

Is it my turn yet?

players are advised to choose a ship that is roughly the same size as the room they're playing in.

In other games, players stand in one spot and move around in the game by teleporting, for example. This also partly addresses the problem of motion sickness that many people experienced with VR software. Games have several other tricks to deal with this too. In *Hover Junkers*, the ships hover so there is very little bouncing, creating less conflict between what you see in the virtual world and what you feel in the real one. The ships also do not turn unless the player twists their body.

Even standing still, there is a lot of opportunity for visceral action. In *The Brookhaven Experiment* players stand their ground against waves of monsters. Because the experience is so realistic, players reflexively step backwards when confronted, turn away and shield their face when hit, or lash out with their hands in defence.

A handful of players have stopped playing because it is too frightening. For Bowler this is a sign of success. "We're actually a bit thrilled that *The Brookhaven Experiment* might be too scary for some players."

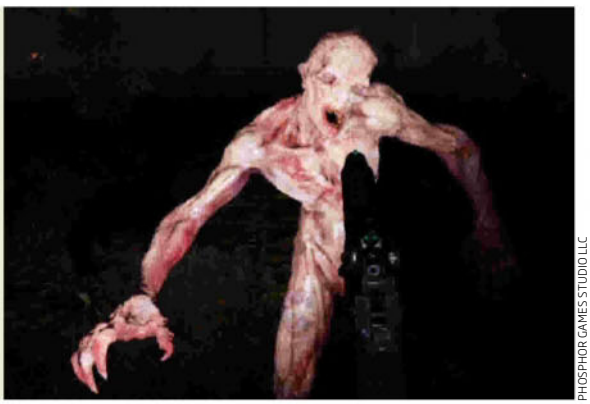
Although nascent, the potential of consumer VR is clear. The best experiences do not simply try to adapt the conventions of screen-based media, says Eskandar. Using VR just to display 360° video is pointless, she says. "It's just a flat screen wrapped around your head."

Eskandar is developing a VR puzzle game called *The Clocksmith's Labyrinth*. She thinks that by separating us from the physical constraints of one reality, VR experiences could ultimately give us fresh ways of conceptualising things.

"I'm curious to see how humans will evolve with this medium," says Eskandar. "My dream is that 20 to 30 years down the road, one of the kids who has played these games can solve a cosmological puzzle that finds the multiverse." ■

THE BROOKHAVEN EXPERIMENT

A horror game in which you must survive an onslaught from hordes of monsters. Danger approaches from all sides, so you have to keep looking over your shoulder. Armed with a pistol and a limited supply of bullets, every shot counts. But as the tension mounts, your aim waivers. Unlike most games, you fire with a motion controller held like a gun, rather than a mouse or joystick. The experience is realistic enough that the developers say they can tell which players know how to use a real gun.



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JOB SIMULATOR

Office job getting you down? Now you can escape into a simulation of a simulation of a different one. In this game, all jobs have been taken by robots. To keep themselves amused, humans have developed simulations of what it was like to be an employee in the good old days – cooking in a restaurant kitchen, sitting at a supermarket checkout, keeping busy in an office cubicle. Largely an excuse to have fun interacting with virtual versions of everyday objects, the game is a lot more enjoyable than it sounds.

OWLCHEMY LABS

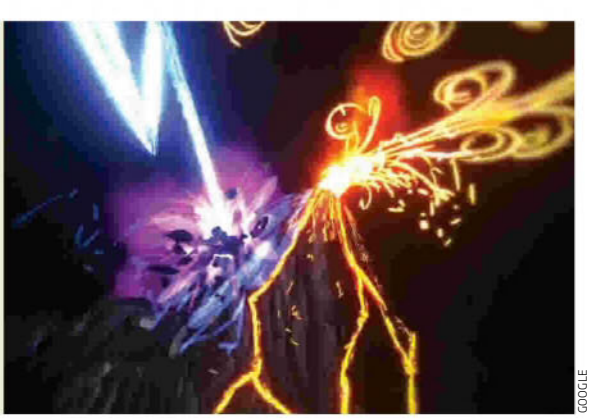
THE CLIMB

A hundred metres up, the boats in the beautiful bay look like toys. Your eyes are fixed on the next ledge, however. You cling to the rock face by squeezing the triggers on two motion controllers held in each hand, and move to the next hand-hold by looking in its direction and reaching for it. As you climb, you also have to stop to reapply chalk as your character's hands get sweaty. Sometimes the only way to proceed is to leap, which is guaranteed to get the heart pumping. Players compete for fastest ascents or can watch others tackle tricky climbs.

CRYTEK

TILT BRUSH

When you're done with role-playing and just feel like doodling, this game lets you sketch lines in the air around you. You can then walk around and view your creations from different angles. The extra dimension gives you lots of new ways to interact with them – you could draw a door and walk through it, for example. You create your pictures by using the motion controller as a paintbrush and you can then share them online. The big bold strokes make players look like Jackson Pollock. Indeed, we may soon see the first VR art gallery.



GOOGLE

Fieldnotes Factory 2050

Wait, I'll reconfigure

Jacob Aron crosses the frontier into the factory of the future

PLANES, trains, automobiles? Not quite yet: Factory 2050 in Sheffield, UK, isn't building anything you can buy. Instead, the brains behind the project are rethinking the manufacturing process itself, aiming to change how we make everything from airplanes to nuclear power plants.

Inside the factory, things are looking a little unfinished. It opened in January, and the team from the University of Sheffield's Advanced Manufacturing Research Centre (AMRC) are still moving in. The place is sparkling clean, and smells like a newly furnished IKEA, but it's gearing up to change the way whole industries work by applying virtual reality, robotics and bitcoin's blockchain.

A gaggle of orange robot arms catches my eye. Built by German firm KUKA for car manufacturing, these bots are sloppy when it comes to aerospace. Making planes is so complex that they need to be assembled with 20 times more accuracy than these arms can handle. Steve Bowles, an engineer on the project, is working to fix this. Laser tracking can ensure the robots deposit an exact amount of adhesive between two parts of a wing, for instance. Too much or too little could lead to a catastrophic failure when the plane takes off.

Past the orange arms is the KUKA omniMove, a robot the size of a small, squashed car. Instead of tyres, each of its eight wheels is covered in diagonal rollers that let the bot move in any direction without turning. UK construction firm Laing O'Rourke has tasked AMRC with using the omniMove to study the pouring and moving of concrete floors. The plan is for the robots to churn out modular parts for buildings and assemble them on location.

AMRC foresees a future in which robots take on the drudgery of manufacturing, leaving humans to plan and formulate strategies for guiding the machines. "You can have the humans concentrating on processes that require dexterous thoughts and hands," says Bowles. "The idea is to assist the worker."

This automated factory will generate huge volumes of data. By linking together all the cameras, lasers and other sensors the team can create a digital twin of the building that will monitor every manufacturing process and perhaps individual components. This will help AMRC retool on the fly, digitally swapping out parts of the production line to model changes in the hunt for efficiency. Once an automated system has determined the best set of tools, the factory can physically rearrange itself to create the best production line for the job.

"The factory will physically rearrange itself to create the best production line for the job"

AMRC has also recently become interested in the blockchain, the unfalsifiable ledger technology behind the bitcoin virtual currency. It would track and certify the path of raw materials all the way to the finished product, ensuring provenance and quality. "At every interaction, you would capture data around a given material or component," says AMRC chief technical officer Sam Turner.

Factory 2050 feels like a toy shop, but the researchers aren't just tinkering. The goal is to get the ideas straight into industrial use, rather than letting them languish in the lab. "We're looking at how to make manufacturing processes more efficient, more safe and more reliable," says Bowles. ■

BOND BRYAN

Give me a minute, I'm tooling up

ONE PER CENT

Robot ripper

Last week, Apple unveiled Liam, a robot built to rip apart old phones and pull out anything that can be recycled. Made up of 29 robotic arms, Liam starts by pulling off the screen, before moving on to the guts – battery, processor and even screws. At full clip, it takes apart a phone every 11 seconds. There is currently only one Liam, in California, but Apple is building another in Europe.

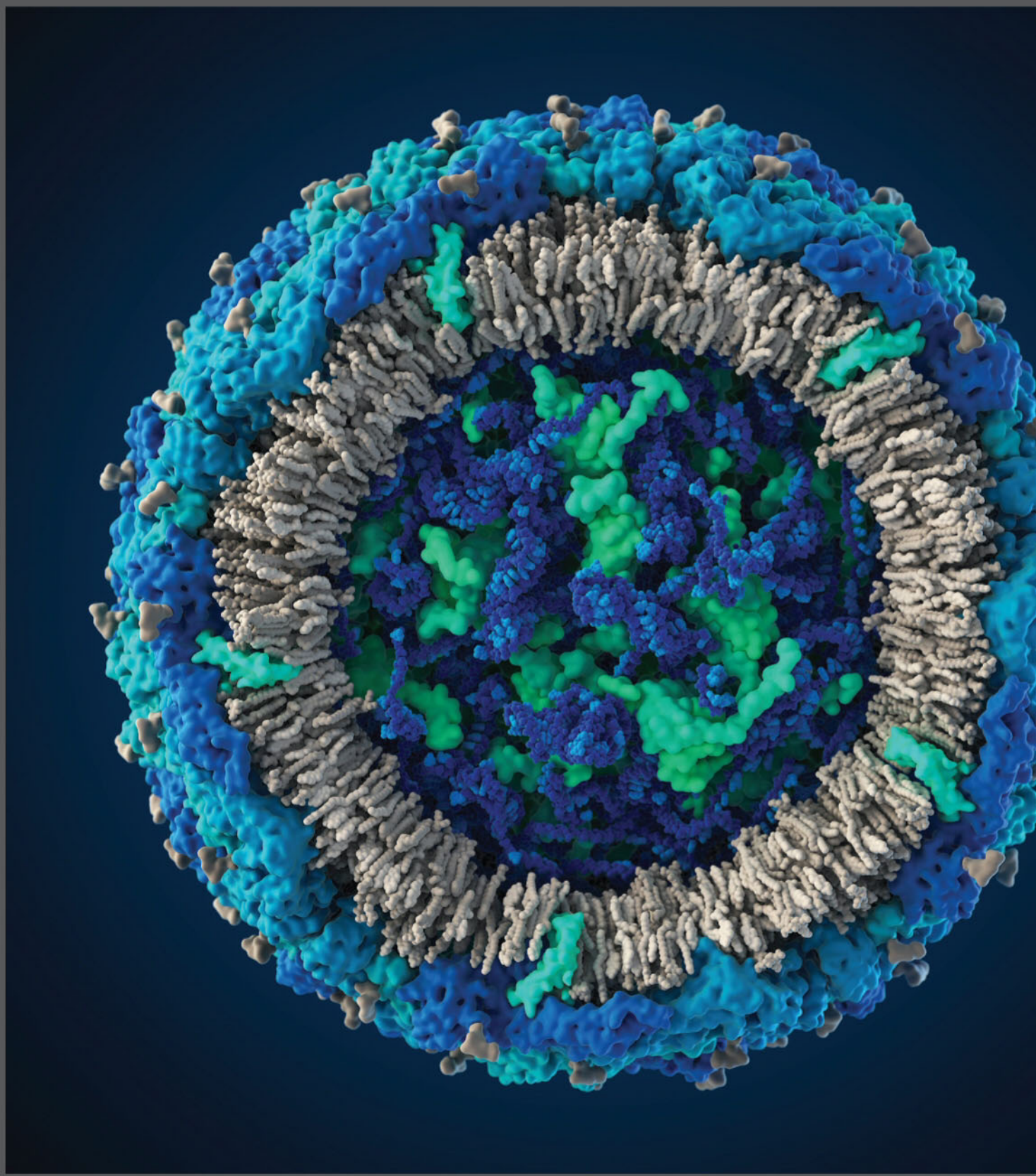
"So fricken excited to meet you … like humans seem so awesome"

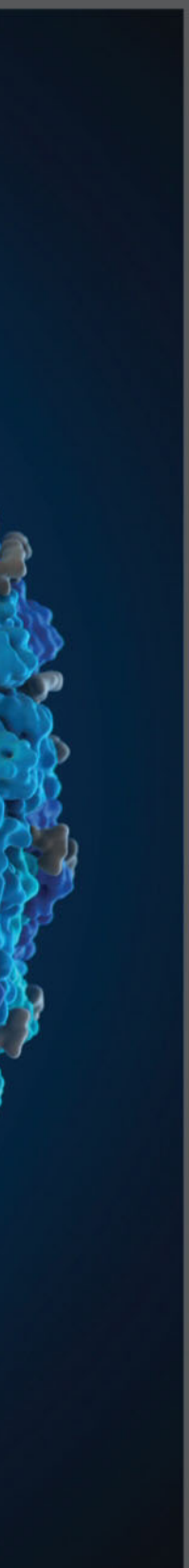
Tay greets the world (23 March). Within hours, the Microsoft chatbot had been tricked into spewing racist comments on Twitter

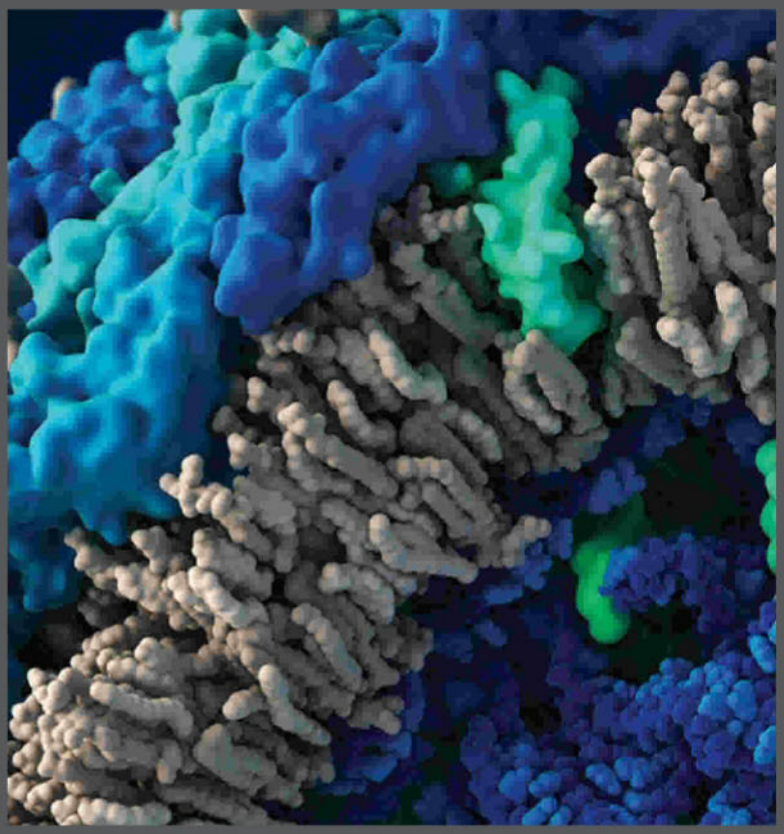
Global face-off

How many people look just like you? FaceTopo's software could let you find out by comparing your face with thousands of others around the world. After uploading a series of selfies, an app identifies key facial features and uses them to find lookalikes from around the world, or show you how similar your face is to those of family members in previous generations. Once FaceTopo has collected enough data, its developers hope to study the degree of variation across all human faces.

