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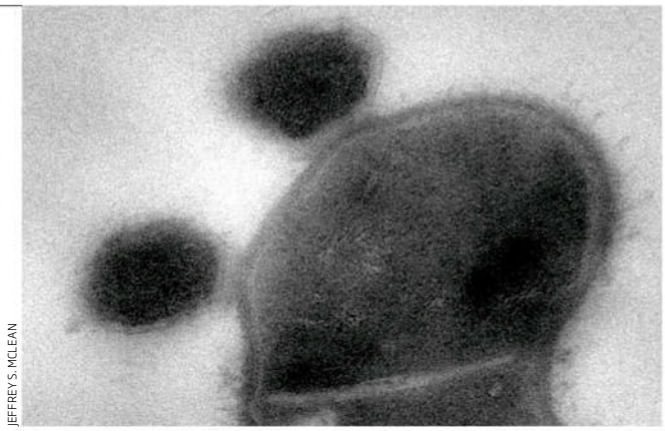

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STEFAN ROUSSEAU/PA/PRESS ASSOCIATION

Take back control!

Cynical pooh-poohing of expertise must not go unchallenged

HOWEVER you feel about the result of the UK's EU referendum, the campaign itself cannot have left anything other than a foul taste in the mouth. The willingness to bend, ignore or invent facts was depressing and shameful.

Both sides were up to it, but Leave told the biggest whoppers. And to the victors, the spoils. It is from their ranks that the next government will probably emerge, so their abuse of facts needs to be held to account.

Let us start with Michael Gove. Pressed in a Sky News interview about expert warnings on the economy, he glibly replied: "I think the people in this country have had enough of experts."

Given that Gove is likely to land a big job in the next government, this claim is troubling. He was not saying "expert opinion is worthless". But he was giving voters permission to dismiss it and trust their own instincts, in cynical pursuit of his own goals. If he is prepared to use this tawdry tactic in the most important UK vote in living memory, there are serious questions about how he will conduct himself in high office.

Similar questions also have to be asked about Boris Johnson, who refused to correct a false claim on the side of his campaign bus, even after being rebuked by the UK Statistics Authority.

Gove and Johnson probably don't care; winning was all. But the fantasy world they seem intent on conjuring up is genuinely dangerous. Reality has a nasty habit of biting back.

Yes, experts can get it wrong. Economists in particular have a poor track record. But that is not a credible or rational reason for rubbishing all expertise.

"The fantasy world of Boris Johnson and Michael Gove is dangerous. Reality has a nasty habit of biting back"

Scientists and other experts are right to be dismayed. It must be tempting to walk away and laugh hollowly as reality takes its course. But that would be a mistake.

We can do better. Sadly, experts must take some of the blame for failing to get their message across. They relied too heavily on spelling out the evidence and scoring factual points – tactics that played straight into the hands of Leave.

For a debate as visceral as this, facts aren't enough. Reams of research has shown that firmly held beliefs – especially those to do with cultural identity – are resilient to conflicting evidence. Trying to change someone's mind by bombarding them with facts usually just makes them dig in. Emotion trumps reason.

Academics in general don't get this. They expect facts and evidence to carry the day, and are left shaking their heads in disbelief when they don't. The Remain campaign shared this assumption, and made little or no attempt to stir any emotion other than fear.

It was never going to work. Rightly or wrongly, many people felt that their national identity was under threat. That allowed Leave to push emotional buttons with slogans such as "take back control". Irrational, yes. Vague, yes. But powerful.

The referendum is over, but the arguments are not. If experts want the debate to be fought in the real world, they need to learn to speak the emotional language of the victors.

That is unpalatable to many. It feels grubby, but it need not be. There were reasons to remain that were truthful and emotionally positive, such as the flowering of scientific collaboration that the EU enabled (see page 18).

Democracy needs experts. And the ones it needs most right now are those who know how to speak truth not just to power, but to ordinary people. It is time for those on the side of rationality to take back control. ■

KEVIN LAMARQUE / REUTERS

Feeling vindicated

Abortion law quashed

IN A win for pro-choice campaigners, the US Supreme Court has struck down a Texas law that made abortions harder to get.

The case, Whole Woman's Health v. Hellerstedt, centred on a law called House Bill 2, or HB2. It requires abortion clinics to meet the same building standards as outpatient surgery centres, such as having advanced air conditioning and heating systems. It also requires doctors who perform abortions to seek "admitting privileges" at a hospital within 48 kilometres of their clinic – a right that can be difficult to secure in areas of the US that are anti-abortion.

Pro-choice advocates argued that HB2 limited access to abortions: since it was passed in 2013, many Texas clinics have been forced to close.

Monday's landmark ruling said that HB2 placed an "undue burden" on women's constitutional right to seek an abortion, particularly for those who are poor, disadvantaged or living in rural areas. It could reverberate in other states with similar laws, such as Louisiana and Mississippi.

"This is a win for Texans & women across the country who need access to abortion," tweeted the sexual health non-profit group Planned Parenthood afterwards.

"This will lead to courts striking down the sham laws that impose restrictions that go beyond what is needed to ensure patient safety," says Maya Manian at the University of San Francisco. It may lead to challenges to other forms of abortion restriction, she says.

Stormy blemish

NEPTUNE has a new freckle – the first we've seen in the 21st century.

The gas giant's most famous feature is a permanent storm in the southern hemisphere called the Great Dark Spot, comparable to Jupiter's Great Red Spot. Neptune's stormy weather is driven by the strongest winds in the solar system, which can reach 2100 kilometres per hour. Because it is so cold, Neptune's atmosphere has a lot of ice crystals, which give the planet its bright blue colour.

"Dark vortices coast through Neptune's atmosphere like huge, gaseous mountains"

Occasionally, a smaller storm will appear, giving astronomers a chance to study how they form and evolve. This latest was first seen by amateur and professional astronomers last July, and confirmed by images taken by the Hubble Space Telescope in May.

It is only the fifth such blemish ever seen – the first two were discovered during the Voyager 2 flyby in 1989, and Hubble saw two more in 1994 and 1996. They are often associated with bright "companion clouds" of methane ice that form when the airflow is diverted above the dark vortex.

"Dark vortices coast through the atmosphere like huge, lens-shaped gaseous mountains," says Mike Wong at the University of California at Berkeley. He hopes to study this storm until it vanishes to understand how it formed, what controls its motions, how it affects the atmosphere and why it eventually breaks up.

Arrival at Jupiter

GET ready for the big one. NASA's Juno spacecraft is due to arrive at Jupiter on 4 July. It is the first dedicated explorer of the gas giant in over a decade.

Juno has spent five years travelling to Jupiter, and will orbit the planet's poles to probe its atmosphere and interior. Planetary scientists know that Jupiter, the largest of the eight planets, played a crucial role in shaping our cosmic neighbourhood, by sucking up much of the gas around in the solar system's early days.

Most of this gas is hydrogen and helium, but trace levels of other elements, such as oxygen and nitrogen, locked up in Jupiter's atmosphere will tell us about its history. Juno will also map the planet's gravitational and magnetic fields to investigate its interior and measure the density of its core, which may tell us whether this is solid.

The spacecraft is expected to orbit Jupiter 37 times over 15 months. Then, in October next year, it will plunge to a fiery end in the planet's atmosphere.

CHINA DAILY/VIA REUTERS

Lofty ambitions

China rocket test

CHINA ramped up its space ambitions last weekend. The country tested its most powerful rocket yet and a prototype crew capsule, both designed to service its future space station.

The medium-sized Long March-7 rocket blasted off for the first time on 25 June from a new launch site in Wenchang, southern China. In future it will propel the uncrewed Tianzhou cargo vehicle into orbit to

resupply the Chinese space station, but this time it carried experimental satellites plus a scaled-down version of its next-generation crew capsule.

Chinese astronauts currently ride Shenzhou capsules, a copy of the Russian Soyuz, into orbit. The prototype launched last week is about half the size of the real thing, which will be capable of carrying larger crews and going further into space – to the moon and beyond.

The craft remained in orbit for around 20 hours before returning via parachute to the Badain Jaran desert in Inner Mongolia.

Long live Hubble

HUBBLE will soon be part of a top double act. NASA has announced plans to keep the famous space telescope running until June 2021. That means it will still be on the job when its successor, the James Webb Space Telescope (JWST), launches in 2018.

NASA launched Hubble in 1990 and it has largely worked well ever since, except when a few difficult repairs by space shuttle crews were needed. The last in-flight servicing was in 2009.

"Hubble is expected to continue to provide valuable data into the 2020s, securing its place in history as an outstanding general-purpose observatory," said a NASA statement.

Hubble and the JWST will complement each other, with Hubble seeing in ultraviolet and visible light, JWST in the infrared. Different wavelengths reveal different aspects of stars and galaxies, so astronomers can study the heavens in greater detail by using the scopes in tandem. "It will allow us to do science with the unique capabilities that both observatories have," says regular Hubble user Boris Gänsicke at the University of Warwick, UK.

Helium haul

IT HAS turned up in the nick of time. Supplies of helium gas, vital for the functioning of MRI scanners and the Large Hadron Collider, have been running low, prompting calls to ban it from leisure use in balloons. Now a team has tracked down a new supply for the first time, by following geological clues.

The source, discovered beneath the Great Rift Valley in Tanzania, amounts to 1.5 billion cubic metres of the gas – seven times the world's annual consumption, and enough for 1.2 million MRI scanners. Without it, we might have run out of helium by 2030.

"This discovery makes it very likely that similar systems can be investigated and, where the geology works in the same way, more helium deposits will be found," says Chris Ballentine at the University of Oxford, joint head of the team, who reported the find this week at the Goldschmidt geochemistry conference in Yokohama, Japan.

But Tom Dolphin, a spokesman on helium use for the British Medical Association, warns against complacency. "The nearest ready supply of helium is on Jupiter, so while it's great we have more for the time being, let's not squander it."

Zika vaccine protects and infects

WHAT one hand gives, the other takes. Just as researchers discover a Zika vaccine that gives mice complete immunity to the disease, concerns are raised that it could make a related virus – dengue – worse.

This week, Dan Barouch at Harvard Medical School and his colleagues reported that a vaccine made of dead Zika virus successfully immunised mice after only one dose (*Nature*, DOI: 10.1038/nature18952).

Human safety trials of the new vaccine will start in October this year.

But other researchers fear that this vaccine could worsen any subsequent infection with dengue. Tests will make sure this isn't the case, since dengue circulates in all regions of the world with Zika.

The problem is that some antibodies to dengue can actually worsen subsequent dengue infections, and there are suggestions that some Zika antibodies may do this too. A vaccine containing the whole virus may elicit such antibodies.

However, research published last week found that antibodies that bind to one particular part of the Zika virus do not seem to have this effect, and instead killed all strains of dengue and Zika.

A vaccine that elicits only those antibodies might protect against both diseases. In the meantime, it may be possible to artificially produce those antibodies to protect pregnant women from Zika.

SUJATA JANA / EYEEM/GETTY

Could make dengue worse

60 SECONDS

Sea scope

Plans for the world's largest neutrino telescope are under way – and underwater. These ghostly particles are incredibly common but hardly interact with normal matter. The KM3NeT telescope, to be built off the Mediterranean coast, will contain a cubic kilometre of detectors, shielded from other radiation by the seawater.

California streaming

Huge extra water reserves have been identified deep under California's Central Valley, and could provide some vital relief in the state's ongoing drought. The valley is estimated to contain 2700 cubic metres of water – three times as much as previously thought (*PNAS*, DOI: 10.1073/pnas.1600400113).

Statin controversy

The brouhaha in 2013 over the UK government's plans to extend the use of statins may have caused 200,000 people to stop taking the drugs in the following 6 months. The proposals resulted in a debate about the pros and cons of the drugs, which are prescribed to lower a person's risk of heart disease, and was widely covered in the media (*BMJ*, DOI: 10.1136/bmj.i3283).

Green team

The US, Canada and Mexico have pledged to produce half of their energy from clean sources by 2025. Announced at a summit in Ottawa this week, the commitment will require the most work from the US, which currently produces about 75 per cent of the three nations' power, a third of which is clean.

Pig shy

Some might say they lack beauty, but pigs do have personality – and they're vocal about it. A study of 72 juveniles has found that the more outgoing a pig is – measured by their curiosity about new objects – the more they grunt (*Open Science*, DOI: 10.1098/rsos.160178).

New life form found in saliva

Previously undetected parasitic bacteria could cause human diseases

Andy Coghlan

PARASITIC bacteria that are entirely dependent on the larger bacteria they infect have been discovered in human saliva. The tiny cells have gone undetected for decades, but appear to be linked to gum disease, cystic fibrosis and antimicrobial resistance.

The finding suggests that many other forms of parasitic bacteria could exist and be living inside us – we just hadn't been able to detect them until now.

"This microbe is clearly the tip of the iceberg," says Roland Hatzenpichler of the California Institute of Technology in Pasadena.

We know of only one other type of bacteria that can infect other bacteria, but that one, called *Bdellovibrio*, is a free-living cell that hunts down its prey. The newly discovered organism seems entirely dependent on its host. The parasite, which appears to make its host more harmful to humans, had evaded discovery because it is difficult to grow and study in the laboratory.

"People with gum disease and cystic fibrosis had high concentrations of the new organism's DNA"

"They're ultra-small bacteria, and live on the surface of other bacteria," Jeff McLean of the University of Washington School of Dentistry in Seattle told the annual meeting of the American Society for Microbiology in Boston in June.

McLean and his colleagues discovered the organisms by searching for bacteria in human saliva. Analysing the DNA of all the species they had managed to grow, they came across a mystery fragment of genetic material. This piece of RNA had been glimpsed by other researchers before, but no one could tell what organism it came from.

McLean's team showed that the RNA belongs to a form of parasitic bacterium that lives on another species called *Actinomyces odontolyticus*. Viewing this larger species under the microscope, they found that its cells were covered with much smaller bacteria.

At first, *A. odontolyticus* is able to tolerate the parasites, which attach themselves to its outer membrane and draw out nutrients. "Later, they start attacking and killing the host," said McLean. Towards the end of the infection process, holes seem to form in the membrane of the *A. odontolyticus* cell and its contents gush out.

"We're trying to decipher what's going on," he said.

The parasitic bacterium is unlike any other known species. It has just 700 genes, whereas *A odontolyticus,* for example, which has 2200. The parasite is the first bacterial strain identified that cannot make its own amino acids – the building blocks for the proteins essential to life. Instead it depends on a supply from its host.

This explains why the species has never been seen before: it can be grown in the laboratory only if it is alongside a host. McLean suspects *A. odontolyticus* is not this parasite's only host, and that many other types of tiny parasitic bacteria exist.

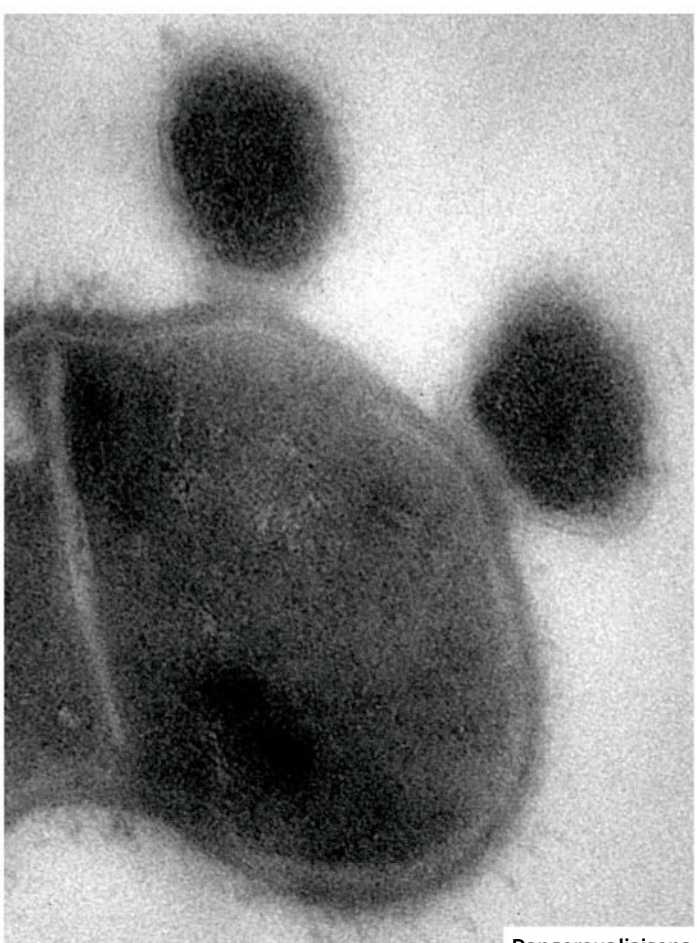
"Gene data from other as-yet uncultivated organisms suggests that host-parasite relationships between microbes are common in nature, so this type of study is a great template for others to follow," says Brian Hedlund of the University of Nevada, Las Vegas.

We might find that these species have an important role in human diseases. McClean's team has found high concentrations of the new bacterium's DNA in people who have gum disease or cystic fibrosis.

Actinomyces bacteria are known to contribute to gum disease, but are usually kept under control by white blood cells called macrophages, which engulf and destroy them. McLean said he has evidence that when these bacteria are infected with the parasite, they can evade macrophages and make gum disease worse.

In previous work, the team had identified a type of bacterium that infects some members of the archaea – a different type of simple single-celled life that is genetically distinct from bacteria.

Both these parasitic bacteria somehow make their host cells resistant to the antibiotic streptomycin – another finding that may prove important as the resistance of microbes to antibiotics spreads. ■



JEFFREY S. MCLEAN

Dangerous liaisons

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Star Wars brainwaves aid sleep learning

FEEL the oscillating force. Brainwaves known as "Princess Leia waves" that rotate as we sleep may help us remember the day's events.

Terry Sejnowski at the Salk Institute for Biological Sciences in La Jolla, California, discovered patterns of electrical activity that sweep through the sleeping brain in a circular motion. He nicknamed them after Carrie Fisher's famous hairstyle in the movie *Star Wars*.

The waves begin their journey in the hippocampus, a region responsible for memory retrieval. From there they propagate to the thalamus, an area that incorporates information vital to our ability to remember events that happen to us personally. They eventually head to the cortex, which is responsible for complex functions such as thoughts and actions.

Sejnowski's team discovered the circular waves by chance after analysing electrical data from eight people with epilepsy who'd had electrodes inserted into their brains for a week to monitor their seizures.

They observed waves of activity that occurred thousands of times per night, each lasting for about two seconds. They tracked these waves and, using a mathematical model, discovered that they were forming almost perfect circular oscillations around the brain.

Each wave had its own specific pattern of peaks and dips. On average, each pattern occurred about 200 times per night, but some repeated around 500 times. Sejnowski presented his results at the State of The Brain meeting in Alpbach, Austria, last month.

Sleep is thought to help us consolidate memories of things we have recently learned. Sejnowski says that each wave pattern may represent a different memory of an event that has occurred during the day. Unusual events may be replayed more often to ensure they are incorporated into long-term memory. Andy Coghlan ■

BLICKWINKEL / ALAMY

Just leave me alone!

Old monkeys choose to have fewer friends

DO YOU see as many friends now as you did 10 years ago? Your shrinking social circle isn't just a human trait – as monkeys get older, they seem to become more selective about who they spend time with too.

We have known for decades that older people are generally less sociable than young adults. This used to be considered a bad thing – a sign that older adults become cut off from society. But on quizzing them, researchers found that older adults were generally no more likely to report being lonely than college students. As a general rule, people seem to choose to be less socially active as they age.

"It's not that they don't like to interact with people, but given a choice they will interact with people they know and like – people who have more emotional meaning in their lives," says Susan Charles at the University of California, Irvine.

Now Julia Fischer at the Leibniz Institute for Primate Research in Göttingen, Germany, and her team have found that some monkeys do the same. Observing free-roaming Barbary macaques living in a wildlife park in southern France, they found that 25-year-old macaques spent less than half as much time grooming other monkeys as 5-year-old adults did, and groomed about half as many individuals (*Current Biology*, doi.org/bkbr).

"The old monkeys become increasingly risk-averse, avoiding unpredictable interactions"

"I think the study is fantastic," says Charles. "It opens the way to looking at the biological or physiological mechanisms that might be at work."

Previously, psychologist Laura Carstensen at Stanford University in California came up with an idea called socio-emotional selectivity theory (SST) to explain this trend in people. Her research suggested that the key factor behind social change as we age is a growing appreciation that our time is precious and limited.

This idea is supported by surveys in which older adults said they would be more likely to make new friends if they knew they had more decades to live.

"SST does describe and accurately predict human behaviour," says Fischer. But her study of macaques suggests this isn't the whole story.

"I don't think monkeys have any awareness of their death, so if there are any changes in their behaviour, they're obviously not to do with that," says Dario Maestripieri at the University of Chicago. "Maybe we would behave similarly even if we had no awareness of our own death."

Fischer thinks the more selective socialising of older monkeys may be a sign that they are becoming more cautious. "The old monkeys become increasingly risk-averse, so they avoid unpredictable interactions. But we need to test this with more data," she says.