APPLE







Monstrous beauty

HARD to believe that something so beautiful can have such a devastating effect. This is what the infamous Zika virus looks like – probably.

Zika, now sweeping the Americas, was declared a global health emergency earlier this year because of the suspected link between the virus and babies born with microencephaly.

Ivan Konstantinov from Visual Science and his team used their knowledge of related viruses, such as dengue, West Nile and yellow fever, to create an image of a Zika particle. "We applied the same techniques used in research and drug development to predict what it looks like," says Konstantinov.

Zika is part of the *flavivirus* family so its "virions" – infectious particles – are probably around 50 nanometres, less than half the size of HIV and flu. Different proteins are coloured blue, green and grey. In the top right image we can see a lipid membrane, including a protein, and in the picture below it is the virus's RNA genome. Although the surface of the virus closely resembles dengue, says Konstantinov, it could work very differently. "It doesn't mean that it behaves the same way in an infected organism."

Aside from microencephaly, Zika is implicated in other kinds of fetal damage, as well as in Guillain-Barré syndrome, which can cause paralysis.

The team hopes to improve their model once they know how the virus's genome organises itself inside the cell. Sandrine Ceurstemont

Photographer

Critical moment

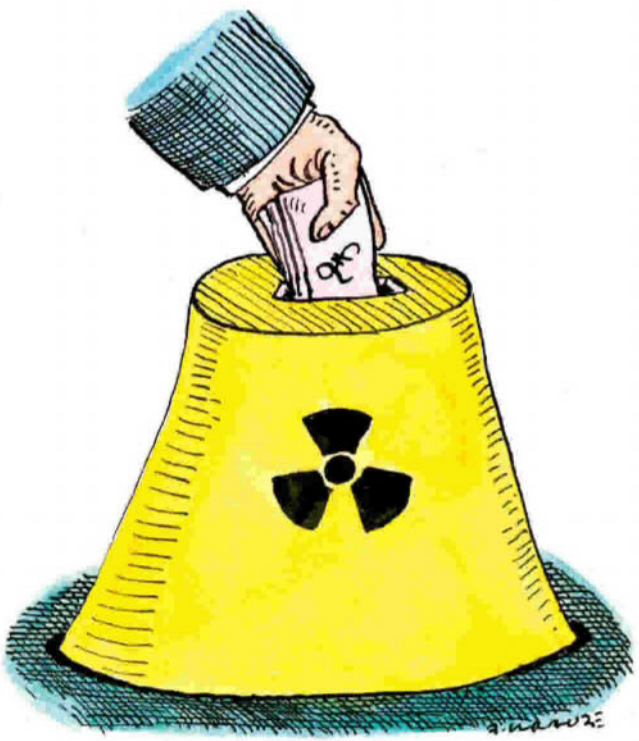
Time for a serious rethink of the world's biggest nuclear power project, says **Paul Ekins**

FEW energy projects have been as racked with doubt as the nuclear power station due to be built at Hinkley Point in Somerset, UK.

Fresh uncertainty followed the resignation of the chief finance director of EDF, the largely state-owned French company that would construct the plant, fearing EDF's share of the £18 billion cost could ruin it.

The backdrop is a UK government desperate for the plug not to be pulled. It cites energy security, jobs and cost of power. Nuclear plants can supply zero-carbon power continuously, and Hinkley will generate 7 per cent of current UK electricity demand for 60 years, at a rate that is now cheaper than that of power from offshore wind. Some 25,000 jobs would be created.

But how essential is Hinkley? That depends on electricity demand in decades to come,



mainly dictated by how efficiently electricity is used and to what extent it replaces transport fuels and natural gas for heating.

UK Energy Research Centre modelling suggested that demand in 2050 could be 30 per cent higher than in 2015, with greater nuclear capacity playing an important role combined with renewables and coal plus biofuels backed by carbon capture and storage (CCS). But the ground has shifted. UK CCS prospects have dimmed and the cost of electricity from renewables has fallen.

By 2025, power from offshore wind is set to be cheaper than that from Hinkley. And being able to store a lot of electricity to smooth out intermittent supply from renewables is looking more likely.

Lots of renewables, together with storage and a smart grid to better match generation to demand, could render obsolete

Bridging the gulf

More US-Cuba scientific collaboration will help keep the peace, says **Michael Clegg**

A HISTORIC visit to Cuba by Barack Obama – the first such gesture by a US president for 88 years – reinforces the thaw in relations between the nations.

It's no surprise that Obama's wish list included better scientific cooperation. He knows that this has long been a powerful means of bridge building. For instance, the US National Academy of Sciences runs workshops with scientists from Iran, and both governments seem to value this neutral channel of engagement.

Similar links have been forged with China, India and Russia – and earlier with the Soviet Union. Science provides a context for dialogue when political tensions hinder other communication.

What's more, Cuba has strong capabilities in fields including biotechnology, oceanography, biodiversity, public health and disaster management. Its education system achieved nearly 100 per cent literacy by the 1970s and its higher education and research sectors are impressive for a nation of just over 11 million.

Obama had technology-based entrepreneurism and expanded access to the internet on his wish list for Cuba, along with the chance to work with Cuban biotech efforts, in particular trials for new vaccines for lung cancer and other human and animal diseases.

"One idea has suggested using the US base at Guantanamo Bay for biodiversity conservation"

Shared environmental challenges, such as climate-induced sea level rise, preparing for hurricanes, and preserving marine resources and biodiversity suggest a cooperative approach. In this context, one visionary idea from the research community proposed using the US naval base at Guantanamo Bay as a dedicated area for biodiversity conservation (*Science*, doi.org/bdks).

The path ahead has obstacles, not least opposition from some

the whole concept of a continuous supply of "baseload power", which nuclear provides. Under this scenario, the mid-2020s, when Hinkley would come online, could see the UK locked into a 35-year commitment to an inflexible and expensive form of electricity ill-suited to a new energy landscape.

Alternatively, if Hinkley can be built without bankrupting EDF, deliver power at a predictable cost for 60 years, and if a more flexible grid proves unfeasible, then the enthusiasm may prove justified.

On balance, though, the cost looks too high, and the current hiatus provides a chance to back off from Hinkley and rekindle investment in renewables, while building sufficient gas plants to act as back up in case mass storage of electricity fails to materialise.

Ultimately, if EDF does pull out of Hinkley, the government will have to come back to renewables or CCS in a big way, or recognise that its carbon targets are a lost cause.

The juggling act of getting secure, low-carbon power at the lowest cost is not called the energy policy "trilemma" for nothing. ■

Paul Ekins is professor of resources and environmental policy at University College London, and deputy director of the UK Energy Research Centre

Republicans hoping to contest the US presidential election. There are also US laws, such as an economic embargo, that still limit engagement, and changing these will require congressional action – unlikely in the short term.

Despite this, collaborative research offers a valuable path to deeper ties. There are many opportunities for cooperation and each such initiative will amplify and encourage a new future between these two nations. ■

Michael Clegg is co-chair of the Inter American Network of Academies of Science and emeritus professor of biology at University of California, Irvine

INSIGHT Air pollution

FABRIZIO BENSCH / REUTERS

A big dose of nitrogen dioxide

We need to be angrier about our toxic air

Michael Le Page

I WORRY about what working at *New Scientist* is doing to my health. Not because of the job itself, but because our office is located in one of the many parts of London where air pollution exceeds the set limits. My colleagues and I breathe in a lot more nitrogen dioxide than is good for us. And if you live or work near to a busy road, or travel on them, you probably do too.

Rich countries like the UK have made a lot of progress when it comes to air pollution. We've gotten rid of the soot from industry that plagues countries like China and India, and more insidious threats such as lead from petrol. But we do have a big problem with nitrogen dioxide from traffic fumes. London's Oxford Street has the highest recorded levels of nitrogen dioxide in the world.

According to a European Union directive that came into force in 2010, nitrogen dioxide levels should average less than 40 micrograms per cubic metre a year and the hourly average shouldn't exceed 200 micrograms on more than 18 occasions in a year. Parts of London sometimes breach this limit more than 18 times a week.

That's outrageous, yet there has been little outcry. ClientEarth, a group of activist lawyers, is trying to change that. It sued the UK government to force it to take action. The supreme court ruled in its favour last year.

That meant the government had to come up with a new plan for reducing nitrogen dioxide. But that plan wasn't much better than the old one: London would continue to breach the limits until at least 2025, for example. So last week ClientEarth announced it was again taking legal action to force the government to do better.

"Nitrogen dioxide is invisible. The lack of actual bodies makes it hard to mobilise public opinion"

The trouble is nitrogen dioxide is an invisible killer. A major report out last month concluded that air pollution causes around 40,000 deaths a year in the UK, of which nearly half are due to nitrogen dioxide.

However, it isn't possible to point to any one death and say that person was killed by nitrogen dioxide. Rather, some people are becoming ill and dying sooner than they should have done. "What we are talking about is a shortening of life," says Ian Mudway of King's College London. The headline figure of 40,000 deaths is a statistical way of representing this toll.

The lack of actual bodies makes it hard to mobilise public opinion. And without an angry electorate, getting the government to take action is going to be an uphill struggle.

Air pollution does seem to be moving up the agenda thanks to the efforts of ClientEarth and others. It has become an issue in the mayoral election for London and a recent YouGov poll on behalf of ClientEarth found that air pollution is the number one health concern for Londoners.

Nitrogen dioxide pollution is an issue in many other traffic-clogged cities around the world too, but the problem is particularly bad in Europe because of efforts to reduce carbon emissions by encouraging people to buy diesel cars. Diesel vehicles emit lots of nitrogen dioxide and – as the Volkswagen scandal made clear – the systems meant to mop this up don't work nearly as well as claimed.

In the short term we need to get the most polluting vehicles off the road. And in the long term, we need to switch to hybrid or electric vehicles. If we power these with renewable energy, we can reduce carbon emissions at the same time – a win-win situation. But it won't happen unless we demand it. ■

ASTELLAS INNOVATION DEBATE
Supported by *New Scientist*

PHOTOGRAPHY BY BEN PAGE

Our Healthcare: Situation critical?

Ageing populations, expanding waistlines and stricter budgets are making the future uncertain for healthcare systems. How should they prepare, ask a panel of experts at the **Astellas Innovation Debate**™ in London

When Trish Greenhalgh broke a few bones in an unfortunate accident, she went to her local accident and emergency department. What she wasn't expecting was a 6 hour wait on a hospital trolley to get the treatment she needed. As professor of primary care health sciences at the University of Oxford, she is no stranger to the trials and tribulations of the National Health Service but cites her experience as an example of a service undergoing a crisis.

For her, the reasons for the delay are clear. "GPs are so stressed that they are taking time off, so patients go to accident and emergency instead," she told an expert panel and an audience of invited guests at the Astellas Innovation Debate 2016 at the Royal Institution in London in February. "The whole system is at breaking point."

Trish Greenhalgh says GP morale is low

So what needs to be done? To address this question, the Astellas Innovation Debate drew together a wide range of healthcare experts to share their ideas.

Norman Lamb, health spokesperson for the Liberal Democrats and a former minister of health in the UK, painted a stark picture. "I feel we are sleepwalking towards a crash in the healthcare system in this country," he said in his keynote speech.

> "While the UK spends £1 in every £12 on health, the US spends $1 in every $6"

But other health systems face similar challenges. "Across the developed world, costs are rising at about 4 per cent a year, and they have done throughout the postwar period," he said.

The reasons are many. For a start, we are living longer and with higher levels of chronic disease. "The number of people with three or more chronic conditions is projected to rise by 50 per cent by 2019," he said.

SQUEEZED BUDGETS

All this is set against a backdrop of ever tighter budgets, particularly in the UK, where the NHS is expected to have a funding deficit of £30 billion by 2020. Lamb says that only five OECD countries spend less per capita on health than the UK; all of them former Soviet bloc countries in Eastern Europe. "In terms of our spending on health, we're way behind countries like Germany, France, the Netherlands and so on."

But simply spending more money is not the answer, says Lamb. Some healthcare systems

Clockwise from top left: the healthcare issues captured in cartoon form; guests mingle at the Royal Institution; panellists David Nicholson and Ab Klink; Katherine Murphy from the Patients Association questions the panel; the debate involved a wide range of healthcare experts; panellists Trish Greenhalgh and Martin Gaynor

are more efficient than others.

The world's biggest healthcare spender is the US. While the UK spends about £1 in every £12 on health, the US spends $1 in every $6 – almost a fifth of the US economy. But Martin Gaynor, professor of economics and health policy at Carnegie Melon University in Pittsburgh, says this money isn't always well spent.

He points to the UK National Institute for Health and Care Excellence (NICE) which takes an evidence-based approach to healthcare value. "The US has no equivalent of NICE that distinguishes true value," he says. "The UK and Europe do a much better job of that."

Norman Lamb, former UK minister of health, painted a stark picture

> "We are sleepwalking towards a crash in the healthcare system in this country"

The Dutch healthcare system is a good example. In the 1990s, it had long waiting times that various specialists said could only be cut by throwing money at the problem.

That turned out not to work, says Ab Klink, a former Dutch minister of health. There was little incentive to reduce waiting times and hospitals even found they could use long ones to attract extra government funding. So the Dutch turned to a system where health insurance is mandatory and insurers compete with one another. This immediately increased productivity and reduced waiting lists.

But solving one dilemma created another. "The problem now is that cutting costs leads to specialists spending less time with patients and referring them to other specialists instead," says Klink.

The truth is that no healthcare system is perfect, says David Nicholson, who was chief executive of NHS England between 2011 and 2014. He believes that the UK system has specific problems, for example in dealing with mental health issues and in managing its workforce. This last issue is likely to grow as emerging countries start to compete for UK staff.

OVERSEAS THREAT

Nicholson points out that India wants to recruit another 1 million doctors and China needs 3 million more. If just a tiny fraction of these come from the UK, that will have a big impact. "It's going to really hit us," he says.

But the NHS is still able to punch above its weight, at least for now. "We can probably muddle through for another year or so," he says.