If the thought of not making any new friends upsets you, fear not. Just like some people, a few monkeys in the study bucked the general trend, remaining sociable into their old age. **Colin Barras** ■

OVIDIO GONZALEZ/NURPHOTO VIA GETTY

It's all about the inner me

Meditators tune in to their unconscious

Clare Wilson

LEARNING to meditate might give you more awareness of your unconscious brain activity – or so a new take on a classic "free will" experiment suggests.

The results hint that the feeling of conscious control over our actions can vary – and provide more clues to understanding the complex nature of free will.

The famous experiment that challenged our notions of free will was first done in 1983 by neuroscientist Benjamin Libet. It involves measuring electrical activity in someone's brain while asking them to press a button, whenever they like, while they watch a special clock that allows them to note the time precisely.

Typically, people feel that they decide to press the button about 200 milliseconds before their finger moves. But electrodes reveal activity in the part of the brain that controls movement a further 350 milliseconds before people feel they make the decision. This suggests it is actually the unconscious brain that "decides" when to press the button.

In the new study, Peter Lush and his colleagues at the University of Sussex in Brighton, UK, did the experiment but omitted the brain electrodes. The team looked at 57 volunteers, 11 of whom regularly practised mindfulness meditation. The meditators had a longer gap in time between when they felt they decided to move their finger and when it physically moved – 149 compared with 68 milliseconds for the other people (*Neuroscience of Consciousness*, doi.org/bkbt).

"Hypnotisability and mindfulness might be at either end of a spectrum of self-awareness"

This suggests the meditators were recognising their unconscious brain activity earlier than most people, says Lush, supporting the belief that meditation helps you to become more aware of your internal bodily processes. It could also be that people who are more in tune with their unconscious meditate.

The non-meditators were also tested on how easily they could be hypnotised. After they were out of any hypnotic trance, the experiment was repeated. Those who could be easily hypnotised felt as if they decided to move their finger 124 milliseconds later than did those of low hypnotisability. In fact, the easily hypnotisable group had the sensation of deciding to move 23 milliseconds after their finger had actually moved.

It is not that these people are puppets, says Lush, but that they may have less conscious access to their unconscious intentions.

"The results indicate that hypnotisability and mindfulness might be at opposite ends of a spectrum of self-awareness," says Stephen Fleming of the Wellcome Trust Centre for Neuroimaging in London. Other research has suggested that people who meditate are less easy to hypnotise and people who can be hypnotised are less "mindful" – less aware of their internal bodily processes.

However, others have warned against drawing conclusions from such experiments in the past, because the artificial set-up means they may not be relevant to real-life decisions. ■

Life could be at home on nearly dry worlds

MICROBES that thrive in the highest known geothermal vents suggest that water isn't the only thing to look out for when searching for alien life.

"Water is necessary, but to what level?" says Adam Solon of the University of Colorado at Boulder. He believes geothermal vents are likely to be vital for life to emerge on other planets and moons.

To test the limits of water's importance, Solon and his colleagues took samples of bacteria from gas-spewing vents more than 6000 metres up Mount Socompa in Chile's Atacama desert, one of the planet's driest places. They compared the samples with ones from two equally elevated environments, one from relatively moist soil among ice deposits, the other more typical of dry soils found at those altitudes.

Although the icy patches had the most water available, the most diverse microbial life was found in the vents, Solon told the American Society for Microbiology last month at their meeting in Boston.

Figuring out why might tell us what conditions are most favourable for life to arise elsewhere, and it seems temperature is a key factor. The vent microbes could have benefited from more constant temperatures than at the other two sites, which varied from -20 °C by night to 40 °C by day, says Solon. Andy Coghlan ■

STEVE SCHMIDT

Works fine as a pied-à-terre


Professor Dame Carol Robinson
2015 Laureate for United Kingdom
By Brigitte Lacombe
For Women in Science
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FIELD NOTES DREAM CHASER

A day in the life of a space trucker

Lisa Grossman

THE Californian desert rushes up in front of me. I can see the runway at Edwards Air Force Base emerging clearly from the hills, and I try to keep the nose of my spacecraft pointed straight down the centre. I am flying the Dream Chaser spaceplane back from a stint at the International Space Station (ISS), and am keenly aware of my delicate cargo.

Well, almost. In reality, I'm trying out the flight simulator for the Sierra Nevada Corporation's spaceplane at Draper Laboratory in Cambridge, Massachusetts. I'm sitting in front of three computer monitors, which show my view out of the cockpit, and rear and side views of the spacecraft as it descends.

The cockpit screen has a red and a green triangle, one showing where I'm aiming and the other where I should aim. All I have to do is keep them lined up. It feels a lot like playing the world's calmest video game – and that's the point. Dream Chaser is designed to be smooth, comfy and easy to fly.

"If you can survive a rollercoaster, you can survive a flight on this thing," says Draper's Seamus Tuohy. "This could be the path where we transition from space travel being reserved for a few to something that is more common."

Dream Chaser is a quarter of the size of the space shuttle, with wings that fold so it can be squished down for launch on top of a wide variety of rockets. It is designed to land as gently as a plane at commercial airports, and will be able to return from the ISS in just 3 to 6 hours – good features for carrying delicate experiments or injured astronauts.

The spacecraft also uses non-toxic propellant, rather than the noxious hydrazine used by the shuttle. That means people can approach the vehicle and unload its cargo without having to wear protective gear. And it is reusable: it should be good to fly again within 30 days.

The first version won't carry astronauts, though. It will be fully automated, guiding itself to the ISS and back to the ground all on its own.

Sierra Nevada switched to working on an automated version of the craft partly because it lost out on a commercial crew contract with NASA in 2014. Earlier this year, the company was chosen for a different contract: hauling cargo and trash to and from the ISS. That sort of space trucking doesn't need human help.

Still, Sierra Nevada and Draper hope astronauts will fly Dream Chaser some day. "We're looking at making sure that we have something we can go back and have a human fly," Tuohy says.

So that's why I'm here testing out the flight simulator as if I were a real pilot. Despite all the advantages of Dream Chaser, it has had some setbacks. The first test flight in 2013 ended in an uncontrolled skid when part of its landing gear failed to deploy.

I'm hoping to do better, but it's harder than it looks. The throttle responds more slowly than I expect it to, and the little guiding triangle seems to dance away from me. But with a light touch and small moves, I bring the wheels down to the runway and hit the brakes.

"That is a comfortable landing! Way to go," simulation engineer Alan Campbell congratulates me.

I leave feeling fairly convinced that this space truck could actually make it easier for ordinary people to fly to and from space. But I'm worried about its prospects. The next test flight is planned for December this year, and missions to the ISS aren't scheduled until 2019. The space station itself only has funds guaranteed until the end of 2024. By the time this plane is ready for a crew, where will they go?

There are several possibilities, including an inflatable space hotel planned for launch by Bigelow Aerospace, or a Chinese-run space station (see page 6) – both are due to start operating in the 2020s. Tuohy doesn't seem worried. "I bet you there will be somewhere else to go by the time the ISS comes down," he says. ■

SIERRA NEVADA CORPORATION

Dream ride to space

It's massive, it's rubber and it cleans the sea

IF YOU see a string of huge rubber sausages afloat in the North Sea, you're not hallucinating. It's all part of an audacious plan to finally start pulling plastic waste out of the sea.

There are at least 244,000 tonnes of plastic floating in the oceans. Vast gyres of the stuff are circulating in the mid-Pacific, and these are now the target of the Ocean Cleanup project, based in Delft, the Netherlands.

Its goal is to install a 100-kilometre-long V-shaped boom in the middle of the Pacific, to collect plastic lapping against it. Wave action pushes the waste towards the V's apex, where it can be collected and sent for recycling.

A 2014 feasibility study estimated that such a device could clean up half the plastic in the gyres in only 10 years – but at cost of about £300 million.

And since only surface waste gets picked up, and we don't know how much of the plastic in our oceans is floating, it's also unclear how effective the technique would be.

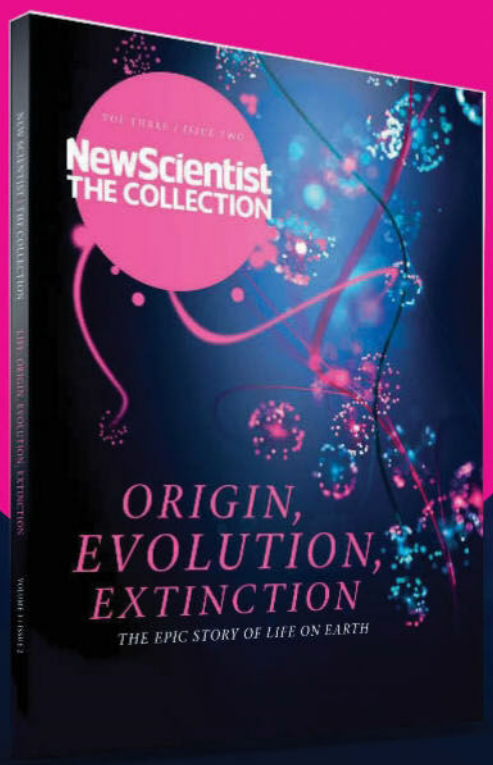
Undeterred, the team is going ahead with their biggest trial yet. "We're not saying this will work," says leader Boyan Slat. "We're saying, let's give it a try."

Last week the team unveiled their latest prototype, named "Boomy McBoomface" in a Twitter contest. The 100-metre-long boom is now floating 23 kilometres off the coast of the Netherlands to see if it can withstand strong currents and storms. Oceanographer and team member Julia Reisser says it is also a chance to test the boom's plastic-collecting ability. "We plan to chuck a load of biodegradable plastic, or maybe ice, in front of it and see how much is caught," she says.

"A few years ago, this would seem berserk. But now we're clearing a space in the North Sea to test it."

"A few years ago this would seem berserk, to think you could clean up the ocean," said Sharon Dijksma, the Netherlands' environment minister, at the launch. "But now we're clearing a space in the North Sea to test it."

Joshua Howgego ■



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NewScientist

JASPER JAMES/GETTY

Tourists pick up antibiotic resistance in just two days

BEWARE the travel bug. In a matter of days after venturing abroad, we acquire genes that make the bacteria living inside us resistant to certain antibiotics.

These genes can be picked up by microbes in your gut. To find out how quickly this happens, Petra Wolffs at Maastricht University Medical Center in the Netherlands and her team took daily stool samples and hand swabs from seven people from the Netherlands before, during and after they visited countries including China, India and South Korea.

The tourists picked up resistance genes within a couple of days of arriving at their destination – probably from food, water and poor sanitation. Two days after reaching India, for instance, two travellers had picked up *qnrB*, a gene that makes bacteria resistant to quinolone, one of the world's most important antibiotics. The tourists' gut flora hung on to the new genes for at least a month after they returned home.

The type of drug resistance acquired depended on the destination, says Wolffs, who presented the results last week at the American Society for Microbiology in Boston. Reassuringly, nobody experienced ill effects from the newly acquired genes. "If you're healthy, it might not have serious consequences," says Wolffs. "We're more worried about people who are immunocompromised – they might be more at risk of some adverse outcome."

Nano-camera lens peers into mirror world

A NEW kind of camera lens can reveal the "handedness" of light. The lens could be used to sort helpful drugs from potentially dangerous mirror versions.

Many molecules come in both a left-handed and a right-handed version. Although both contain the same atoms, they are mirror images of each other and can have different chemical properties. Thalidomide, for example, was once a morning sickness drug but led to birth defects in its right-handed form – an issue, since the body can convert left into right.

One way to tell twin molecules apart is to look at how they scatter light waves, as handedness is imprinted on the direction the waves vibrate. But measuring this usually involves multiple lenses, which can degrade the image.

Now Reza Khorasaninejad of Harvard University and his colleagues have come up with a single nano-lens that can do the job. It is made of titanium dioxide etched by electrons into rows of pillars just 600 nanometres high that sit on a sheet of glass (*Nano Letters*, doi.org/bj9p). Alternating rows twist in opposite directions, creating two side-by-side images without the need for bulky optics.

"We have huge control over the light shaping," says Khorasaninejad.

Pluto must still have a liquid sea

PLUTO probably has a liquid ocean sandwiched between a rocky core and an icy shell.

When the New Horizons probe flew by the tiny world last year, it saw signs of geological activity, perhaps caused by a subsurface ocean. Noah Hammond of Brown University in Rhode Island and his colleagues say such an ocean must still be liquid today.

If it had frozen solid, the pressure from the outer ice would have squished the ocean into a denser form called ice-II, reducing its volume. Pluto would have contracted, covering it in wrinkles.

But New Horizons saw deep cracks instead, suggesting Pluto is slowly growing through the formation of normal ice, which has a larger volume than liquid water.

If so, something must be keeping the ocean wet – probably heat from radioactive decay in Pluto's core (*Geophysical Research Letters*, doi.org/bj9n).

How to hypnotise baby turtles

HOW do you weigh a squirming baby sea turtle? Simple, just hypnotise it.

The frantic movements of hatchlings help them to escape predators but make them hard to measure for conservation studies.

"We often heard about novice researchers dropping hatchlings," says Mohd Uzair Rusli at the University of Malaysia Terengganu in Kuala Terengganu.

Such a fall can be fatal, but Mohd Uzair has found a trick: flipping turtles on their backs, closing their eyes, and gently pressing on their chests.

The technique makes green turtle hatchlings freeze for about 25 seconds – long enough to weigh them precisely without hurting them.

Tiny dinosaurs flew like birds

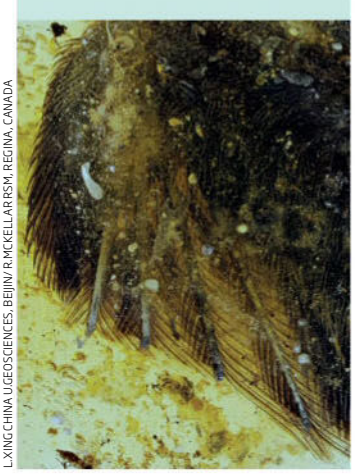
AROUND 99 million years ago, this tiny dinosaur had a sticky encounter. Today, its feathered wings look almost exactly as they did when it became stuck in resin.

Lida Xing at the China University of Geosciences in Beijing, who has led an analysis of two similar partial amber fossils, says these dinosaurs may only have been 3.5 centimetres in length. Their size suggests they were probably juveniles.

The wings are so well preserved it's possible to tell that these dinosaurs were Enantiornithes – a cousin group to today's birds (*Nature Communications*, DOI: 10.1038/ncomms12089). Although this group has a different shoulder structure from birds, their flight feathers are nearly identical, suggesting they flew in the same way birds do today.

As fossils like these come to light, we are beginning to understand the origin of flight as a gradual process, with gliding birds giving rise to crude powered flight, followed by skilled powered flight. These new fossils may help us determine when skilled flight began.

"It really looks like the common ancestor shared between modern birds and the Enantiornithes is exactly where many of the features that we see in modern bird flight evolved," says Richard Prum at Yale University.



L. XING, CHINA U. GEOSCIENCES, BEIJIN/ R. MCKELLAR RSM, REGINA, CANADA

Shampoo bottles get slippy makeover to squeeze every drop

WASH and go. A plastic embedded with nanoparticles repels sludgy shampoo, so that every last drop slides easily out of the bottle.

Wasting a bit of hair product might seem like a petty annoyance, but it's actually a serious environmental problem, says Bharat Bhushan at the Ohio State University in Columbus. "You throw the bottle away and you still have these harsh chemicals [inside]," he says.

It's relatively easy to repel water-based liquids like juice or ketchup from plastic. Their high surface tension means that the molecules stick to each other instead of to the bottle. But liquids like shampoos, soaps and detergents have low surface tension, so get stuck to the sides.

To create a slippery surface, Bhushan and his colleagues put silica nanoparticles into a liquid called xylene and spun and heated it up in a chamber with a piece of plastic to simulate a real bottle.

The nanoparticles crashed into the hot plastic and embedded themselves in it, forming hooked structures that rose above the surface. As the plastic cooled, it reformed around the silica bits. The surface was then treated with UV light and coated with a neutral chemical called fluorosilane.

The resulting hooks keep liquids away from the plastic surface so that they slide easily across the bottle (*Philosophical Transactions of the Royal Society A*, DOI: 10.1098/rsta.2016.0135).

The technology could also be used for medical supplies or food as bacteria won't cling to it, says Sushant Anand at the University of Illinois in Chicago.

Dark hydrogen may hide inside Jupiter

JUPITER and Saturn could have a layer of darkness beneath their colourful surfaces – previously unseen "dark hydrogen".

The element makes up much of these gas giants and research suggests hydrogen near their centres is a liquid metal. But it's not clear what happens between there and the wispy clouds at the surface. Experiments involving squeezing hydrogen in a diamond vice and shooting it with lasers can recreate the conditions within the planets, but the small atoms of hydrogen can easily escape.

Now Stewart McWilliams at the University of Edinburgh, UK, and his colleagues have used a laser pulse lasting just a few microseconds to heat compressed hydrogen to 3000 kelvin. During this brief window, the team saw the hydrogen enter a phase that doesn't reflect or absorb light, which they call "dark hydrogen" (*Physical Review Letters*, doi.org/bkbs).

The discovery of this intermediate phase of hydrogen between gas and metal suggests gas giants have a black layer inside, and its thermal properties could explain how they cooled after formation.

RICHARD NOWITZ/NATIONAL GEOGRAPHIC CREATIVE

Electric fields could mess with pigs

WHICH way is north? Ask a pig. They seem to sense Earth's magnetic field – a finding that could help us win the fight against feral animals.

Pascal Malkemper at the University of Duisburg-Essen, Germany, and his colleagues made this discovery by observing more than 1600 wild boar in the Czech Republic, and more than 1300 warthogs in Africa. Estimating the direction each animal was pointing in, the biologists found that, on average, they lined up closely with the north-south axis (*Mammal Review*, doi.org/bj9f).

"The fact that the animals align with the field lines suggests that they have a magnetic compass which they might use to navigate," says Malkemper. Wild pigs can migrate over 50 kilometres, so perhaps a magnetic map of the landscape helps them find their way.

Feral pigs, descended from escaped farm animals, are a damaging invasive species, causing at least $1.5 billion of damage a year in the US. Malkemper's finding suggests it may be possible to use electric fields from power lines to disrupt their navigation by skewing their compass.

Almost human?

When is an animal a person? It's a question that advances in neuroscience mean we can no longer ignore, says **Aviva Rutkin**

MONKEYS controlling a robotic arm with their thoughts. Chicks born with a bit of quail brain spliced in. Rats with their brains synced to create a mind-meld computer. For two days in June, some of neuroscience's most extraordinary feats were debated over coffee and vegetarian food at the Institute for Research in Cognitive Science in Philadelphia.

The idea wasn't to celebrate these accomplishments but to examine them. Martha Farah, a cognitive neuroscientist at the University of Pennsylvania, assembled a group of scientists, philosophers and policy-makers to discuss the moral implications for the animals involved.

"Neuroscience is remodelling – in sometimes shocking ways – the conventional boundaries between creatures versus organs versus tissue, between machines versus animals, between one species versus blended species," Farah told *New Scientist*. "We thought, let's look at the ways in which advances in animal neuroscience might raise new ethical issues that haven't been encountered before, or that might have changed enough that they need revisiting."

"An animal would go from being a thing to a person, with all the moral and legal status that implies"

It's a timely question. Animal welfare has been hotly debated in some corners for years, but a handful of recent cases have brought the issue to the fore.

Last year, under pressure from activists and Congress, the US National Institutes of Health shut down its chimp research programme, and sent the animals to sanctuaries.

Meanwhile, the non-profit Nonhuman Rights Project has drawn attention for its attempts to take legal action to free captive chimps – so far Hercules and Leo from a Long Island research lab and Kiko and Tommy from private ownership. A new documentary, *Unlocking the Cage*, chronicles the group's so-far-unsuccessful quest for what its president Stephen Wise describes as "legal transubstantiation". If the courts ever find in its favour, "the non-human animal would come out of that courtroom looking the exact same, but her legal status would be forever changed", Wise said on the film.

That invisible change would hinge on a small but slippery word: "personhood". In the eyes of the law, a person is something distinct from a human, and distinct from a thing. Personhood carries major implications for the legal, moral and psychological status of the being that is said to possess it. "I think of it as more of an honorific term than any sort of scientific term," says Kristin Andrews, a philosopher at York University in Toronto, Canada. "It says, this is an animal that's worthy of respect."

It's not unthinkable for an animal to make the leap to personhood. In New Zealand, a river of importance to an indigenous group has been recognised as a person; so has a mosque in Pakistan. Courts outside the US have also struggled over animal personhood cases: dolphins in India and an orangutan in Argentina. With animals, the conversation often revolves around those with recognised cognitive capabilities, like dolphins, elephants, chimps and other great apes.

At the Philadelphia meeting, participants argued over what traits might qualify an animal for this vaunted status (see "A checklist for personhood", right). Is tool use, or language, or

CYRIL RUOSO/MINDEN PICTURES

Awaiting personhood

planning for the future proof of personhood? A few definitions set the bar so high that they exclude some humans, such as young children or the cognitively impaired. One requires persons to be rational, self-conscious and a full-blown moral agent – a standard that would be hard to meet for children under 7.