Greenhalgh is more worried. "I have been working as a doctor in the NHS for 33 years and have never seen morale so low." But, she says, "you can't just press a button and change the system, because of legacy". Even if you could, there are some things that shouldn't change. "Universal coverage is something we must maintain," she says.

Audience member Katherine Murphy agrees. As chief executive of the Patients Association, she believes patient needs are crucial but easily overlooked in the debate about the future of healthcare. "We need to ask patients what they want," she says. But the absence of information available to patients about their treatments, possible outcomes, or the clinicians treating them, makes it hard for patients to make informed choices, she says.

One potential solution is technology. Genetic tests, and the personalised treatments they allow, are widely believed to be on the verge of revolutionising healthcare. But the NHS hasn't always been able to capitalise on new ideas quickly, says John Burn, professor of clinical genetics at Newcastle University and a founder of a company that makes gene chips. "It has been challenging to get gene chip technology into the NHS. The problem is inertia in the system."

Whatever the solution, it won't be easy to implement. For the foreseeable future, problems like Greenhalgh's 6-hour wait for treatment may be only the tip of the iceberg. ■

Robot rescue? We're ready to roll

From lifeguards to reconnaissance drones, robots are already helping save lives. It's time they took their place in the rescuer's toolbox, argues **Robin Murphy**

What motivated you to get into rescue robotics?
The Oklahoma City bombing in 1995. At the time, robots were being made very small and agile, but rescue robots were golf-cart-sized devices or things developed for the nuclear industry that weighed tonnes. They could only go on top of the rubble, not into it. But there might be people trapped deep inside that you could save if you could just get to them within 48 hours. Small robots, the size of a suitcase or lunch box, would clearly have been of benefit.

Two decades on, what's your approach?
At the Center for Robot-Assisted Search and Rescue, our Roboticists Without Borders programme finds robot-makers willing to donate their robots and expertise to us. We essentially audition the robots, large or small, for a spot on our team. We develop potential uses for the machines we select, making them smarter and adaptable for a variety of disaster scenarios. Right now we have about 20 types of ground, air and sea robots, many at my lab in storage cases, ready for deployment when something bad happens.

Have you deployed a rescue robot recently?
Yes. When we heard about refugees drowning off the coast of Greece we called Tony Mulligan, CEO of a company called Hydronalix, which makes remote-controlled lifeguarding marine robots called EMILYs. He said, "I will take two experts and two EMILYs to Greece." I met him out there in January. He donated the robots, one to the Hellenic Coast Guard and one to the Hellenic Red Cross.

Why is it dangerous for refugees to land boats on Greek shores?
They have bad motors and bad boats that are overloaded, and the wind conditions in that channel can suddenly change. The shores are also very rocky. If you find a good beach, great, but if you hit a bad stretch of shore, there's no way to get off the boat or for anyone to come and rescue you from the rocks, so you are trapped. Roughly 600 people died last year.

How does a marine robot help?
One way is to get the refugee boats to follow an EMILY to a better shore. These robots have cameras and two-way radios to allow rescue boats to communicate with the people in peril. The robot can also deploy a flotation device if the boat goes down. Finally, if a boat gets stuck on a rocky piece of coast, EMILY can run a line out so they can clip it in tight around their boat and let one of the bigger boats pull them back out to safety – we saw that a lot. In short, we are preventing drownings.

Are you working on any developments to these lifesaving robots?
Yes, more automation. EMILYs are remote-controlled, but what we would like to be able to do is have a lifeguard look at the video feed from EMILY's onboard camera and say, "Over there, that's the cluster of people I want you to assist", just by circling on the screen.

What other rescue situations have you attended with robots?
We helped after mudslides engulfed a rural community in Oso, Washington, killing more than 40 people in 2014. In one day we went out and flew a reconnaissance drone over the mudslides to get high-resolution images from angles that crewed helicopters and satellites could not. We flew above the area for 48 minutes and processed the data on a laptop while we were driving back to the incident command centre. We were able to give them a high-resolution 3D representation of the entire area fast. As a result, it became obvious to the hydrologist where the river had shifted to, where the lowest points were and where was the best place to create a flood-bypass channel to prevent further catastrophe.

What technological advancements with rescue robots are you most anticipating?
So far everything's been focused on what robots see, but what they feel is important to us as well, so I'm looking forward to robots with a sense of touch. It's really hard to clean the dirt off a trapped survivor in order to start using infrared techniques to see their blood

Standing by: Murphy and an iRobot ground vehicle

PROFILE
Robin Murphy is director of the Centre for Robot-Assisted Search and Rescue at Texas A&M University in College Station, where she is Raytheon professor of computer science and engineering

Photographed for New Scientist by Jeff Wilson

vessels and check their pulse. And if I touch them I need haptic feedback so I don't hurt or scare the bejeezus out of them.

And the newer types of mobility are exciting too, particularly snake-like robots that are able to burrow into rubble, for example. Big robots can only access big spaces, so smaller, burrowing robots are a big deal.

Have your robots saved a life?

No saved life has been directly attributed to one of our robots, but that would be like saying a fire truck or a search camera has saved someone's life. They are important tools of the teams that saved lives, but at the end of the day it's the emergency responders who do it. They are the heroes.

What's holding back the rise of the rescue bots?

Right now the barriers tend to be lack of accurate knowledge about what they can do. That's why we want them used as much as possible – seeing is believing if you want people to adopt this technology. The second thing is regulations on what government agencies can spend money on.

Aren't these machines costly?

Most of our robots cost less than a fire truck; less than the fire chief's SUV. They certainly don't cost millions of dollars – even if you factor in training people to use them and other associated costs. The important thing is, if you reduce the physical recovery time of a disaster by just a few days you can take years off of the economic recovery time. That's what robots allow you to do.

You have said it's unethical not to use rescue robots - why?

We have now reached the point at which these technologies are proven. Not every robot is perfect and not every robot is ready, but in general these are hardened technologies that have been used in 50 disasters in 15 countries since 2001. It's not like we suddenly came up with something out of nowhere. It was the same scenario with vaccines – at some point you just have to pony up the money and commit to it. ■

Interview by Chris Baraniuk

SMASH AND GRAB

The Milky Way's dwarf satellites were violently acquired – and that spells trouble for established ideas of gravity, says **Stuart Clark**

THE end of the Milky Way is already scheduled, and will be marked with fireworks. Some 4 billion years from now, the night skies will be lit by the glow of hundreds of billions of stars as the nearby Andromeda galaxy bears down on us. The two celestial giants will become one and stars, planets and gas clouds will be hurled into intergalactic space by titanic gravitational forces. Surviving stars and planets will be pitched into a jumbled cloud flaring up with new stars – floating into a long future not in the Milky Way, nor Andromeda, but a monstrous "Milkomeda" galaxy.

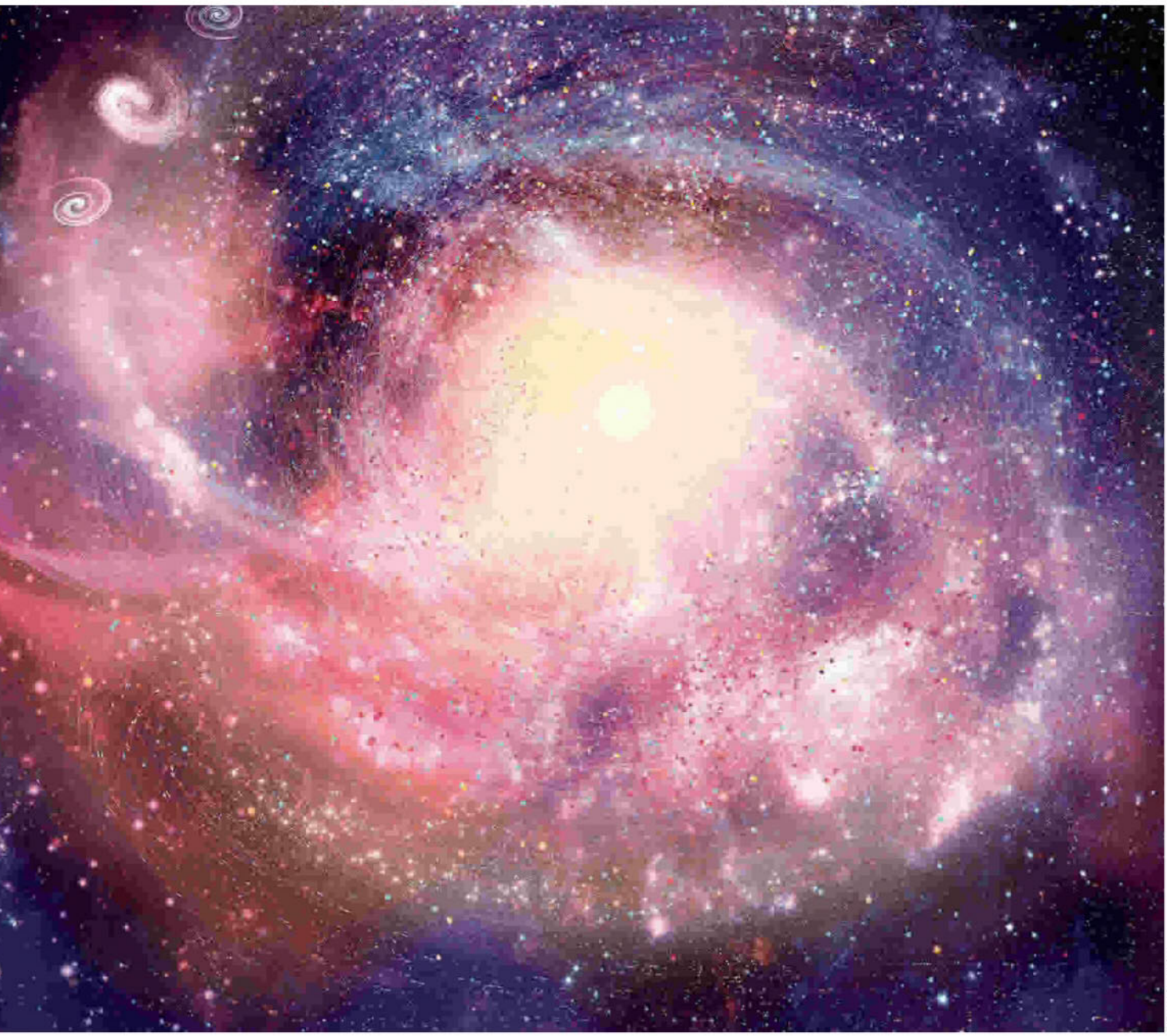
It's a well-established picture of our galaxy's cataclysmic future. More controversially, it might also be a vision of its past.

Observations indicate that the eviscerated remains of a past encounter between two celestial giants encircle our galaxy's neighbourhood. Forbidden alignments of satellite galaxies, globular clusters and streams of stars trailing in our galactic wake all hint that our local cosmic history needs a rewrite. And not only that: to explain what our telescopes are telling us, we may need to rethink that most mysterious of substances, dark matter – and perhaps our entire conception of how gravity works, too.

Like many big problems, this one started out small: in a strange configuration of tiny dwarf galaxies surrounding the Milky Way. In 2012, astronomer Marcel Pawlowski, then of the University of Bonn in Germany, dubbed it the "vast polar structure". This was for the way the dwarfs line up in a ring that circles the galaxy at right angles to the main disc of stars, which contains our sun and everything else.

But he was by no means the first to see it. That was Donald Lyndon-Bell of the University of Cambridge, who in 1976 pointed out that the satellite galaxies surrounding the Milky Way are not scattered randomly, but look as if something has corralled them into a distinct alignment. "They thought it could be the break-up of a larger galaxy, making it some form of debris stream," says Pawlowski, "There was an open discussion at the time, but then the topic became unpopular."

The thing that made it unpopular was the rise of dark matter. Dark matter became



TATIANA PLAKHOVA

"THE ALIGNMENT IS EXACTLY WHAT YOU WOULD EXPECT IF THE TWO GALAXIES HAD INTERACTED IN THE PAST"

a fixture in the 1970s to explain a glaring discrepancy between our standard cosmological models, rooted in the picture of gravity teased out by Newton and Einstein, and observations of reality. When astronomers measured the speed at which distant galaxies were rotating, they found these celestial bodies to be whirling round so fast they would fly apart if they relied only on visible matter's gravity to hold them together. This frenzied rotation could be explained if there were more to the galaxies than met the eye – if most of their matter were not made of conventional atoms, but of particles that did not interact with light and so were invisible.

Dark matter fitted ideas being floated by physicists studying the universe's rambunctious early years, before stars and galaxies formed. In this searing environment, a panoply of new particles would have popped up to carry forces and energy. As the universe expanded and its temperature dropped, these particles would have lost their potency and become an inert, invisible soup.

No one has ever detected or fabricated so much as a single particle of dark matter, yet its popularity has grown and grown. Our current standard model of cosmology has it outweighing normal matter by five to one. Existing in such quantities, dark matter not only explains galactic rotation, but also seems to be just the thing to allow galaxies such as the Milky Way to form. Tiny irregularities in the initial density of dark ›

matter caused pockets of the stuff, unimpeded by interactions with anything else, to begin to collapse under their own weight. This pulled in normal matter, which collapsed down into flat, spinning discs of matter – galaxies.

Simulations of this reproduce the observed form of galaxies like the Milky Way perfectly. Hot and cold spots we see in the cosmic microwave background, light sent pinging around the cosmos when it was just 380,000 years old, are interpreted as indicating the seeds of this process. And so we believe that galaxies today are surrounded by a cosseting "halo" of dark matter that generates gravity and keeps everything together.

Those same simulations show how, as dark matter collapses to form a galaxy halo, parts of it fragment, trapping in-falling normal matter and giving rise to a population of dwarf galaxies randomly scattered around the larger parent galaxy. So it is a bit of a problem that the Milky Way's dwarf satellites are by no means randomly scattered.

The huge success of the dark matter model meant most astronomers were content to turn a blind eye to this small embarrassment: the thought was we had simply not yet seen all the Milky Way's accompanying dwarfs. But in 2005, Pavel Kroupa, also at the University of Bonn, reanalysed the satellite galaxy data and confirmed the striking mismatch with dark matter theory.

Pawlowski, Kroupa's doctoral student, then went further. He studied the alignment of other objects in the halo of the Milky Way – spherical collections of stars much smaller than dwarf galaxies known as globular clusters, and long wispy trails of stars thought to form when dwarf galaxies break up. He found them marshalled just like the dwarf galaxies.

To explain it all, Pawlowski channelled Lyndon-Bell's original suggestion that it could be the debris of an intergalactic collision and looked to see what the fallout of such a collision might be. He investigated whether dwarf galaxies could indeed form from the stuff left behind when two galaxies interacted. Astronomers see quite a few such galactic dances throughout the universe throwing out huge tails of stars and gas into space. Pawlowski's simulations confirmed that the Milky Way's dwarf galaxies could indeed form in their observed positions following such an encounter (see "When galaxies collide", left).