Studying the brain could provide a clue, says Farah. Intelligent animals could have brains with characteristics reminiscent of human brains, such as the presence of sophisticated building blocks called spindle cells. But it's still not well understood how particular psychological states or traits manifest in the brain.

The line between person and non-person becomes even more blurry when you consider the more radical side of neuroscience. Genetic engineering and chimera experiments can now endow an animal with brand-new traits. Just last month, for example, researchers in Japan revealed marmosets engineered to have a mutated human gene known to cause Parkinson's disease. In 2014, extra brainy mice were created with half of their brains made of human cells. Some at the meeting posited that possessing a dash of human DNA might lift moral status – though it would be hard to say when that line was crossed.

In the end, the room seemed to agree that it may be difficult to ever pin down the definition of a "person". The idea of personhood has ignited the debate – but rather than chase a perfect definition, society might need to settle for a practical middle ground. Instead of giving animals the full upgrade, we could start to understand them as near-persons, or at least as creatures of heightened moral value. We could then bestow rights in proportion to their abilities and intelligence.

"If sentience gets you moral status, but personhood is needed for full moral status, then the entire range of animals that are sentient but not persons have a status in between persons and things," says David DeGrazia, a philosopher at George Washington University in Washington DC. "I think a lot of people would find a picture of moral status like that to be pretty plausible."

Public opinion does seem to be shifting toward giving animals at least some rights. Last year, a Gallup poll found that 32 per cent of people in the US believe that animals should receive the same rights as people – an eight-point rise since 2008.

But what rights might those be? The Nonhuman Rights Project focuses on *habeas corpus*, to protect against unlawful imprisonment. The group wants captive chimps to be sent to a sanctuary, where they can live in a wilder and more open environment. So far, no judge has ruled in favour of their cause. However, in May, it was announced that the chimp research facility where Hercules and Leo live will transfer the pair, along with the 200 others, to a sanctuary.

Upgrading animals' moral status might not close the door entirely on research, but it is likely to make the rules much stricter. Like human children, animals might need a guardian to provide consent for research, and then only when it might be therapeutic or would present minimal risk; there would be no more infecting animals with serious diseases to test drugs.

In certain kinds of research, animals could have the chance to give their own assent. At the Smithsonian National Zoo's Think Tank in Washington DC, computers built into part of the enclosure give great apes the choice to participate in a memory study for treats or wander away.

Alternatives to animal models might spawn their own ethical quandaries. One presentation, by Helena Hogberg at Johns Hopkins University in Baltimore, extolled the virtues of the "brain-on-a-chip" – a miniature, living model of the organ on a plastic lab dish. These models show functional characteristics like electrical activity and include a variety of cell types.

How brain-like would they have to be before we started to ascribe them interests and rights, asked one participant. Hogberg paused to consider, then said, "I don't think we are worrying about that at this point." ■

A CHECKLIST FOR PERSONHOOD

Philosophers disagree on exactly what it would take for an animal to qualify as a person. Kristin Andrews at York University in Toronto, Canada, suggests searching for the six attributes listed here.

SUBJECTIVITY
Showing emotion, perspective and a point of view. Chimps and bonobos throw tantrums when they don't get their way. One researcher has reported a baboon urinating on a rival as a form of revenge.

RATIONALITY
The ability to think and reason logically. Elephants, monkeys, birds and even fish have shown some understanding of basic maths. Some animals can handle tougher problems: in one study, orangutans worked out the principles of water displacement to get a peanut. Many animals have also mastered tools: chimpanzees use leaves as toilet paper, for example, and crows make their own hooked tools to forage.

FRANS LANTING/NGS

PERSONALITY
A distinctive, individual character. Individual squid can be shy or bold; sharks may be more social or solitary; and some great tits act cautiously while others are the reverse. Members of some spider species can vary in how docile or aggressive they are. As for chimps, their personalities can be assigned to sit on a six-point scale.

RELATIONSHIPS
The capacity to form bonds with other creatures, and to care for others and be cared for. Pilot whales stay close to one another as they dive, and use frequent bodily contact, behaviour that looks like it is giving social comfort. Monkeys and elephants grieve the loss of fellow creatures. Imitation, too, could be a sign of the ability to form relationships – newborn chimps can imitate facial expressions, for example.

NARRATIVE SELF
The sense of having an autobiographically connected past and future. Dolphins can remember tricks they did in the past. Apes have some ability to look forward and backward: by remembering major events from previously watched movies, or taking a tool with them to solve a human-posed puzzle.

TOM SOUCEK/ALASKA STOCK/NGS

AUTONOMY
The ability to make decisions for oneself. Communication might indicate an animal's preference – like when an orangutan was observed pantomiming for help with a coconut. Some species also show signs of distinct social cultures; orcas, for example, live in groups with their own lifestyle, social structure and hunting techniques.

Britain's wrong turn

Brexit is the heartbreaking outcome of a misinformed debate. Scientists must fight to pick up the pieces, says **Mike Galsworthy**

EARLIER this month, I wrote on these pages that a vote for Brexit would do terrible damage to UK science (4 June, page 18). Now it has happened, I haven't changed my mind. If anything, I am very frustrated at this turn of events.

There are some who say that Prime Minister David Cameron should never have called the referendum. I disagree. With so few in the UK understanding how the EU worked, it was time to put the issue on the table and have an informed debate.

Unfortunately, what we saw was misinformed debate, long on personalities and hyperbole and short on insightful information. Where were the expert-led public debates on issues such as science, technology, farming, fishing, defence and universities?

Science is the future of the UK's economy and an unequivocal success story of the EU. All the issues of the referendum debate – immigration, democracy, sovereignty, money – could have been discussed through practical examples like science.

As programme director for the campaign group Scientists for EU, I can assure you that we constantly tried to put science on the agenda. We wrote letters and articles, explaining the added value of teamwork across shared policy development, infrastructure, pooled funding and freedom of movement. These have all lowered barriers to scientific progress, empowering UK researchers and bringing huge value to the country.

However, there appeared to be widespread mistrust of analysis brought to the debate. Repeated warnings from universities, economic bodies, health professionals and scientists were dismissed and widely disbelieved.

No more animal magic

Homeopathy is still favoured by a few vets. It is time to end its use, says **Danny Chambers**

PEOPLE trust vets because their medical knowledge is the result of years of study and training at formally accredited institutions, based on sound research.

You certainly wouldn't expect to be recommended treatments based on belief in therapies that have no grounding in science. And yet it happens.

I'm talking about homeopathy, which has no effect beyond placebo. Amazingly it is still offered and promoted by a small number of vets in the UK.

This is weird. Animals don't experience a placebo effect because they are unaware they are being treated. Any perceived medical benefit is merely due to the caregiver effect – the subjective assessment by the animal's owner or clinician, which is also known as wishful thinking. Unlike people, animals don't even receive psychological benefits from homeopathy.

The practice is based on diluting a supposedly useful ingredient many times until in effect none is left. Surely a dose of nothing is harmless? The danger is not only due to the remedies being ineffective, but because some homeopaths believe they can replace orthodox treatment.

"Allowing a small minority to prescribe these remedies adds legitimacy to a pseudoscience"

Substituting effective and appropriate treatment with homeopathy for serious diseases – such as hyperthyroidism in a cat – could lead to tragedy. It would also be devastating for, say, a dairy farm that went under because homeopathic treatments failed to control an outbreak of mastitis.

Vets who practise homeopathy should not be permitted to use their professional standing to promote its validity. They should not be allowed to charge a fee for something proven ineffective. This line must be drawn. After all, no one would argue vets should

I do believe the official Remain campaign made mistakes. It used up all media oxygen on its own thunderous warnings about the economy at the expense of giving visibility to the myriad pro-EU grassroots campaigns at its disposal. However, Remain's basic pronouncement was correct. And I believe it was right to relay solid, independent expert opinions on the consequences of Brexit. It was uninspirational, but it was true.

The country has now been hauled into a no-man's land without a plan. The result ejects the UK from its driving seat on the EU's colossal science engine and leaves its relationship with the science programme in limbo. If anything is certain, it is that this uncertainty will have a negative impact on investment, hiring and probably on the inclusion of UK scientists in research consortia that are currently shaping up.

Throughout, the science community was overwhelmingly for Remain. Polls showed a steady 80 to 90 per cent support. Many scientists in the UK, myself included, are distraught and angry at the result. But we must get over our disbelief and fight to pick up the pieces. ■

Mike Galsworthy is programme director of Scientists for EU

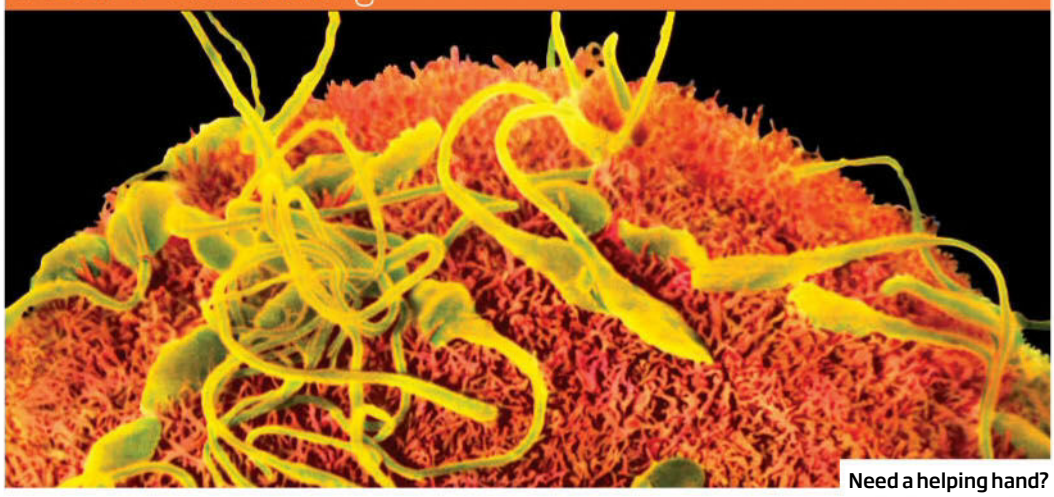
be allowed to offer crystal healing.

The fact veterinary homeopathy persists is so worrying that more than a thousand vets are among those who have signed a petition asking the Royal College of Veterinary Surgeons to intervene.

Allowing a small minority to prescribe these remedies adds legitimacy to a pseudoscience, perhaps leading to belief that it is a genuinely effective medicine. Animal owners may divert limited resources on a "treatment" that offers only false hope. Above all, animal welfare is at risk. ■

Danny Chambers is a vet based at the University of Edinburgh, UK

INSIGHT Gene editing



DR YORGOS NIKAS/SCIENCE PHOTO LIBRARY

Need a helping hand?

Male infertility will get us over genetic red line

Michael Le Page

IMAGINE you're having trouble conceiving only to be told it's because you or your partner don't produce viable sperm. Sometimes genetic mutations are at fault and in these instances a radical treatment could soon be available.

The idea is to extract the stem cells that give rise to sperm and correct the mutation. The corrected stem cells would then be implanted back into the man's testes, allowing him to produce healthy sperm and father his own biological child.

All this can already be done in mice, and several groups are working on it for humans. It is more difficult in people, however, because human sperm stem cells are hard to grow outside the body, says Geert Hamer of the University of Amsterdam, who studies these cells. But it could become possible within the next five or 10 years.

Curing infertility would be huge. But there's a bigger story here. When I read a recent review of the field by Hamer, what struck me was that this was the first good reason I've come across to edit the genomes of our children.

Since the CRISPR genome editing method burst onto the scene a couple of years ago, reams have been written about how it could be used to alter our genes and cure disease. Few argue with its use to help treat blindness or cancer. But using it to prevent genetic diseases is far more controversial because it would involve changing the DNA of our children – it would be "germline" gene editing, in which sperm, eggs or embryos are edited. For many, this is an ethical red line.

It's a discussion that has seen much hand-wringing, but what's often been missing from the debate is the fact that

"Curing male infertility is the first good reason I've come across to edit the genomes of our children"

we don't need to resort to germline gene editing to prevent inherited diseases caused by single mutations. This can already be done more safely with existing screening methods such as preimplantation genetic diagnosis of IVF embryos.

The other reason for germline genome editing is to make designer babies. Whatever you think of this, we don't (yet) know how to turn our children into Einsteins.

But allowing previously infertile men to father a biological child of their own does seem like a persuasive reason to allow genome editing. What's more, this approach will overcome the key safety issues revealed by the first such attempts.

In these experiments, embryos rather than sperm were edited. The result was a mixture of modified and unmodified cells, which would be unacceptable if, say, you wanted to use genome editing to stop people inheriting harmful mutations. If the desired genetic edit is made much earlier, so it is present in sperm, every cell in the embryo will have it. The corrected sperm stem cells could then be checked before re-implantation to ensure there are no undesired changes – the other concern.

It seems certain that some IVF clinics will start offering this service as soon as it becomes technically possible. So treating male infertility may be the thing that ushers in the germline genome editing revolution.

If it proves safe – and acceptable – then undoubtedly it will be used for other purposes, too. If you are fixing one mutation, why not correct a few harmful ones while you are at it?

Some will call this a slippery slope. For others, it's about the health of our grandchildren. Either way, I'm betting curing male infertility gets us there. ■

Heard but not seen

Touchscreens are so last year. **Frank Swain** explores a future in which audible guides will be our constant companions

YOU heard it here first. When it comes to navigating information, headphones may be about to put screens in the shade. A handful of start-ups are creating devices which promise to transform not only how you hear the world, but also the way you interface with the gadgets in your life.

Here One, launched this week by New York firm Doppler Labs, is one example. Looking like a pair of outsized earplugs, it samples the audio environment and plays back an augmented version. Using a smartphone, users can tweak the levels of individual sounds – adjusting the bass and treble at a concert, for example – or silence intrusive noises such as traffic and wailing infants. It goes on sale later this year and will cost $299 in the US.

Doppler Labs isn't alone. The German company Bragi has the Dash, a wireless "smart earphone" that incorporates a music player, pedometer, pulse rate monitor, and much more. As if to underline the trend, Apple is rumoured to be ditching the headphone socket on a forthcoming iPhone, in a move that will make wireless headsets more appealing.

"Microsoft put a computer on every desk. Our goal is to put a computer in every ear"

These products are competing for control of an emerging space in which we will interact with our devices using audio. "We believe that voice input and output is the future of computing," says Doppler Labs' CEO Noah Kraft. One day, he says, "we'll look back at images of people with their heads down, thumbs punching a tiny screen, and say 'how did we walk down the street that way?'"

Silicon Valley's tech giants have already poured millions of dollars into developing voice-controlled assistants: think Apple's Siri, Microsoft's Cortana, OK Google and most recently Alexa, the AI that lives in Amazon's Echo device. Just as smartphone apps took over from web pages as the way most of us use the internet, "hearables" promise to take over from screens, bringing relevant information directly to our ears. Want to know what the weather is like in Rome, the contents of your inbox, or how long it will be until your next train arrives? Just wonder aloud, and hearables will whisper the answer discreetly into your ear. "Microsoft put a computer on every desk," says Kraft. "Our goal is to put a computer in every ear."

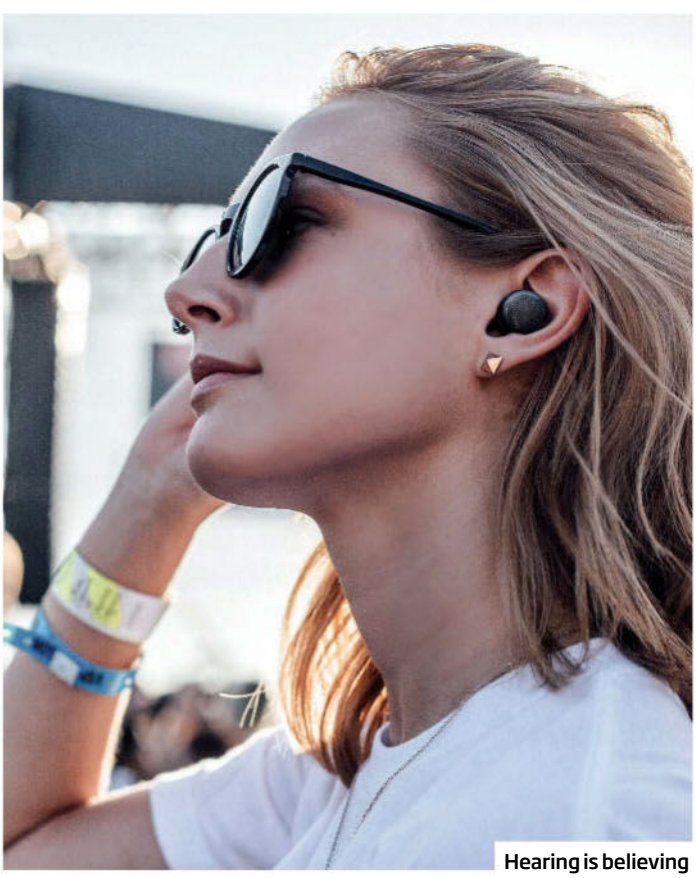
Nikolaj Hviid, managing director of Bragi, shares this vision. "Wearable connected computers will supersede pocket and desk computers. It will change the industry even more than the introduction of the iPhone," he says. Unlike visual interfaces, which demand your attention, audio provides an ideal interface for pervasive, background connectivity. The end goal is a more immersive type of computing, where the interface itself becomes invisible.

Unusually, this trend started outside Silicon Valley. For years, the makers of hearing aids have been crafting small, powerful in-ear computers, designed to augment the user's audio environment. The latest models, such as the Starkey Halo and ReSound LiNX, can stream calls and music from a paired iPhone. This week, Oticon, which has its headquarters in Copenhagen, Denmark, announced a connected hearing aid that integrates with IFTTT, a popular web service that allows users to create customised scripts for internet-linked devices. The wearer can set this up so that they hear a chime if their stocks suddenly fall, or a warning to pack an umbrella the moment the weather forecast changes.

So far, these devices only promise to make our audio landscape more appealing. But the Dash, Here One and so on are not so much a filter for noise as a synthetic layer between you and the real world.

With widespread adoption, it won't be long before companies try to exploit that space. It's not hard to imagine a future in which hearables play you the sizzle of flame-grilled patties uninvited every time you walk past a Burger King.

Until then, Kraft is focused on adding enticing features to get people used to the idea of wearing an earpiece for long periods. "The reason it's called the Here One is that this is the beginning," he says. "One day people will have tech in their ear all day, every day." ■



DOPPLER LABS

Hearing is believing

One giant leap for AI's reading comprehension

SOON you could be chatting with your computer about the morning news. An AI has learned to read and answer questions about a news article with unprecedented accuracy.

Creating AI systems that can learn in the background from humanity's existing stores of information is one of the big goals of computer science. "Computers don't have the kind of general knowledge and common sense of how the world works [that we get from reading] about things in novels or watching sitcoms," says Chris Manning at Stanford University.

To work on building that ability, last year, Google's DeepMind team used articles from the *Daily Mail* website and CNN to help train an algorithm to read and understand a short story. The team used the bulleted summaries at the top of these articles to create simple questions that trained the algorithm to search for key points. Without looking, the algorithm had to fill in blanks in the summaries based on its understanding of the article.

Now a group led by Manning has designed an algorithm (arxiv.org/abs/1606.02858) that beat DeepMind's results by an impressive 10 per cent on the CNN articles and 8 per cent for *Daily Mail* stories. It scored 70 per cent overall.

Streamlining the DeepMind model led to the improvement. "Some of the stuff they had just causes needless complications," says Manning. "You get rid of that and the numbers go up."

"It makes sense," says Robert Frederking of Carnegie Mellon University in Pittsburgh. "Making something more complicated doesn't make it better."

Before we turn AI loose on the world's texts, we must overcome a few challenges, says Frederking. "It's hard to keep these things on track and figure out what information to keep and what to throw away," he says. "If you're not careful, your AI system will think Obama was born in Kenya."

Connor Gearin ■

AFRICAGREENTEC.COM

Catching rays in rural Africa

IKEA-style solar power plant folds into a box

HERE'S a bright idea for flat-pack energy. A German start-up has figured out how to cram an entire solar power plant into a shipping container. It has sent its first kits to off-grid villages in Africa, where they provide a source of clean, affordable electricity after just 2 hours of assembly.

More than 620 million people in sub-Saharan Africa have no access to electricity – a situation that can perpetuate poverty – and population growth means that this number is rising. Those with access tend to rely on inefficient diesel generators, chugging along with crippling financial and environmental costs.

Despite that, diesel is standard for off-grid energy. "If there's no diesel, there's no electricity," says Rolf Kersten of Africa GreenTec in Hainburg, Germany, which shipped its first solar generator to Mali in December last year.

Kersten's team is using crowdfunding to build its containerised power plants. Solar panels and batteries are packed up and folded into a standard shipping container. On arrival, the equipment unfurls around the container with minimal assembly, and starts generating electricity. "For remote places away from a grid, these kinds of solution are very promising," says Mat Evans at the University of York, UK.

"The boxes will be useful anywhere with a lot of sunlight not connected to a national grid"

Air pollution is a pervasive, silent killer in Africa, says Evans. Diesel generators pump out smoke particles, fostering a host of respiratory and cardiac diseases. Generator emissions also contribute to acid rain, which affects crop yields and biodiversity, as well as releasing carbon dioxide, which contributes to global warming. Solar power has none of these problems.