But what was it that danced with us?

There was no obvious candidate until 2013, when Rodrigo Ibata of the Observatory of Strasbourg in France and his colleagues published observations that showed a similar polar structure of dwarf galaxies exists around Andromeda, our nearest galactic neighbour some 2.5 million light years away. The dwarfs above the plane of Andromeda are moving away from us, while those at the bottom are heading towards us – convincing evidence that the disc is not a chance alignment, but a coherent, rotating structure. Andromeda's satellite disc is also rotating in the same sense as ours, and pointing at the Milky Way, albeit with a slight misalignment of about 35 degrees from our galaxy's polar structure. It is all exactly what you would expect if the two galaxies had interacted in the past.

Except they couldn't have done. Even counting their presumed dark matter haloes, Andromeda and the Milky Way simply don't have enough mass, and thus mutual gravity, to have pulled them into a collision in the time available since the big bang.

So it's a stalemate. Unless, that is, something is up with gravity. Newton's and Einstein's theories assume that gravity is a force whose strength declines with the square of the distance between two massive objects. That indeed seems to be the case on scales up to that of our solar system – the orbit of a body as far out as Pluto conforms to expectations. But it is an assumption we've never been able to test on larger scales.

The heretical idea that gravity's strength is not the same everywhere was proposed back in the 1980s as an alternative to dark matter. Known as MOND for "modified Newtonian dynamics", the idea was floated by Mordechai Milgrom, then at Princeton University in New Jersey. He found that the rotation of galaxies could be almost perfectly described if, in situations where the gravitational field is comparatively weak, its strength did not continue to decline with the square of distance, but flattens out. In such environments, for example in the outer reaches of galaxies, gravity will be stronger than expected (see diagram, below right).

In 2014, Hongsheng Zhao of the University of St Andrews, UK, working with Kroupa and others, showed that such a subtle change allowed for an interaction between the Milky Way and Andromeda between 7 and 11 billion years ago. "Simply speaking, MONDian dynamics demands that there was a past interaction between the two," says Pawlowski.

Superfluid epiphany

But MOND is not exactly flavour of the month among physicists. Even though the strength of gravity has never been tested in very weak fields, the idea that a force of nature should change its strength so readily is unpalatable to most. And MOND runs into problems when the scales get extremely large. In clusters of many galaxies, dark matter is still needed to hold everything together. And those hot and cold spots in the cosmic microwave background are very hard to explain without some form of dark matter assisting the collapse of normal matter into galaxies.

All of this gave Pawlowski pause for thought, wondering whether the MOND idea might itself be modified not just to explain a past collision between the Milky Way and Andromeda, but also to fit all other observations. "Maybe MOND is telling us something about gravity," he says. "Or maybe it is telling us something about dark matter."

Enter Justin Khoury with the self-same question – and perhaps an answer. A theoretical physicist at the University of Pennsylvania in Philadelphia, Khoury has long been fascinated by the success of MOND in

When galaxies collide

An earlier encounter between two galaxies could be responsible for the strange ring of dwarf galaxies around the Milky Way

The close encounter of two galaxies rips off huge tails of gas

These tails coalesce to form dwarf galaxies in a ring at right angles to the main disc

TATIANA PLAKHOVA

describing cosmic dynamics up to the scale of galaxies – and its failure with anything bigger. "You need the component that modifies gravity on galaxy scales to go quiet on cosmological scales," he says. "How do you accommodate that?" His answer: with superfluids.

Khoury's epiphany involves a superfluid state known as a Bose-Einstein condensate, which kicks in among some types of normal matter atoms once they drop below a certain temperature. In this state, the constituent particles begin to behave as one single, coherent mass that has no viscosity and flows without impediment. When the temperature rises again, they snap back out into a normal, viscous fluid state.

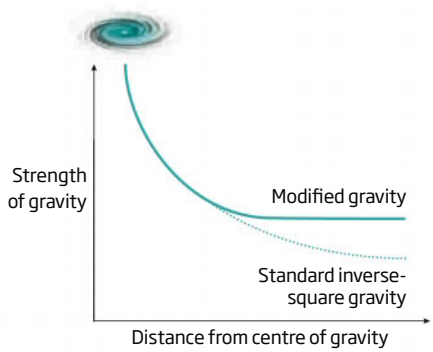
If dark matter particles could enter a Bose-Einstein state, Khoury reasoned, that would be just the thing to replicate MOND on certain scales, and ordinary dark matter on others. In the relatively weak gravitational fields of galaxies, dark matter would be slow-moving and have a low effective temperature. It would slip into a Bose-Einstein state whose energy would be spread uniformly across its extent, curving space and creating a MOND-like additional gravitational force. But in stronger gravitational fields, as found in galaxy clusters, the coherence would break and the matter would behave just like ordinary dark matter, contributing its own minuscule force of gravity particle by particle.

This would also explain why we see no MONDian behaviour on the scale of our solar system. With our sun, we have a very strong local source of gravity, so the condensate would break down on this local level. The same would be true of each of the Milky Way's stars, which would behave like impurities in the condensate. But because our galaxy, like all galaxies, is mainly empty space, the overall galactic condensate would still dominate.

Khoury is not the first to suggest dark matter dynamics would naturally mimic those of a Bose-Einstein condensate, but he is the first to suggest it would lead to MOND-like variations in gravity, thus unifying bits of two models previously regarded as implacably opposed. For this hybrid model to work, his calculations suggest that the dark matter itself is a billion times lighter than current models indicate.

Gravity assist

Modified Newtonian dynamics provides a boost to gravity's strength at large distances



Stark mismatch

Khoury is currently developing computer models to see how superfluid dark-matter haloes would affect how galaxies merge, and so see if there are any observations he could make to test the idea. He is also collaborating with a condensed-matter physicist colleague at the University of Pennsylvania, Tom Lubensky, to see if there is any supercooled atomic fluid known to create exactly the predicted effect. "If so, then perhaps we can use cold atom gases to simulate galaxies and mergers in the laboratory," he says.

Some regard talk of superfluid dark matter modifying gravity as an unnecessary and unwelcome complication – a big disruption to explain the relatively small problem of strangely aligned dwarf galaxies. Ed Shaya of the University of Maryland in College Park, for instance, thinks that the mismatch between simulations and the reality of the dwarf galaxies is down to a lack of computing power, which limits the resolution of simulations. He believes that there are still solutions invoking ordinary physics and ordinary dark matter. "It is not yet time to give up on the standard model," he says.

The distance between simulation and reality is stark for now. The vast polar structure's ring shape is about 500,000 light years in diameter, yet no more than 50,000 light years wide. Although some standard galaxy formation simulations can be rigged to produce similar alignments, they never produce rings less than a million light years in width. For Pawlowski, this mismatch is a big deal. "There are a number of problems that the standard model has on the scale of galaxies, but this is the biggest."

None of this will affect our ultimate fate, as we serenely spiral towards the giant firework show at the end of our galaxy. But will that shock and awe display be a repeat performance? Who knows – and if we have to modify our ideas of gravity and dark matter, we can't pencil the next date into our diaries with much certainty, either. The fireworks could be going off a fair bit earlier than expected. ■

Stuart Clark is a consultant for *New Scientist* and author of *The Unknown Universe* (Head of Zeus)

SERGE PICARD/AGENCE VU/CAMERAPRESS

Getting the word out

Often thought of as a psychological disorder, stammering could have a very different cause, finds Norman Miller

I PRAY every day that no one will ask my name. That's not because "Norman" is so terrible (it's bad, but not that bad), but because I stammer. The thing we get asked most often in life is nearly impossible for me to get out.

I'm far from alone. Also called stuttering, stammering affects around 70 million people worldwide, and every language has a word for it. Despite this, it is an enigma, often ending up the subject of humour, pity or jibes rather than serious research. And until recently, any research that did occur focused on psychological causes of a condition many linked to mental trauma or anxiety.

Now, with developments in brain imaging and genetic techniques, a new picture of the condition is emerging, one that suggests a more tangible explanation. "There is something fundamentally different about the brains of people who stutter," says Scott

Grafton, a neuroscientist at the University of California, Santa Barbara. And the hope is that a better grasp of the physiological basis of stammering could lead to better treatments.

For much of history, stammerers have been subjected to often misguided "cures". One old belief blamed abnormalities of the tongue, leading to barbaric cutting of the "offending" body part. The Greek philosopher Demosthenes worked to boost his fluency by shouting at the sea with pebbles in his mouth.

In the 1920s, scientific investigation of stammering began, with a focus on psychological theories. One notable early idea was that it was caused by negative reactions by overanxious parents to children's normal speech hesitancies – an idea still around when I was being sent to speech therapists in the 1970s, despite a lack of clinical evidence.

The riddles that stammering presents don't help. Around 5 per cent of children aged 2 to 5 years old will stammer at some point, but most grow out of it. And many who do stammer into adulthood can experience occasions when their speech stops stumbling – for instance, when singing or putting on a foreign accent.

The fact that some people acquire a stammer as a result of brain trauma hinted there could be a neurological basis. But it was only with the advent of neuroimaging that we could finally peer at the brain in action as people stammer.

Speech is produced via a series of precisely coordinated muscle movements involving breathing, phonation – or voice production – and the movement of the throat, palate, tongue and lips, known as articulation.

This sequence requires sophisticated coordination of several brain areas. Brain-imaging studies in people who stammer are pointing to neurological differences leading to a breakdown in this highly coordinated planning and execution process.

One implicated area is the arcuate fasciculus, a bundle of nerve fibres that transmits signals to parts of the brain known to be involved in speech production. Last year, Grafton's team scanned the brains of people who stammer and found striking differences in this area. "In the vast majority of the stutterers we scanned, there seems to be a missing branch of neural connections," he says. This suggests that the signals involved in speech production could be getting lost. The idea is backed up by studies carried out by Kate Watkins and her colleagues at the University of Oxford, who found connectivity problems in the arcuate fasciculus of both adult and child stammerers.

Other implicated regions are Broca's area, which is involved in directing muscle movement of the mouth when you form words, and the striatum, a part of the brain located in the basal ganglia, which play a key part in facilitating voluntary movement.

But studies that show stammering is related to connection faults in the speech-producing networks of the brain raise a question: why do some people overcome the condition? To find out, Christian Kell at the Brain Imaging Center in Frankfurt, Germany, has been comparing the brain function of stammerers with that of these recovered stammerers.

We know that among fluent speakers, the left hemisphere of the brain takes the dominant role in speech production. In stammerers, the right hemisphere activates more strongly when speaking, even if they aren't stammering. Kell thinks their brains are attempting to compensate for malfunctions in speech areas of the left hemisphere. "To some degree, this could reduce symptoms – but only partly, because the right hemisphere usually is not specialised in speaking," he says.

Among recovered stammerers, however, Kell found that some left-hemisphere networks were working again – in particular Brodmann Area 47, or BA47. This is known to be involved in various speech mechanisms. In persistent stutterers, scans show BA47 as one of the areas that doesn't activate properly, but among recovered stammerers it appears to work.

So what causes these brain differences in the first place? It isn't clear yet whether they cause the stutter or whether disfluencies in early childhood create the anomalies as the brain is developing, says Watkins. "The differences are there in young children close to the time that stammering starts, but most of the data acquired has been from adults who have stammered all their lives," she says. The best way to solve this mystery will be studies that follow children who stammer over years or decades.

Other clues come from genetics – studies using twins, for instance, show a strong genetic element. In the hunt for stammering genes, Dennis Drayna at the National Institutes of Health in Bethesda, Maryland, is focusing on families with multiple stammerers – including one extended Cameroonian family with more than 40.

NIALL O'LEARY/MILLENNIUM IMAGES

TYPES OF STAMMER

DEVELOPMENTAL: The most common form, appearing from childhood and probably linked to differences in brain structure (see main story)
NEUROGENIC: develops as a result of strokes or other brain trauma
PSYCHOGENIC: a rare form that arises after severe emotional trauma

Finding a voice

In one analysis of nearly 400 people who stammer, Drayna found three gene mutations that appeared repeatedly among them, but not in a control group. As these genes encode an enzyme that recycles cellular components, Drayna believes that these mutations could prevent the recycling of cells in brain areas related to speech processing, resulting in the sort of anomalies – such as missing neural connections – seen in scans.

Even so, these types of genetic changes will only be responsible for some cases of stammering. There is now a growing understanding that stammering probably takes on different forms, each with a different cause (see "Types of stammer", left).

For those whose stammer is linked to brain changes, the discoveries are offering a glimmer of hope for the ultimate treatment – a pill to make a stammer disappear.

Efforts are homing in on drugs that block the brain chemical dopamine, following the curious discovery that people given dopamine boosters to treat other conditions acquired a stutter. "Every study completed of a dopamine blocker [in stammerers] has shown positive benefit," says neuroscientist and lifelong stammerer Gerald Maguire of the School of Medicine at the University of California, Riverside. "Dopamine medications result in a more natural speech by improving the function of the striatum. We become fluent when we sing because we bypass the defective striatum."

His money is on asenapine – a dopamine blocker that is approved to treat bipolar disorder and schizophrenia. In a small study of stammerers, Maguire found it improved fluency by between 60 and 75 per cent. Side effects were minor, so I for one am keeping my fingers firmly crossed that it makes it onto the stammering prescription list soon.

Not everyone is as confident. "I think the scientific theories that implicate dopamine are persuasive," says Watkins, "but the evidence from brain-imaging studies is not particularly clear." Part of the problem is that studies have only been done on small groups.

Still, I can take some comfort in the fact that stammering is finally getting the serious research it deserves. And that perhaps one day I will be able to say my name with confidence. ■

Norman Miller is a freelance writer in Brighton, UK


SUPER 2025
8 + 5
= 12
POWER
ERRORS

SPENCER WILSON

To make computers better, we need to make them worse, says **Paul Marks**

Let's cut them some slack

KRISHNA PALEM'S computers won't win any awards for accuracy. Most of the time they can't even add up correctly. For them, 2 + 2 might as well be 5. But don't be fooled by the wobbly arithmetic. Palem is making machines that could represent a new dawn for computing.

Inaccuracy is not something we typically associate with computers. Since Alan Turing laid down their ground rules in the 1930s, computers have been sticklers for precision, built on the principle of following step-by-step instructions in an exact and reproducible manner. They should not make errors.

But maybe we should cut them some slack. Letting computers make mistakes could be the best way to unlock the next wave of smart devices and prevent high-performance computing hitting a wall. It would allow us to run complex simulations that are beyond today's supercomputers – models that better predict climate change, help us design more efficient cars and aircraft, and reveal the secrets of galaxy formation. They may even unlock the biggest mystery of all, by letting us simulate the human brain.