GreenTec sent its first container to Mourdiah, a village in south-west Mali a few hours' drive from the capital Bamako, last September. Before then, only a few villagers had access to patchy electricity. Now, 120 houses are connected to a local grid.

To power Mourdiah's nightlife, the container stores electricity in batteries, as well as producing it from solar panels. Enough energy is stored to light up the village for several hours each evening. "Most life starts at night there," says Kersten. Education, for instance, takes place in the cooler evenings.

Studies of rural electrification have not always painted a rosy picture. In 1994, the World Bank found that the high costs of providing electricity to rural areas often meant that the people it was intended to help could not afford it. Energy from GreenTec's containers is cheaper than that produced by the diesel generators it replaced, though.

"The social aspects are often the trickiest," says Mark Borchers, director of Sustainable Energy Africa. "Who pays? How much? Who's in charge? Who gets the power?"

The next version of GreenTec's generator is bigger, with more panels and double the battery capacity. It should store enough juice to last a village like Mourdiah through the night, powering everything from lighting to built-in water pumps. One container set to arrive in the village of Nafadji in Mali this December has a built-in water-purification system that uses solar power.

The containers will be useful anywhere with a lot of sunlight that isn't connected to a national grid, and for everything from hotels to hospitals, says Kersten. Across the African continent, that's hundreds of millions of people who could really use some power. **Richard Kemeny** ■

Rise of the ballot bots

Fake social media is rife in modern politics, finds **Chris Baranuik**

BRITAIN has voted itself out of the EU. But in the build-up to last week's referendum, researchers became increasingly concerned about the impact of automated social media accounts attempting to sway the vote.

Philip Howard at the University of Oxford and Bence Kollanyi at Corvinus University in Budapest, Hungary, discovered bot accounts furiously sharing and promoting messages on both sides of the campaign.

Of 1.5 million tweets with referendum-related hashtags sampled between 5 June and 12 June, they found that 54 per cent were pro-Leave and 20 per cent were pro-Remain. But a third – half a million tweets – were generated by just 1 per cent of the 300,000 sampled accounts. This level of activity suggests that many of these were automated, say Howard and Kollanyi. The Brexit bots were much more active, tweeting more than three times as frequently as the Remain bots.

"We have seen botnets emerge in the 36 hours before an election – they can spread massive amounts of misinformation," says Howard.

"Only 10 per cent of the 200 most frequent retweeters of referendum content were human"

Another group of independent researchers at Sadbottrue.com also found a string of apparently automated accounts targeting the EU referendum. Only 10 per cent of the 200 most frequent retweeters of pro-Leave and pro-Remain content could be identified as human.

It's not the first time that political bots have been detected. Lee Jasper, a candidate in the Croydon North parliamentary by-election in London admitted using Twitter bots as far back as 2012. Bots were also used during Mexican elections that year, according to Emiliano Treré at the Autonomous University of Querétaro in Mexico. "Digital tools have been successfully deployed by Mexican parties and governments in order to manufacture consent, sabotage dissidence, threaten activists and gather personal data," he said in a report published in the *Institute of Development Studies Bulletin* in January.

The upcoming US presidential election looks set to face bot manipulation too. Howard has identified fake Donald Trump followers with names and profile pictures that look like they belong to people of Latin American origin. The bots retweet Trump's every word, even the anti-immigrant rhetoric that has alienated so many real voters.

In the UK, the impact of Twitter is limited as it has a fairly small user base of about 15 million people. But bots may have had a larger influence during the referendum because social media is used by journalists. If bot-boosted messages are interpreted as a shift in the public mood, or if bots force unsubstantiated rumours into the public conversation, then the potential to influence a wider audience becomes much greater.

"To have a healthy democracy, a modern citizen should be aware that their feed is shaped by bots," says Howard. ■

ROB STOTHARD/PA

This date is not going well

ONE PER CENT

ZUMA/REX/SHUTTERSTOCK

We shall be viewed

Democratic members of Congress sat on the floor last week, refusing to move and demanding legislative action on gun control. Republicans responded by turning off the TV cameras in the house, blocking the protest from public view. But live feeds from Democrat phones, using the Periscope app from Twitter, kept coverage of the protest flowing.

"For the first time in history, we are building artefacts endowed with the ability to make autonomous decisions that have moral consequences"

Iyad Rahwan of MIT on the dilemmas posed by self-driving cars that must make decisions about human life.

Your robot slave

It's good news for those who hate housework. OpenAI, a start-up funded to the tune of $1 billion by Elon Musk, has announced that it aims to build a household robot. "We're working to enable a physical robot (off-the-shelf; not manufactured by OpenAI) to perform basic housework," OpenAI said in a blog post.

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Forever in blue jeans

THIS frog looks like it's got something to say.

The strawberry poison-dart frog is native to Central America and the species varies widely in colour, from bright red all over to splashes of blue on its limbs – giving it the nickname blue jeans frog.

Cristobal Serrano has been photographing these creatures for years, but this one, spotted in the humid lowlands of a forest near the city of Puerto Viejo de Sarapiquí in Costa Rica, was special. The frog (*Oophaga pumilio*) had particularly well-defined blue trousers and sleeves and was perched in a Venus wine cup fungus. Its proud stance and outspread arm looked to Serrano like a speaker addressing a crowd, making an oratorical gesture.

To illuminate the scene, Serrano carefully set up three flashes: one backlight, one from the right and a spotlight just the right size for the frog. "In macro photography, you need to control the flashes very well," he says.

He named the photo *The Speaker* to reference both the theatrical amphibian and the fungus cups, which look like audio speakers.

The photo won a string of awards, including France's Nature Images Award, and the Memorial Maria Luisa contest and LUX award, both in Spain. Serrano attributes his success to the image's lighting and composition – as well as the popularity of the animal under his spotlight. "This frog is the most iconic of the poison-dart frogs," he says. Conor Gearin

Photographer
© Cristobal Serrano
cristobalserrano.com

The big freeze

An exclusive peek at a groundbreaking cryogenic centre leads **Helen Thomson** to investigate how it could revolutionise health

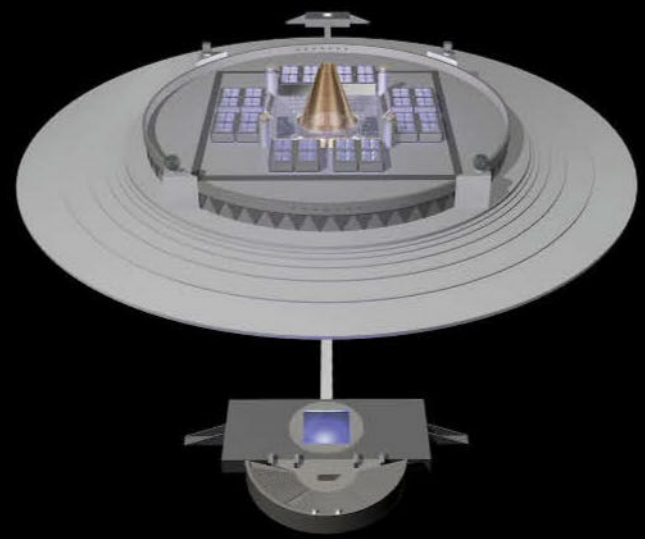
"WE'RE taking people to the future!" says architect Stephen Valentine, as we drive through two gigantic gates into a massive plot of land in the middle of the sleepy, unassuming town that is Comfort, Texas. The scene from here is surreal. A lake with a newly restored wooden gazebo sits empty, waiting to be filled. A pregnant zebra strolls across a nearby field. And out in the distance some men in cowboy hats are starting to clear a huge area of shrub land. Soon the first few bricks will be laid here, marking the start of a scientific endeavour like no other.

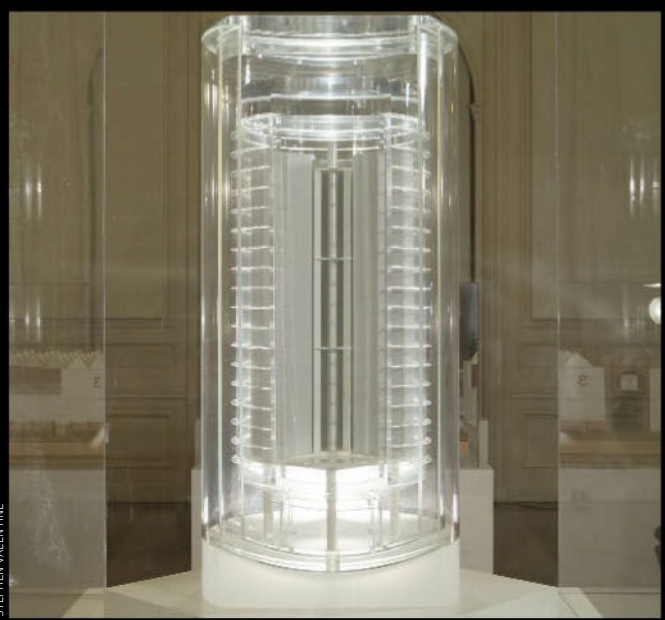
After years of searching, Valentine chose this site as the unlikely home of the new Mecca of cryogenics. Called Timeship, the monolithic building will become the world's largest structure devoted to cryopreservation, and will be home to thousands of people who are neither dead nor alive, frozen in time in the hope that one day technology will be able to bring them back to life. And last month, building work began.

Cryonics, the cooling of humans in the hope of reanimating them later, has a reputation as a vanity project for those who have more money than sense, but this "centre for immortality" is designed to be about much more than that. As well as bodies, it will store cells, tissues and organs, in a bid to drive forward the capabilities of cryogenics, the study of extremely low temperatures that has, in the last few years, made remarkable inroads in areas of science that affect us all; fertility therapy, organ transplantation and emergency medicine. What's more, the cutting-edge facilities being built here should break through the limitations of current cryopreservation, making it more likely that tissues – and whole bodies – can be successfully defrosted in the future.

Timeship is the brainchild of Bill Faloon and Saul Kent, two entrepreneurs and prominent proponents of life extension research. Their vision was to create a building that would house research laboratories, DNA from near-extinct species, the world's largest human organ biobank, and 50,000 cryogenically frozen bodies. Kent called it "all part of a plan to conquer ageing and death".