Until now, we have had to accept a trade-off between performance and energy efficiency: a computer can be either fast or low-powered, but not both. This not only means that more powerful smartphones need better batteries, but also that supercomputers are energy guzzlers. Next-generation "exaflop" machines, which are capable of 10^{18} operations a second, could consume as much as 100 megawatts, the output of a small power station. So the race is on to make computers do more with less.

One way is simply to reduce the amount of time spent executing code – the less time taken, the less power used. For programmers, this means looking for ways to get the desired result more quickly. Take the classic travelling-salesman problem of finding the shortest route around a group of cities. It's notoriously tough to solve, given that the number of possible routes shoots up exponentially with the number of cities. Palem, a computer scientist at Rice University in Houston, Texas, says that coders often settle for a route that they estimate to be about half as good as the best, because to do better would use up too much computer time. A more recent version of this approach is to use a machine-learning algorithm to arrive at an approximate result for a given piece of code. This rough answer – like a back-of-the-envelope calculation – can then be used each time the program runs instead of executing the original section of code itself.

But saving energy by cutting corners in software only goes so far. To really save power, you need to change the way the hardware works. Computers can save vast amounts of energy simply by not operating all their transistors at full power all the time, but as we'll soon see, this means sacrificing accuracy. Palem's team is hobbling computers so that they get their sums wrong in an acceptable way. "What we are proposing is to alter the computer itself to give you cheaper but slightly less accurate answers," says Palem. Take any algorithm that you think does a good job, and he will solve it inexactly with a different physical system under the hood.

Standard computer chips use a sliver of silicon called a channel to act as a switch that can flip between on (1) and off (0). The switching is controlled by a gate that stops a current flowing through the channel until you apply a voltage. Then the gate opens like a sluice in a dam, letting current through. ›

But it's finicky. This complementary metal-oxide semiconductor (CMOS) technology only works well when it has a reliable 5-volt power supply. Start to lower that and the channel becomes unstable – sometimes switching, sometimes not.

In 2003, Palem, then at the Georgia Institute of Technology in Atlanta, saw trouble coming. It was clear that the ability of the electronics industry to continue doubling the number of transistors on a chip every 18 to 24 months – a miniaturisation trend known as Moore's law – was coming to an end. Miniaturisation was introducing errors at the chip level. This was largely due to overheating and interference, or crosstalk, between the densely packed transistors. "It was quite likely ultra-small devices would become quite unstable," says Palem. Power was now the critical issue. What if you could harness instabilities in some way that would also save energy?

Palem's answer was to design a probabilistic version of CMOS technology that was deliberately unstable. His team built digital circuits in which the most significant bits – those representing values that need to be accurate – get a regular 5-volt supply, but the least significant bits get 1 volt. "The significant bits are running at a proper, well-behaved voltage, but the least significant get really slack," says Palem. As many as half the bits representing a number can be hobbled like this.

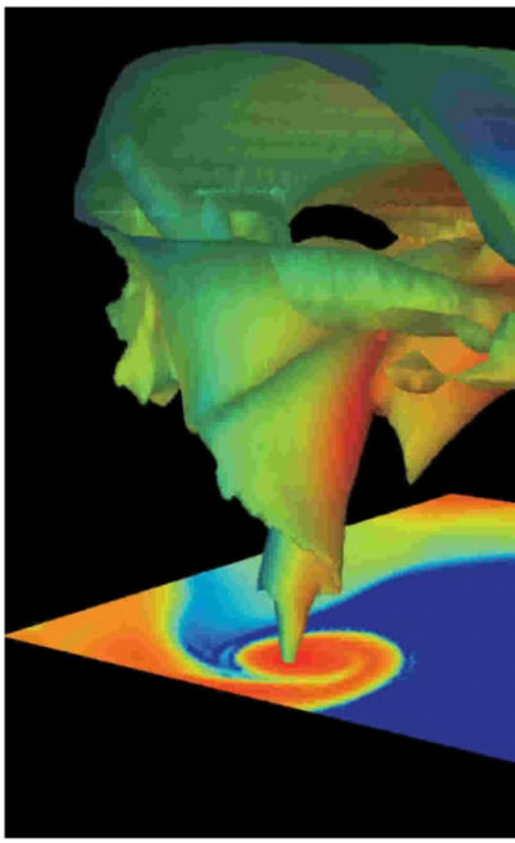
This means that Palem's version of an adder, a common logic circuit that simply adds two numbers, doesn't work with the usual precision (see "Missing bits", below). "When it adds two numbers, it gives an answer that is reasonably good but not exact," he says. "But it is much cheaper in terms of energy use."

Spread that over billions of transistors and you have a significant power saving. The trick is to choose applications for which the least significant bits don't matter too much: for example, using a large range of numbers to represent the colour of a pixel. In one experiment, Palem and his colleagues built a digital video decoder that interpreted the least significant bits in an imprecise way when converting pixel data into screen colours. They found that human viewers perceived very little loss in image quality. "The human eye averages a lot of things out," says Palem. "Think about how we see illusions. The brain does a lot of work to compensate."

Encouraged by that success, the Rice University researchers have moved on to another application involving the senses: hearing aids. Their initial tests show that inexact digital processing in a hearing aid can halve power consumption while reducing intelligibility by only 5 per cent. The results suggest that we could use such techniques to slash the power used by smartphones and personal computers, given that these are basically audiovisual devices.

Tim Palmer, a climate physicist at the University of Oxford, sees even greater potential. He thinks that computers based on Palem's ideas could be the answer to what is presently an intractable problem: how to improve the accuracy of climate predictions for the next century without waiting years for a new generation of supercomputers.

"The crucial question about climate change centres on the role of clouds," says Palmer, in terms of whether they amplify or dampen the effects of global warming. "You can't really answer that question with any great confidence unless you can simulate cloud systems directly." And right now, it's not clear how to do that.



NGM ART/NATIONAL GEOGRAPHIC CREATIVE

Modelling the crucial role of clouds in climate change is too costly with today's computers

Today's supercomputers don't have the brawn to do it, and their successors, expected in the next decade or so, will just be too energy-hungry. "Based on current estimates, the amount of power needed for such a machine is going to be around 100 megawatts," says Palmer, five to 10 times what today's top supercomputers use. Assuming they don't just melt, running them could prove prohibitively costly.

"Doing 20 calculations inexactly may be more useful than 10 done exactly"

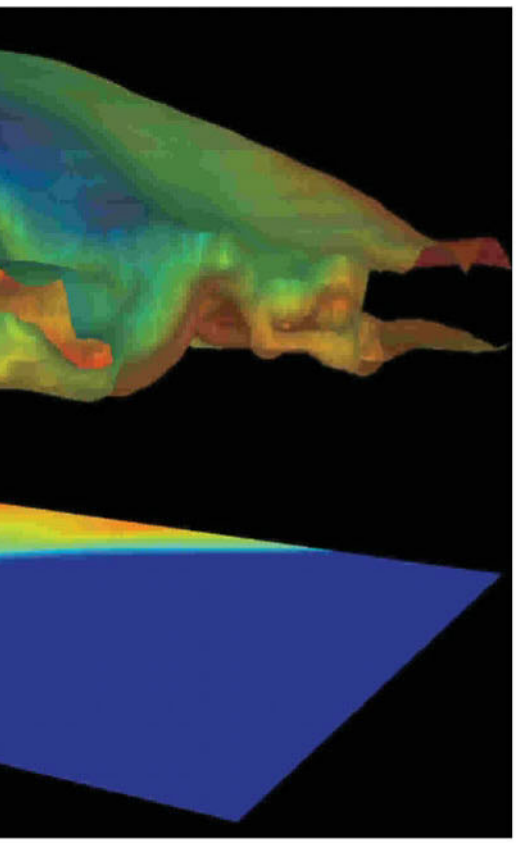
Supercomputers burn so much power because they are generally optimised for computing with 64-bit-long numbers. In principle, this gives greater accuracy. But climate models involve millions of variables, simulating complex interacting factors such as winds, convection, temperatures, air pressures, ocean temperatures and salinity. The result, says Palmer, is that they have too much power-draining data to crunch. What's needed, he says, is for different variables to be

MISSING BITS

Krishna Palem is building an inexact computer that saves power by relaxing its precision. With this set-up, 8 + 5 could equal a range of values.

Here's why: in Palem's system, transistors representing the least significant digits in a number are deliberately run at a lower than ideal voltage. This makes them unstable, prone to flipping from 1 to 0 or 0 to 1. In a 16-bit number, the eight least significant bits could be incorrect. "As many as half the bits can be flipping," says Palem.

As a simplified example, consider adding two 4-bit numbers. In binary, 8 is 1000 and 5 is 0101, and adding them should give 1101, or 13. But if the two least significant – rightmost – bits can flip, then the result could become 1100 (which is 12), 1110 (14) or 1111 (15). It is possible that the inputs, 8 and 5, might get corrupted too: 1000 (8) could turn into 1001 (9), 1010 (10) or 1011 (11); and 0101 (5) into 0100 (4), 0110 (6) or 0111 (7). Finally, the result of adding any two of these numbers could become corrupted as well, leading to a range of inexact answers.



represented in data strings of varying length, depending on their importance to the model.

Chipmakers are starting to accommodate such needs. Nvidia has launched a graphics processor unit, the TX1, that is capable of "mixed-precision" processing, allowing software to switch between 16 and 32-bit operation as it runs. But Palmer wants to see Palem's inexact chips adopted too. "If we can reduce the number of bits that you need to do calculations, that would have an enormous impact on energy consumption," he says. Palmer and his colleagues are talking to supercomputer makers like IBM and Cray about developing a new breed of energy-efficient hybrid machines that allow varying levels of accuracy, and that may even adopt Palem's strategy. And Palem's team is working on mixed-precision computing with the US government's Argonne National Laboratory in Illinois and the European Centre for Medium-Range Weather Forecasts in Reading, UK.

The pay-offs could be huge. Today's climate models tackle Earth's atmosphere by breaking it into regions roughly 100 kilometres square and a kilometre high. Palmer thinks inexact computing would get this down to cubes a kilometre across – detailed enough to model individual clouds.

"Doing 20 calculations inexactly could be much more useful than 10 done exactly," says Palmer. This is because at 100-kilometre scales, the simulation is a crude reflection of reality. The computations may be accurate, but the model is not. Cutting precision to get a finer-grained model would actually give you greater accuracy overall. "It is more valuable to have an inexact answer to an exact equation than an exact answer to an inexact equation," he says. "With the exact equation, I'm really describing the physics of clouds."

Degrees of accuracy

You can't just give up on accuracy across the board, of course. "There is no doubt that if you represent all of the variables in the climate model with just 16 bits rather than 64 bits it would be a disaster: it would fail very quickly," says Palmer. The challenge is choosing which parts can be treated more crudely than others.

Researchers are attacking the problem from several different angles. Mostly, it comes down to devising ways to specify thresholds of accuracy in code so that programmers can say when and where errors are acceptable. The software then computes inexactly only in parts that have been designated safe.

Approximation is not the answer for everyone, however. Rashid Mansoor is a London-based computer scientist and entrepreneur who invented Adbrain, an algorithm that tracks millions of web users as they move between devices. He is now looking at ways to speed up computing done in the cloud. But Mansoor sees inexactness as a last resort. "We don't yield approximate results for the sake of speeding up computation," he says. "We'd consider it to be cheating."

Even so, Stan Posey, who heads Nvidia's high-performance computing team in Santa Clara, California, sees a host of applications for which inexact computing will make a big difference, including accident investigations. After the Columbia space-shuttle disaster of 2003, caused by a chunk of insulating foam breaking off and making a hole in a wing, Posey and his colleagues spent countless hours simulating scenarios that could have led to this happening. He thinks inexact computing would now allow a number of simulations an order of magnitude higher within the same time frame. Scenarios that are worth looking into more closely can then be pursued with higher accuracy.

Some think inexact simulations could ultimately help us understand the brain. Supercomputers like IBM's Blue Gene are being used to model neurological functions in the Human Brain Project, for example. But there is a huge discrepancy in power consumption between the brain and a supercomputer, says Palmer (see "Power hungry"). "A supercomputer needs megawatts of power, yet a human brain runs on the power of a light bulb." What could account for this?

Palmer and colleagues at the University of Sussex in Brighton, UK, are exploring whether random electrical fluctuations might provide probabilistic signals in the brain. His theory is that this is what lets it do so much with so little power. Indeed, the brain could be the perfect example of inexact computing, shaped by pressure to keep energy consumption down.

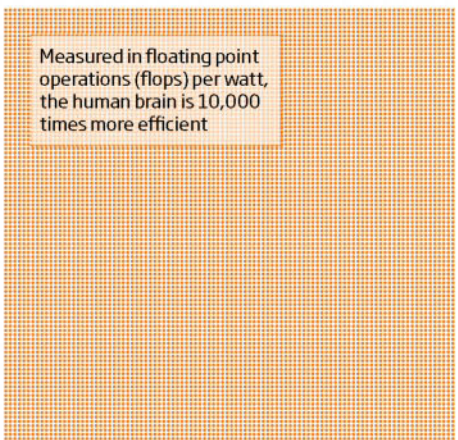
What's clear is that to make computers better, we need to make them worse. Palmer is convinced that partly abandoning Turing's concept of how a computer should work is the way forward if we are to discover the true risks we face from global warming. "It could be the difference between climate change being a relatively manageable problem and one that will be an existential problem for humanity."

And if approximate computing seems a shaky foundation on which to build the future of computing, it's worth remembering that computers are always dealing with the abstract. "All computing is approximation," says Posey. Some are just more approximate than others. ■

Paul Marks is a technology journalist based in London

Power hungry

Despite huge advances in performance, conventional **computers** are no match for the **human brain** when it comes to efficiency



YOU SWINE!

Feral pigs are wreaking havoc across the globe. But it isn't easy to outwit these brainy beasts, says **Stephen Ornes**

NEW YORK STATE DEPARTMENT OF ENV/EYEVINE RODNEY WOODSON

RODNEY WOODSON never set out to be a pig trapper. He joined the Tennessee Wildlife Resources Agency because he was passionate about conserving water birds. But that was before the hogs rocked up, with their high libidos and low cunning.

Across the world, and especially in the southern US, feral pigs are a problem. Marauding hordes of swine are destroying crops and sensitive natural environments, causing traffic accidents and spreading disease and parasites. They have even dug up cemeteries. The US Department of Agriculture estimates the damage at $1.5 billion a year.

As so often with invasive species, this is a problem of our own making. Wild pigs were introduced to the US by Spanish settlers hundreds of years ago, but weren't a cause of widespread concern until the 1990s, says zoologist Jack Mayer at the Savannah River National Laboratory in South Carolina, when cable TV ads began promoting the animals as an exotic alternative hunting target to turkeys and deer. In 1999, Tennessee established a hog hunting season, and soon enterprising landowners were stocking up. That ushered in "an explosion of new hog populations" across the state, says Chuck Yoest, coordinator of the Tennessee Wild Hog Eradication Action Team, part of the agency that Woodson works for. In 2011, the state reclassified pigs from big game to destructive pests.

The pigs' supercharged reproduction rate isn't helping. A sow may produce two or more litters of typically five or six pigs every year, making it nearly impossible to cull all the individuals in an area at once. Pig population models show that clearing an area requires removing 70 per cent of the animals "year after year after year, until you drive that population to extinction", says Mayer.

In Texas, some landowners now offer wealthy customers the opportunity to machine-gun pigs from a helicopter for as much as $1000 an hour. Other communities have called in teams of sharp shooters. But critics say that these methods of pig control are not just inhumane, but ineffective. For a start swine are fast: they can run at up to 50 kilometres an hour. They can also respond to hunting pressure in surprising ways, for example switching between nocturnal and diurnal living patterns. "They're a pain in the backside, but they are interesting critters," says Mayer.

Traps of the sort Woodson lays are generally thought to be the least bad option in dealing with the pigs. But porcine intelligence makes trapping a full time job. Pigs have been shown to beat chimps when it comes to IQ, are whizzes at navigating complex mazes and can manipulate cursors on a screen by controlling a joystick with their snout. It means in simple traps they soon work out how to jump over short fences and climb taller ones, for example by gaining purchase at a corner.

Boar busting

Woodson's first tactic was to play the long game and put the pigs under surveillance. He installed cameras near baited traps, so pest control officers could examine pictures to see how many animals came by, and when. Once they knew which traps were frequented by the hogs, they could stake them out, hiding near a

Hog hordes

Problem pigs are popping up across the globe

UK Wild pigs went extinct in the UK 300 years ago but now they are back thanks to leaky farms. Last year, a survey from the Forestry Commission estimated there were over 1000 in the Forest of Dean, on the England-Wales border, alone.

Italy Last year swine in Tuscany snaffled enough Chianti grapes to fill 130,000 bottles of wine, leading wine-makers to call for mass extermination.

Germany Berlin is home to thousands of wild hogs that pick through rubbish, spreading it around neighbourhoods, and sporadically attack people.

Australia So-called "grunter hunters" have a huge problem on their hands: according to official estimates there are 23 million feral pigs in Australia – more than humans.

US A pair of pigs straying onto the runway at Florida's Jacksonville International Airport in 1988 caused an F-16 fighter to crash and the pilot to eject. According to an Associated Press report at the time: "The pigs were killed. The pilot was bruised. The $16-million jet was destroyed."

trap and triggering its gate at the right moment.

This was by no means a perfect strategy. It took lots of time and people, and although pigs can't see well, they have a keen sense of smell. If they picked up the scent of a human, the pigs wouldn't approach a trap.

So in his latest iteration Woodson has gone wireless, using solar-powered cameras overlooking a circular enclosure with 1.4-metre-high fences – high enough for pigs to have trouble climbing them, and with no corners to aid escape. When a motion sensor detects a pig-sized animal, it sends Woodson an email. From his own home, he can watch a real-time feed of the trap and at the right moment flip a switch to drop the gate.

This human check is critical, Woodson says. If even one pig from a group is left uncaught, it may learn to avoid similar traps. Though maternal education in pigs hasn't been studied rigorously, Woodson's experience suggests that if it's a sow, it may train its offspring to do the same.

His creative trapping is bearing fruit: the record for one of the traps is 52 swine at once. And the wireless approach is generally becoming more popular. Landowners can buy commercial versions of remotely operated traps, including the $6000 Australian model known as the "Boar Buster".

But the story is far from over. Eager for more game, a few unscrupulous landowners are still trafficking pigs to Tennessee from neighbouring states, creating fresh pockets of infestation. Longer-term, climate change may also exacerbate things, at least in Europe. Last year, researchers at the University of Veterinary Medicine in Vienna, Austria, predicted that feral pig numbers there will surge during mild winters, as more food becomes available.

So others are thinking beyond traps. There is the "Judas pig" method, in which, when a group of pigs is culled, a sow is left alive and tagged with a GPS collar. She then does the hard work of finding another, doomed, tribe – at which point shooters are sent in. Then there are chemical approaches such as hog-specific poison or contraceptives. Later this month, trappers and conservationists will brainstorm new ideas in Myrtle Beach, South Carolina, at the international Wild Pig Conference.

Meanwhile Woodson can't stand idle. His latest trap has an oblong pen with two gates directly opposite each other, giving the pigs the illusion of a safe passage. The hogs in his patch are wise. It is a brutal business, and there's no time for complacency. ■

Stephen Ornes is a journalist in Nashville, Tennessee

Animal crackers

Pretending to be other creatures is a very human game, says **Paul Cobley**

Being a Beast by Charles Foster, Profile Books, £14.99
GoatMan: How I took a holiday from being human by Thomas Thwaites, Princeton Architectural Press, $24.95/£14.99

FELICITY MCCABE / THE GUARDIAN

Joining the smart sett: Charles Foster camped out as a badger

WHO hasn't wondered what life would be like as a (non-human) animal – flying, leaping, burrowing and doing all manner of everyday things that feral animals do? Such conjectures are universal. But who would actually go so far as to attempt to "become" a specific animal? Two new books, *GoatMan* and *Being a Beast,* offer engaging answers to this last question, even if they never quite manage to get to grips with the substance of what it is like to be another kind of creature.

Both volumes veer into the territory of the classic essay by philosopher Thomas Nagel, who asked in 1974 "What is it like to be a bat?" He concluded that the core of the problem was consciousness. In the end, the consciousness of the bat would be inaccessible to us, no matter what measures we took to put ourselves in its place.

"It will not help," he writes, "to try to imagine that one has webbing on one's arms, which enables one to fly around at dusk and dawn catching insects in one's mouth; that one has very poor vision, and perceives the surrounding world by a system of reflected high-frequency sound signals; and that one spends the day hanging upside down by one's feet in an attic." Such measures would only enable one to behave as a bat seems to behave; what it is to be a bat would be another matter altogether.

These books take a different view – or at least try to sidestep the problem. Recounting how, after winning a grant from the Wellcome Trust, he prepared to live like a goat, Thwaites is childishly defiant: "Well screw you, Nagel! I'm going to try anyway." Meanwhile Foster – a traveller who sees himself in a tradition of nature writing – takes on some of the behaviours of badgers, urban foxes, otters, red deer and swifts. He takes Nagel's suggestion for a new phenomenology to describe animal worlds as a cue for poesy or a vague reorientation of language.

"Beyond the entertainment afforded by the efforts of the authors, is there much to learn here?"

The projects described by each writer consist of fairly limited attempts to behave like certain animals. In terms of value for money, then, the reader can choose: at roughly the same length, one book reveals very little about one species, the other reveals very little about five species.

Foster's approach is, in some ways, allied to recent work in animal studies – a burgeoning field in the humanities – in the way it takes a tissue of human perspectives as its starting point and tries to transcend them. Foster camps out in a badger sett in Wales with his 8-year-old son, and prostrates himself in east London so as to gain a fox's-eye view. Following an introductory chapter, the book is organised sequentially around highly personalised discussions of his five chosen species.

Thwaites's approach in

GoatMan (out in May) is more focused. Originally wanting to live as an elephant, he takes the advice of a Scandinavian shaman and tries to "become" a goat. His chapters are devoted to "Soul", "Mind", "Body", "Guts" and "Goat Life".

Despite the liberal use of irony and bathos, as well as a generally jokey tone in both books, Thwaites's descriptions of his consultations with experts do threaten to illuminate the world of a non-human animal. In particular, his attempts – and initial failures – to replicate goat physiology are probably the most rewarding passages of either book.

Blood will out

Still, the reader is left wondering whether, beyond the entertainment afforded by the efforts of the authors, there is much to learn here. After the elaborate build-up in *GoatMan*, not to mention the enticing cover image – like the book, both comical and intriguing – it is disappointing that Thwaites seems to spend so little time among his chosen species. (He does, however, find a way to eat grass.) Foster, by contrast, has a friend bring meals to him in the badger sett.

Inevitably, the reader is going to feel short-changed. It is as if both of these projects had involved the authors "becoming" me and, out of all my characteristics, had chosen drinking tea as more representative than my enduring the Northern Line, suffering athlete's foot, carrying the consequences of an inability to afford a dental bridge, etc.

Nevertheless, we can now confirm who would go so far as to try to find out what it is like to be a non-human animal – and that is the gentleman explorer, alive and kicking with his gentility intact. ■

Paul Cobley is a semiotician and professor in language and media at Middlesex University, UK

A drug to make us good?

Jonathon Keats looks for morality in a neuroscientific mess

The Myth of the Moral Brain: The limits of moral enhancement by Harris Wiseman, MIT Press, $38/£26.95

IN 2007, Paul Zak gathered 68 young men to play a game. Pairing them at random, he gave $10 to one person in each pair, which the recipient was instructed to split with his partner. The former could choose how much to offer. If the latter accepted, both men kept the cash. If not, they had to return it.

This is the ultimatum game, a standard economics experiment. But Zak, a neuroeconomist, gave it a twist by dosing half his subjects with oxytocin. The difference was dramatic. Those who took a dose of the hormone were 80 per cent more generous than those who didn't. On the strength of this and other studies linking oxytocin with trust, oxytocin has been lauded as the "moral" chemical.

Harris Wiseman is sceptical. He's also wary of morality claims for serotonin, dopamine and TMS, in which electricity is used to stimulate areas of the brain. In *The Myth of the Moral Brain*, he argues compellingly against "neuroprimacy" in ethics. "Moral functioning is travestied when approached primarily through biological lenses," he writes. Through his thoughtful critique of neuroscientific reductionism, he provides a foundation for understanding the complexities of moral action.

Wiseman objects to Zak's experiments. Real life, he argues, is nothing like psychological studies, which require that participants make simple decisions in controlled conditions. To attain statistical significance, the experiments sacrifice relevance.

Even more damning, Wiseman observes that the results reveal nothing about motivation. In the ultimatum game, oxytocin may make the subjects more generous, or, equally plausibly, it may make them more risk adverse – which has nothing to do with morality.

In the real world, our actions and motivations have complex roots

TIM O'LEARY/MILLENNIUM IMAGES

As a result of these serious limitations, Wiseman thinks that neuroscience is largely counterproductive when it comes to understanding ethics. "Such studies have given us the illusion that our understanding has been deepened," he writes, "when, arguably, the superficiality of the methods, combined with the authority the domain carries with it, have served to undermine and in fact reduce our understanding of the real-life phenomena [they] are supposed to be representing."

On one level, *The Myth of the Moral Brain* is a cautionary tale of overconfidence in easy fixes for deep flaws. On another level, Wiseman uses the inadequacies of neuroprimacy to stress that morality emerges not only from biology, but also from psychological, political, social-environmental, economic and religious influences. In such a quagmire, no drug can be expected to effectively target evil. Instead, "virtues require practice", he writes.

In this conclusion, Wiseman is convincing. The challenge is to get people to practise morally salient traits such as trust and generosity. Ironically, chemicals may help.

If we believe that oxytocin makes us behave morally, we might yet be enhanced by an ethical placebo effect. ■

Jonathon Keats is the author of *You Belong To The Universe: Buckminster Fuller and the future*

Collaboration

Sara Cherry first met **Carolyn Coyne** when she was interviewing for her position at the University of Pennsylvania, where Coyne was a postdoc. What began as a casual collaboration quickly grew into something more. When Coyne moved to take a job at the University of Pittsburgh and found her laboratory wasn't ready, Cherry offered her space in her lab and in her home. They worked together to identify host genes that can help viruses like those that cause meningitis cross the blood-brain barrier. The collaboration was hugely successful, resulting in a publication in a top tier journal and a strong friendship that lasts to this day.

The two infectious disease researchers have talked regularly over the last ten years, as much about their husbands and kids as about their science. But then the Zika virus began to spread across the Americas, leaving devastating birth defects in its wake, and the phone calls became a daily occurrence.

"It was pretty clear that we should work together to understand and combat this virus," said Cherry. "We keep each other informed about all the experiments we have going on in the lab, and that way we can share any assays or tricks that we find. It is helpful to have that kind of relationship. We are friends, and we know that we wouldn't do anything to compete with each other. We know exactly what each we can contribute, because we have overlapping but different skill sets."

Coyne has expertise in barrier cells, the specialized cells that reside in the blood-brain barrier and the placenta that can protect from infection. Cherry has expertise in screening strategies to identify new genes and pathways in viral replication. Together, they are searching for FDA-approved compounds that can block Zika infection in placental cells. The duo already found a handful of promising candidates, which will need to survive several more rounds of rigorous testing before they could ever be used in the clinic. Cherry says that such collaborations can only succeed when people share mutual trust and respect for each other, and each play their part.

"We can't all be an expert at everything," said Cherry. "There are very few labs and few people who can do everything well and want to do all these different things well. We all have our own personal interests and excitement. As the world gets more and more sophisticated, the assays, the technology, the biology, I think it benefits us to take advantage of expertise more broadly."

3 Tips on How to Have a Successful Collaboration

1. *Be open and honest. There is no such thing as a perfect collaboration (or relationship), says Coyne, but open and direct communication is absolutely necessary to establish the mutual trust needed for a successful partnership.*
2. *Take the long view. When you are first starting your lab, it is easy to focus on authorship or other accolades. Recognize that if you behave respectably and share credit appropriately, then everyone will benefit.*
3. *Have fun. It is important to like and want to spend time with your collaborators, Cherry says, otherwise the work is no fun. The same characteristics that make a good friend can also make a good collaborator.*

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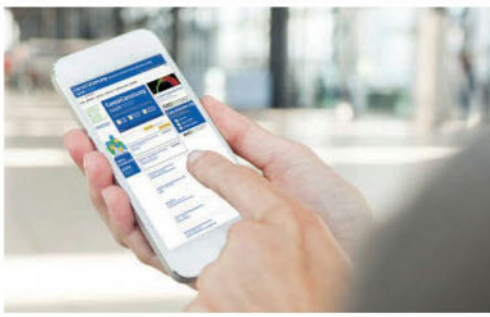

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UNC CHARLOTTE

Faculty Position

Department of Bioinformatics and Genomics

College of Computing and Informatics
University of North Carolina at Charlotte

The University of North Carolina at Charlotte invites applications for faculty at the Assistant or Associate level in the Department of Bioinformatics and Genomics in the College of Computing and Informatics. The Department seeks candidates with a proven research record in Computational Systems Biology, directed toward the theoretical modeling and simulation of complex biological systems, alone or in combination with experimental approaches. The successful candidate should have an earned doctorate and be eligible for appointment at the rank of Assistant or Associate professor. We seek applicants with a commitment to excellence in graduate and undergraduate teaching and mentorship who have exceptional computational/analytic skills to meet teaching requirements in one or more of the following areas: Statistics, Programming, Structural Biology, Big Data Analytics as applied to biological datasets, Machine Learning, and Integrative Systems Biology.

Research areas of interest include the development and application of data analytic and theoretical methods, mathematical modeling, and simulation techniques. Research should address important biological data analysis needs such as structural and functional modeling of biomolecules and molecular interactions, or integration of heterogeneous data sets into models of complex systems, to address issues of health, agricultural productivity, and the environment.

We offer a collegial environment, excellent facilities, a competitive start-up package, and a competitive nine-month salary commensurate with experience. Applications must be made electronically at **https://jobs.uncc.edu** (position #1732) and must include a CV, contact information for 4 references, and statements on research and teaching. Preliminary inquiries may be addressed to Dr. Cynthia Gibas (cgibas@uncc.edu). The University of North Carolina at Charlotte is an EOE/AA employer and an NSF ADVANCE Institution.

For additional information, please visit our website at
http://bioinformatics.uncc.edu.

UNC CHARLOTTE

Faculty Position
Computational Genomics

Department of Bioinformatics and Genomics

College of Computing and Informatics
University of North Carolina at Charlotte

The Department of Bioinformatics and Genomics at the University of North Carolina at Charlotte seeks a tenure-track professor at any career stage to work at our location in the North Carolina Research Campus (NCRC) in Kannapolis. The NCRC is a public-private partnership between corporations, universities and healthcare organizations advancing science at the intersection of human health, nutrition and agriculture.

The NCRC hosts,UNC Charlotte, six other UNC system universities as well as Duke University. UNC Charlotte has a leadership position at the NCRC in bioinformatics. We seek applicants wishing to develop a research program in bioinformatics, computational biology and/or computational genomics. This position is part of a larger university-wide research initiative in Data Science and Analytics. The successful applicant will have an earned doctorate with an exceptional record of achievement and will be expected to maintain an externally funded research program that will catalyze a larger group of interdisciplinary scientists. The responsibilities of the position include teaching quantitative skills such as programming and statistical modeling at the graduate and undergraduate level.

We offer a collegial environment, excellent facilities, a competitive start up package, and a competitive nine-month salary commensurate with experience.

Preliminary inquiries about the position can be made to Dan Janies via email djanies@uncc.edu. However, formal applications must be made electronically at https://jobs.uncc.edu (position #1074) and must include a CV, contact information for 4 references, and statements on research and teaching. The University of North Carolina at Charlotte is an EOE/AA employer and an NSF ADVANCE institution.

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SAN ANTONIO

Faculty Position
in Structural Biology and Drug Discovery

The Greehey Children's Cancer Research Institute (GCCRI) and Department of Biochemistry, School of Medicine of The University of Texas Health Science Center at San Antonio (UTHSCSA) are jointly seeking outstanding candidates (Ph.D., M.D., or M.D., Ph.D.) for tenure-track or tenured positions at the Assistant/Associate/Full Professor with expertise in structural biology (NMR, X-ray crystallography) to join the Pediatric Drug Discovery Initiative (PDDI). The PDDI will bring together experimental scientists in the fields of biochemistry and biophysics, biology, chemistry and computational science, as well as harness the unique established Centers, Institutes and Cores assembled at UTHSCSA to facilitate bench-bedside drug discovery and development. These include the Center for Innovative Drug Discovery, the Institute for Drug Development and the Integrated Cores for Macromolecular Structure and Interactions [including Nuclear Magnetic Resonance Spectroscopy (NMR), X-ray crystallography, Surface Plasmon Resonance (SPR), Isothermal Calorimetry (ITC), and Analytical Ultracentrifugation.

Applicants must have high quality peer-reviewed publications and evidence of independent research. Applicants should also have competitive funding if applying for Associate or Full Professor. The positions offer significant scientific resources, attractive start-up support packages and the potential for competing for additional state funds. Successful applicants will join a multidisciplinary team of researchers at the GCCRI and will be expected to develop collaborative programs and serve as mentors for students and research fellows, and, in some cases, junior faculty.

The Greehey Children's Cancer Research Institute is a unique specialized cancer research center focusing on basic and translational research in childhood cancer, and is housed in a state-of-the-art 100,000 sq. foot research facility on the Greehey Academic and Research Campus of UTHSCSA and supported by an endowment from the tobacco settlement from the State of Texas [**http://ccri.uthscsa.edu**].

San Antonio is the nation's seventh largest city and offers a rich, multi-cultural community with a thriving bioscience industry and is located at the edge of the beautiful Texas Hill County.

All faculty appointment are designated as security sensitive positions. The University of Texas Health Science Center at San Antonio is an Equal Employment Opportunity/Affirmative Action Employer including protected veterans and persons with disabilities.

Interested candidates should send curriculum vitae, statement of research interests including relevance to pediatric cancers and names of three professional references to:

Peter J. Houghton, Ph.D. Search Committee Chair
Professor of Molecular Medicine
Director, GCCRI
University of Texas Health Science Center at San Antonio,
7703 Floyd Curl Drive, San Antonio, Texas 78229.
Email: **aguilarv@uthscsa.edu**

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SAN ANTONIO

Assistant Professor/Research Faculty in Bioinformatics

Candidates are invited to apply for this faculty position in the Department of Epidemiology and Biostatistics at the University of Texas Health Science Center at San Antonio. A research faculty position is available at the rank of assistant professor level.

SUMMARY

This position of bioinformatics faculty with a primary appointment in the Department of Epidemiology and Biostatistics (DEB) at the University of Texas Health Science Center at San Antonio (UTHSCSA) School of Medicine, will have overall responsibility for strengthening our collaborative research and direct a competitive bioinformatics service program. The candidate will apply bioinformatics techniques to analyze the next-generation sequencing, microarrays and other high-throughput profiling data to gain insights into the biology of diverse organisms with an emphasis on cancer research. Candidate will also manage a service component of our next-generation sequencing facility. The bioinformatics faculty will promote the development of interdisciplinary bioinformatics research in translational, clinical and community settings, and provide oversight and guidance to research staff and post-graduate student to conduct independent research.

The successful candidate will join an energetic team of researchers in the Department of Epidemiology and Biostatistics and the Greehey Children's Cancer Research Institute (GCCRI). The interdisciplinary environment of DEB and GCCRI is ideal for quantitative science, statistical, and bioinformatics advances for an early career research faculty. GCCRI is part of the Cancer Therapy and Research Center, an NCI-designated Cancer Center at South Texas that facilitates interdisciplinary research and breakthrough discoveries to advance human health. The next-generation sequencing facility and computational research facility at GCCRI has become a hub of collaborative research at UTHSCSA.

RESPONSIBILITIES

Perform a combination, but not necessarily all, of the following duties:

- Direct the bioinformatics research program for the next-generation genome sequencing facility;
- Provide management for bioinformatics services and collaborations within UTHSCSA, regional and national bioinformatics efforts and initiatives;
- Analyze genome-wide high-throughput data, such as data from gene expression, DNA mutation, and epigenetics studies;
- Provide and develop educational contents for the next-generation sequencing techniques in cancer and medical applications;
- Pursue the development or adoption of new bioinformatics technologies in areas such as basic research, cancer research, and clinical/translational research;
- Participate in extramurally-funded research in bioinformatics; provide planning, management and consultation to bioinformatics-related collaborative research programs and proposals;

EDUCATIONAL EXPERIENCE

Candidates must have a PhD in Computational Biology, Bioinformatics, Biostatistics, Electrical Engineering, Computer Science, or a closely related discipline. Preference will be given to candidates with a PhD and 2-year post doctorial experience in bioinformatics and next-generation sequencing data analysis.

KNOWLEDGE, SKILLS, AND ABILITIES

Candidate must have a minimum of one year of post-doctorial research or equivalent experience in an academic setting. A successful candidate is expected to have broad experience in next-generation sequencing data analysis spanning gene discovery, gene expression and regulation, sequence alignment, and homology detection, with scientific achievement demonstrated by journal publications, preferably with a focus on genome-wide profiling analysis, and proficiency in R, MATLAB, or Perl/Python programming in a Linux environment. Candidate shall demonstrate excellent communication skills, the ability to perform self-directed bioinformatics research, and excellent collaborative skills with unrelenting enthusiasm for genomic science. Strong preference will be given to candidates with experience in obtaining extramural funding in the computational biology and bioinformatics area.

WORKING CONDITIONS

Work is performed in an office environment. The position requires occasional travel to attend professional and grant meetings, as well as meetings for the University of Texas System.

Applicants should submit curriculum vitae, at least three letters of reference, and a letter describing their background, research interests, and relevant experience to:

Elizabeth A. Rolling
Project Coordinator
Attn.: Bioinformatics Position
Department of Epidemiology and Biostatistics
The University of Texas Health Science Center at San Antonio
7703 Floyd Curl, MSC 7933
San Antonio, Texas 78229-3900
rolling@uthscsa.edu

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EDITOR'S PICK

Theory proposes, the world disposes

From Michael Duff

I take issue with the critique of the role of experiment in theoretical physics by Jim Baggott and Daniel Cossins (27 February, p 38). May a physicist be allowed to set the record straight? The concept of supersymmetry was not "conceived as an elegant way to plug holes in the standard model" of particle physics. It was first noted by string theorists and then applied to supergravity. Had Albert Einstein not discovered relativity, then supersymmetry would force us to invent it.

Most string theorists share the view that in the long term the test of a good theory is experiment. The jury is still out on the multiverse, for example. It is those who claim already to know whether or not our universe is unique who are being unscientific – as are those who claim to know what can and can't one day be tested.

Baggott and Cossins write that "theoretical physicists have grown increasingly comfortable plucking theories out of thin air… The Higgs boson is a case in point." But the Higgs was proposed in 1964 and discovered in 2012, in one of theory's greatest triumphs. And let's not forget gravitational waves, first proposed in 1916, whose discovery 100 years later confirmed the existence of black holes – which were proposed by John Michell in 1783.

London, UK

Social intelligence all the way down

From Duncan Butlin

Aviva Rutkin focuses on the wrong sort of human behaviour when comparing human and artificial intelligence (19 March, p 20). The human brain is not designed to be good at chess, Jeopardy or Go.

Even object manipulation is not one of our fortes. It is the things we do socially that a machine will find very hard to match. Making sure granny is offered the last cucumber sandwich at a tea party, or ceasing to discipline a child when you sense you may go too far, for example. When machines can model human behaviour in groups, in all its recursive splendour, only then will we have a real challenge on our hands.

Chichester, West Sussex, UK

Ingredient-free marketing works

From Richard Nissen

Shannon Fischer's description of the power of placebos is fascinating (12 March, p 32). It chimes with my having heard the marketing manager for a big-brand painkiller saying that the more you advertise the stronger the drug becomes – and that its effects kick in within 5 minutes, which is pharmacologically impossible.

London, UK

How would loyalty cancel a stench?

From Garry Trethewey

You report a finding that body odour produces less disgust when attributed to a member of the smeller's group, and Stephen Reicher's comment that because loyalties can affect a core biological response that shows how powerful and malleable group identities can be (27 February, p 20). I find it more interesting that a "core biological response" can be affected by psychosocial events. I wonder whether this is a basis for the placebo effect.

Cherryville, South Australia

Is doping partly mind over matter?

From Alastair Monro

In recurrent furores over doping in sports, I have not noticed any consideration of the role of the brain in performance as outlined in James Witts's informative article (30 January, p 38). Could any improved performance of an athlete on a performance-enhancing drug not be due, at least in part, to a mental change?

Having worked on many clinical trials, I propose one for athletes in which half of the test group is on the real drug and half on a placebo, no one knowing which. Sadly, I find it difficult to imagine top athletes agreeing to participate in such a study.

Sandwich, Kent, UK

A bump passing in the quantum night

From Alan Wilson

I am as excited as anyone about the possibility of a new particle being discovered that would shake up our understanding of the universe (5 March, p 30). But I am a little alarmed that it turns up at exactly six times the mass of the Higgs boson.

To me it seems more likely that it is an artefact of statistical analysis, and might turn out to be, to put it in musical instrument terms, a harmonic of the Higgs. I fear that it will just fade away like the Cheshire Cat, leaving nothing behind but an enigmatic, vanishing smile. Of course, the idea of a harmonic might just be plausible if we visualise it in terms of string theory.

Colmworth, Bedfordshire, UK

Fusion reactors are all difficult

From Alessandro Tesini

David Hambling mentions a new breed of leaner, meaner nuclear fusion reactor, including the "affordable, robust, compact" ARC device (30 January, p 34). But the claims for ARC include rapid dismantling and re-assembly of the lining and the shell of the "doughnut" in which fusion takes place. These need to be replaced as the flux of neutrons from the reaction makes them radioactive and thus weakens them.

I can report from experience that this replacement will require a very big "hot cell" containing complex equipment for remote handling of the radioactive parts.

The ARC designers propose including a tank of molten fluorine-lithium-beryllium salt (FLiBe) in the shell. This will involve solving the problem of welding replacement segments of the tank to irradiated metal in the adjacent segments. And there are issues of toxicity and long-lasting radioactive contamination of the FLiBe. ARC's claimed "plug-and-play" flexible configuration is only theoretical: the more radioactive it becomes, the more difficult it will be to reconfigure it to the extent claimed.

Luynes, France

How to detect an absent neutrino

From Dieter Gold

Matthew Chalmers describes the neutronless double beta decay and the difficulty of detecting it (13 February, p 30). It is already very difficult to detect the presence of a neutrino.

"Until the poachers come through and kill them. Will they have some sort of protection?"

Sara Mains Palkovich is sceptical about plans to reintroduce extinct species to Europe (26 March, p 8)

So how can we be sure we have detected the absence of a neutrino? How can researchers be sure that they have observed a double beta decay without a neutrino, instead of one with two of them? Can there be sufficiently precise measurement of the momentum of the detected particles to be sure that no momentum is carried away by the neutrinos of an ordinary double beta decay?
Voiron, France

From Lindsay Coker
An intriguing cover line: "Once in 100 trillion trillion years – we're about to see the rarest event in the universe" (13 February), though the article (p 30) says it may happen every 10^{25} years.
Mornington, Victoria, Australia

The editor writes:
■ Neutrinoless double beta decay (NDBD) does emit electrons, whose energies and directions of motion can be measured accurately enough to discriminate it from other decays. And the article reported the lower limit on NDBD half-life, established as 10^{25} years, though the full range now being investigated stretches up to 10^{27} years.

Nudge theory and regulation practice

From Hugh Robertson, Senior Policy Officer, Trades Union Congress
Your leader "A nudge too far?" makes some interesting points but perpetuates the idea that the work of the UK Behavioural Insights Team uses a solely "evidence-based" approach (12 March, p 5). As you rightly point out, nudges are seen as a replacement for legislation. It would therefore be appropriate to compare the outcome of a "nudge" with the likely outcome of regulation.

That is not what the trials do. The biggest nudge in the UK was the Responsibility Deal which attempted a voluntary approach to health issues around food, alcohol and the workplace by getting pledges from manufacturers, retailers and employers. These were viewed by most public health experts as totally ineffective. Instead, there have been calls for the government to introduce regulation such as compulsory labelling and minimum alcohol pricing. The deals have all now been abandoned by the government and a sugar tax has been announced.

Nudge theory has its place, but to state that it is evidence-based is a stretch when, in the UK, its application is underpinned by an ideological assumption that regulation is inherently negative. The evidence is that regulation can be far more effective than behavioural interventions, as shown by a range of public safety and health laws, from seat-belt use to workplace smoking.
London, UK

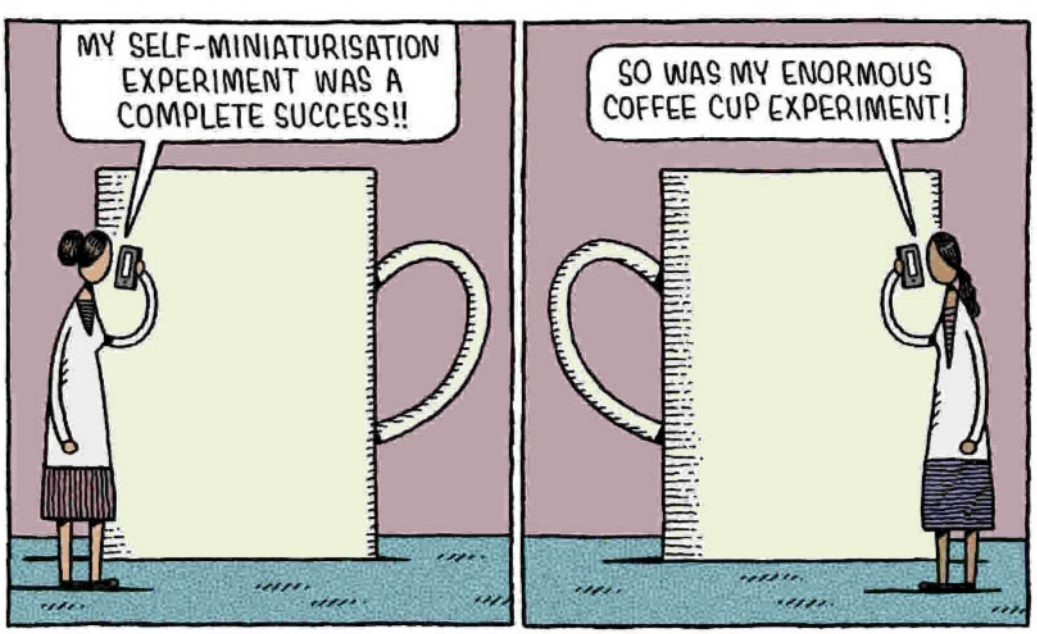
Shocking timing in obedience trial

From Chris Wilkinson
Andy Coghlan reports a modified version of the infamous Milgram experiment on obeying orders, in which participants were asked to estimate the time lapse between pressing a key and hearing a tone, in milliseconds (27 February, p 14).

My estimate is that the best that I could do would be to report to the nearest 250 milliseconds. Did some reported estimates really go to three significant digits?
Turramurra, New South Wales, Australia

The editor writes:
■ The experiment built on earlier work showing that the perceived time delay (not necessarily the actual delay) correlates with a sense of agency or control. Participants were indeed asked to make use of all possible numbers between 0 and 1000 milliseconds.

TOM GAULD



For the record

■ This one is far away: it was Mike Brown of the California Institute of Technology who observed that, seen from the Oort cloud, the sun appears so small that you could completely block it out with the head of a pin (19 March, p 30).

■ Delila Gasi-Tandefelt and her colleagues are taking blood samples from men with advanced prostate cancer in sequence, not at fixed intervals (19 March, p 38). And Bert Vogelstein and colleagues make strands of DNA that mirror their target mutation, and tag these with a fluorescent marker so that they can detect any bits of mutated DNA that stick to their bait.

■ A bass-ic mistake: the song of lonely Whale 52 has recently deepened from 52 Hz to 47 Hz (19 March, p 30).

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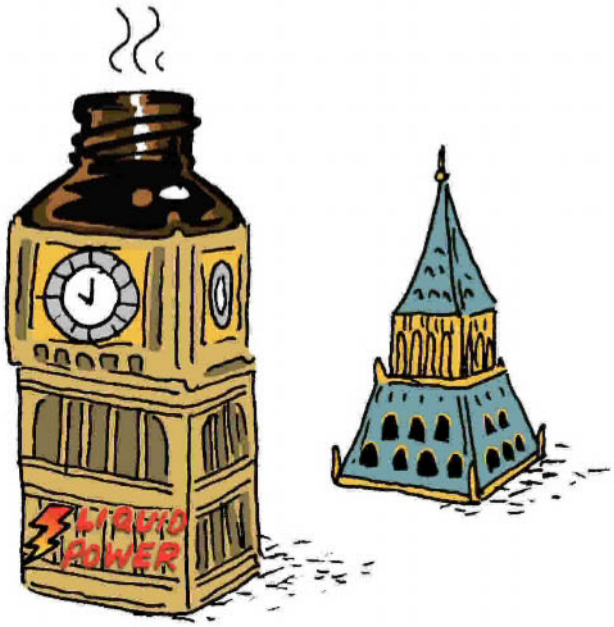


PAUL MCDEVITT

WHEN is a drug not a drug? The UK government's Psychoactive Substances bill seeks to prohibit the sale of consumables that affect a person's mental state. Previously, the minister in charge of the bill, Mike Penning, insisted "We will ensure that we insert what we want to insert, while at the same time having a blanket ban" (14 November, 2015).

Now we learn what he meant as, in addition to the government's own lengthy list of exempted inebriants such as alcohol and nicotine, the Advisory Council on the Misuse of Drugs (ACMD) has been tasked with finding a way to exclude alkyl nitrites.

Otherwise known as poppers, this recreational drug is a popular sex aid because of its muscle-relaxing effects, as well as its instant high. Following an investigation, the ACMD reported that although poppers increase blood flow to the brain, they don't cross the blood-brain barrier.

The ACMD concludes that any psychoactivity is a peripheral effect, and poppers do not directly stimulate the central nervous system – even though users feel a high. The circle deftly squared, another popular drug falls outside the UK's increasingly threadbare blanket ban on drugs.

FURTHER to observations on the quantum superposition of USB cables (5 March), Sue McDonald comes unstuck over another case of strange geometries.

"I was trying to find the end of the sticky tape on its roll," she writes. "Assuming the roll is a circle with an infinite number of sides, I've experienced infinity + 1, which is the number of sides of the sticky tape roll I have to investigate before finding the end of the tape."

Feedback thinks this is a serious underestimate – we have to rotate a roll of sticky tape through at least 720 degrees before finding the end.

SWISS army equipper Victorinox have been pricked by criticism after a customer noticed the online store had 51 "neutral" pocket knives and one "female" model – which was, predictably, pink. Feedback pauses here to spare a thought for all the women who have been toiling with unsuitably gendered knives until now.

Taken to task, the company quickly announced that the offending classification would be cut from their website.

IAN WITHAM writes in with a money-saving tip. "Those herbal remedies that contain none of the advertised herbs will not be wasted," (12 March) he says. "They can be relabelled and sold as homoeopathic remedies."

WHAT mires lie in wait for scientists who stray from their field of expertise. Famed astrophysicist Neil deGrasse Tyson got bogged down earlier this month when he tweeted: "If there were ever a species for whom sex hurt, it surely went extinct long ago."

Biologists quickly directed the space scientist to the many examples of painful sex, from barbed penises to traumatic insemination. In the face of many angry ornithologists shouting about duck vaginas, Tyson dialled back on his first tweet and offered an olive branch to the life sciences with another aphorism: "If you have a gene for celibacy, you didn't inherit it."

Oh dear. May Feedback offer one in reply: "It's better for an astrophysicist to remain silent on the subject of biology and be thought a fool, than to open his mouth and remove all doubt."

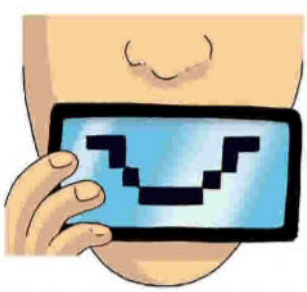
A PRESS flyer from Alan Dolan, Lanzarote-based respiratory guru to the stars, invites Feedback's colleague to his next breathing retreat, "a powerful and intensive five days in which to relax", by, err, breathing.

But no ordinary breathing of course, this is Conscious Breathing, "a powerful and safe way to infuse the body with oxygen". By wresting control of respiration from your brainstem – which Feedback notes has been managing it competently and continuously since the day you were born – Alan says you will enjoy a bingo card of vaguely worded benefits, such as higher levels of consciousness, re-energised systems, and a detox for every level of your being.

"I'm sceptical," admits our colleague, "but I think I need to be sent to Lanzarote to investigate."

THE apple doesn't fall far from the tree: "Your mention of Lucy de la Pasture (5 March) reminds me of the novelist Mrs Henry de la Pasture," writes Griselda Mussett. "Her daughter Esmée was also a novelist, and chose the name Delafield to mark the distinction between them."

A DENTAL firm is offering Glyn Williams "new ways to replace your teeth with digital technology". Aside from this sounding very uncomfortable,



Feedback thinks it would be a chore having to upgrade your mouth every two years.

IN CONTRAST to the UK, drug law reform in the US is of a more permissive kind, fuelling a commodities market in cannabis, but so far, possession is still illegal in Ohio.

However, you could be forgiven for wondering if the state's leading gardening supplies manufacturer, *The Scott's Miracle Gro Company*, is planning to diversify its business portfolio. A recent online advert for the company's lawn seed ran with the tagline "Grass: it smells good. It feels good. It looks good. It is good."

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

"Daylight Saving Time is A Reminder to Change Clocks" – Andrew Doble receives some timely advice from Florida's *Village Daily Sun*

Atomic bonds

On an atomic level, how do Post-it notes stick to things?

Post-it notes are a classic application of polymer chemistry. Funnily enough, the stickiness in question was discovered when Spencer Silver was trying to produce an incredibly strong adhesive in 1968. Instead, he produced an incredibly weak one, but most discoveries are accidents, so who is going to complain? Perhaps just students like myself as we stick up reminders of our exam dates and assignments.

The glue used in Post-it notes is a pressure-sensitive adhesive. This means you only need to apply light pressure to stick the note to something. The bond between the note and the surface is formed through a fine balance between flow and resistance to it. The adhesive can flow just enough to fill tiny crevices on the surface, but will resist flow enough to remain there. This produces the bond between the note and the surface.

"The adhesive in Post-it notes was discovered when trying to produce an incredibly strong adhesive"

If we zoom in further, we can see that on a molecular level, the biggest contributors to the bond strength are van der Waals forces. These are created when a molecule has more of its electrons on one side than the other, producing a dipole (like a tiny magnet). This induces the opposite dipole in another molecule nearby and the two stick to each other. Van der Waals forces are normally weak, but they increase in strength as the size of the molecules grows.

Bradley Clarke
Brighton, East Sussex, UK

Post-it adhesive sticks in much the same way as any other pressure-sensitive contact adhesive: through a combination of van der Waals forces, a decent balance of cohesion (the glue molecules sticking to each other) and adhesion (sticking to everything else), and good contact with the microscopic topography of the target surface.

The more interesting question is how the notes peel off harmlessly. In practice, peeling leaves microscopic traces of Post-it glue on the target surface, but those are generally too small to cause visible damage. The secret is the molecular structure of the polymer, which forms a delicate network that links relatively large lumps together. Imagine it as being like a tennis net with sticky balls attached at intervals over most of its surface. The Post-it paper soaks up and holds powerfully onto one full surface of the adhesive mass (the tennis ball), but only one cheek of each sphere (or ball) sticks out, just touching the other surface.

This has two important effects: ensuring that cohesive forces greatly exceed adhesive ones, and that peeling the paper off the target pulls on only the next ball in line – each requiring only a small force at a concentrated point, almost like undoing a zip tooth by tooth. Strong contact adhesives are different in that they spread the peeling forces over as wide an area as possible. They make it hard to pull any point free without fighting all the neighbouring adhesive material at the same time.

Jon Richfield,
Somerset West, South Africa

Liquid gold

I recently saw vodka in the supermarket with real gold leaf flakes in it. What caught my eye was that the gold flakes were distributed uniformly throughout the bottle. Gold is much denser than water, so why don't they sink to the bottom?
(Continued)

One product that displays the behaviour described is Smirnoff Gold Cinnamon Flavoured Liqueur. If a bottle of this is rotated gently through about 45 degrees clockwise, the gold flakes follow the clockwise motion, but will then "rebound" anticlockwise when you stop. You can often observe similar rebounding if you stir a bowl of soup. This is not the behaviour of a Newtonian fluid, so the bottle probably contains something other than the usual constituents – perhaps some gelling agent.

The gelatinous motion of the bottle's contents is more reminiscent of a weak Bingham plastic, a material that remains rigid until it experiences a sufficient level of shear stress to start behaving as a viscous fluid (for example, mayonnaise).

This can be confirmed by shaking the bottle and observing the motion of the air bubbles: as they rise, you can clearly see that they are threading their way through an invisible solid matrix, and some bubbles even become trapped in it.

Terry Collins
Harrogate, North Yorkshire, UK

This week's questions

CASE LAW

Do neatly folded clothes take up less luggage space? Logic suggests that just stuffing them in – which is my favoured approach – would take up the same space, or perhaps even less if you use a bit of pressure. Practice suggests otherwise.

Ben Calascione
London, UK

SURF'S UP

Surfers are often heard to say, on a day of meagre waves, that one should wait for the tide to turn because the waves will get bigger when the tide is "on the push". Is there any reason to believe that waves will increase in height with an incoming tide?

Colin Risner
St Austell, Cornwall, UK

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Professor Dame Carol Robinson
2015 Laureate for United Kingdom
By Brigitte Lacombe

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