In 1997, Kent asked Valentine, an architect based in New York, whether he could design a building that was stable enough to operate continuously for 100 years with minimal human input. It needed to withstand earthquakes, to be protected from natural disasters and acts of violence, and to survive without the main power supply for months on end. It was a list of demands that no building in the world currently satisfies. ›





STEPHEN VALENTINE

MURRAY BALLARD, FROM THE BOOK 'THE PROSPECT OF IMMORTALITY'

Above: computer renderings of the Timeship project. Right: conceptual model of the Temperature Control Vessels that will store bodies and tissues

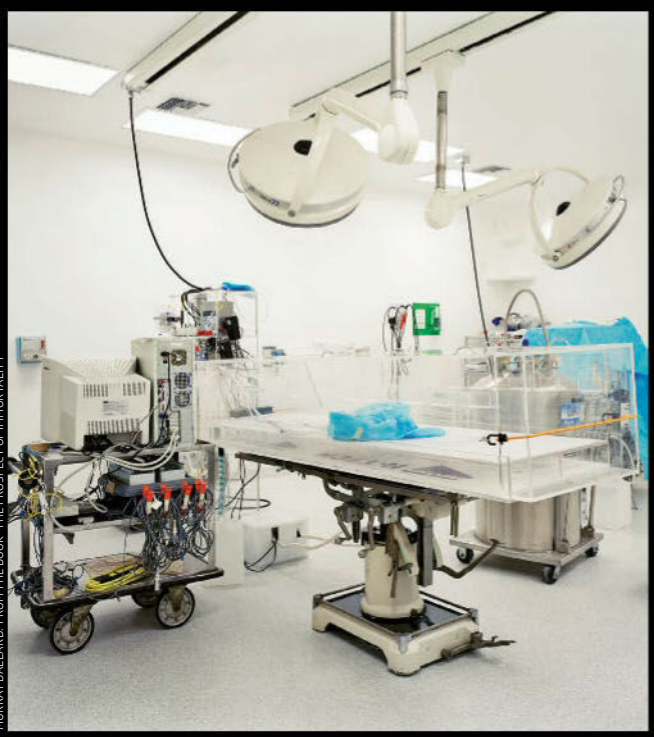
WHAT HAPPENS WHEN YOU ARE FROZEN?

Cormac Seachoy, a graduate from Bristol, UK, was just 27 when his body succumbed to metastatic cancer of the colon. He was pronounced dead on 16 December last year. Not long after, he became Alcor's 142nd cryopreserved member. Seachoy, who had decided he wanted to be frozen after death, had planned to relocate to Scottsville, Arizona, to be close to Alcor's main facility, but his condition went downhill too fast. "Ideally, we are there at the bedside so that we can take over within 60 seconds of the patient being pronounced dead," says Aaron Drake, head of Alcor's medical response team. Instead, Drake made the journey to the UK but was still in the air when Seachoy passed away. An organisation called Cryonics UK stepped in, cooling the body and administering the first lot of drugs until Drake and his team arrived." As soon as death is pronounced, we want to mitigate as much from happening in the cells as possible," says Drake. To do that, his team restores blood circulation using a pump to mechanically do chest compressions and intubates the patient to restore oxygen to the lungs. "We can do bloods at this point to show they are every bit as normal as a living patient, biologically speaking," he says.

Next, the team reduces the rate of metabolism to slow decay. "We immerse the patient in an ice bath and circulate chilled water that draws heat away from the body," says Drake. "We then administer drugs that are designed to prevent clots from forming, break up existing clots and keep a good pH balance and blood pressure. And a general anaesthetic acts to reduce metabolic activity in the brain."

The next step is to replace all the blood in the body with medical-grade antifreeze. "We are trying to prevent any ice from forming when we take the body below freezing point," says Drake. "We continue to cool the body and eventually everything turns into a glass-like solid."

Seachoy's body was held in this state using dry ice, and flown to Alcor to be stored along with Alcor's other members in liquid nitrogen at −196 °C. Here he will remain, possibly for hundreds or thousands of years, waiting for the day that technology can treat the cancer and bring him back to life. "We can't promise that they'll be able to be resuscitated some day," says Drake. "That will depend on future technologies – but if we've been successful and started the process within seconds of clinical death, we've been able to mitigate all types of cellular damage."



MURRAY BALLARD, FROM THE BOOK 'THE PROSPECT OF IMMORTALITY'

The operating theatre at Alcor, where new members are prepared for storage

Valentine spent months drawing up proposals for the building, together with advice from engineers who had previously worked for NASA and security experts from around the world. "We had to address everything from pandemics and cyberattacks to snipers and global warming," says Fred Waterman, a risk mitigation expert on the Timeship team. The designs were approved by Kent but immediately put on ice. He believed the technology that would make the building worthwhile was not yet advanced enough to warrant its construction.

At body temperature, cells need a constant supply of oxygen. Without it they start to die and tissues decay. At low temperatures, cells need less oxygen because the chemical activity of metabolism slows down. At very low temperatures, metabolism stops altogether. The problem faced when trying to preserve human tissue by freezing it is that water in the tissue forms ice and causes damage. The trick is to replace the water with cryoprotectants, essentially antifreeze, which prevent ice from forming. This works well for small, uncomplicated structures like sperm and eggs. But when you try to scale it up to larger organs, damage still occurs.

But in 2000, Greg Fahy, a cryobiologist at 21st Century Medicine in Fontana, California, made a breakthrough with a technique called vitrification. It involves adding cryoprotectants then rapidly cooling an organ to prevent any freezing; instead the tissue turns into a glass-like state. Fahy later showed that you could vitrify a whole rabbit kidney that functioned well after thawing and transplantation. This was the breakthrough Kent and Faloon had been waiting for.

Cold comfort farm

The pair gave Valentine a multimillion-dollar budget and told him to find land on which to build Timeship. Valentine spent five years scouring the US, believing it to be the country most likely to remain politically stable for the next 100 years. He homed in on four states that fitted his exacting criteria. And after evaluating more than 200 sites in Texas alone, Valentine ended up in Comfort. Here he discovered the Bildarth Estate, which came with acres of land, a 1670-square-metre mansion and even a few zebras.

Since then, Valentine, together with a team of specialists, has fine-tuned the project. Timeship's architectural plans make it look like something between a fortress and a spaceship. The central building is a low-lying square with a single entrance. This sits inside

"THERE'S AN URGENT NEED TO BE ABLE TO STORE WHOLE ORGANS FOR LONGER"

MURRAY BALLARD

Old-style body vats: time for an upgrade?

a circular wall surrounded by concentric concrete rings. Inside are what Valentine calls "neighbourhoods", collections of thermos-like dewars that will store the cryopreserved DNA, organs and bodies (see "Cool design", right).

Parts of the project are somewhat theatrical – backup liquid nitrogen storage tanks are covered overhead by a glass-floored plaza on which you can walk surrounded by a fine mist of clouds – others are purely functional, like the three wind turbines that will provide year-round back-up energy.

The question is, do we need Timeship? Such an extravagant endeavour might not be vital, but it looks as if something similar will be necessary sooner or later. In fact, the strongest argument for such a facility, and the technological developments it promises, might have nothing to do with the desire to be frozen for the future.

We already have small biobanks for storing bones from human donors, as well as tendons, ligaments and stem cells. But with rapid advances in regenerative medicine, there is a growing need for large-scale facilities in which we can store more cryogenically frozen biological material.

Stem cells, for instance, are increasingly cryopreserved after being extracted and grown outside the body for use in regenerative therapies. "Beyond the age of 50, it's harder to isolate stem cells for regenerative medicine," says Mark Lowdell at University College London. "If I were in my 30s, I would certainly be cryopreserving some bone marrow for future tissue to fix my tennis injuries." Lowdell will soon do the first transplant of a tissue-engineered larynx created from a donor larynx that has been seeded with cryopreserved stem cells to reduce the risk of rejection.

Then there's the problem of organ shortage. In the US, almost 31,000 transplants were carried out in 2015, but at least six times as many people are on the waiting list – each day 12 people die before they can get a kidney. To make matters worse, many organs go to waste because their shelf life is too short to find a well-matched patient. Nearly 500 kidneys went unused in the US last year because the recipient couldn't get the organ in time.

So there's an urgent need to be able to store whole organs for longer. The issue is so important that the US government this month pledged to start funding research into this very area. We can already reversibly cryopreserve small bundles of cells – many thousands of babies have been born from vitrified human embryos. Doing the same with large organs, like kidneys or hearts, is harder, but not impossible. Over the past decade, for instance, several babies have been born from ovarian tissue that was removed before chemotherapy, cryopreserved and later replaced. Similarly, rabbit kidneys and rat limbs have been cryopreserved, thawed and placed in a new body. Fahy says his team is well on its way to the first human trial of a cryogenically frozen organ. "After decades of research, we're now at a tipping point," he says. Having improved both the vitrification technique and the cryoprotectant solution, they are moving to trials in pigs, and human trials could follow within five years, he says.

That might help prevent wastage, but we would still have a shortage of organs for transplant. Another solution is to grow them from scratch using our own stem cells, and keep them until we need them. So far, tiny 3D heart-like organs have been made from stem cells alone, as well as mini kidneys and livers, all with the ultimate aim of bioengineering replacement organs for transplantation.

Once organs can be produced like this, we will need a way of storing either the raw material or the organs themselves. "I'm not enthusiastic about the notion of freezing whole heads, but I can certainly imagine people needing to freeze cells, or 'starter kits' for the development of tissues, or even whole organs – and in the not-so-distant future," says Arthur Caplan, a bioethicist at New York University Langone Medical Center.

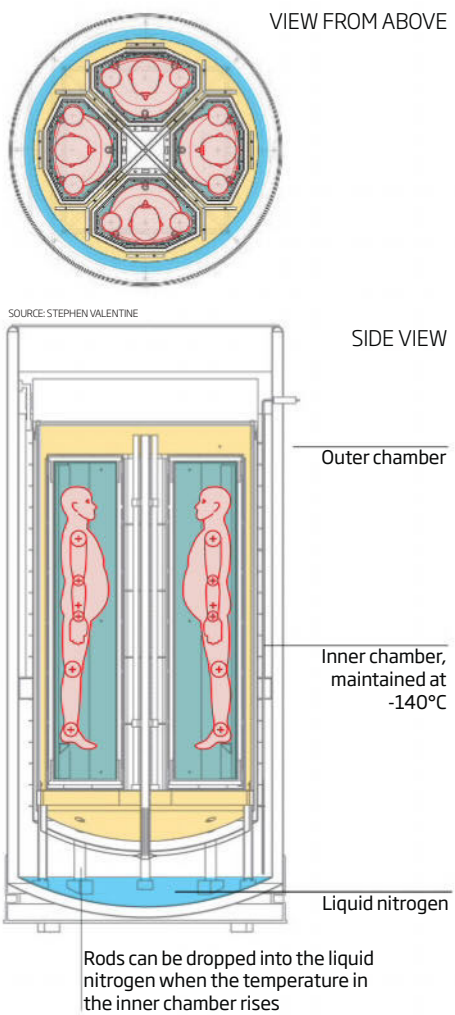
Like Caplan, most scientists I spoke to said it was becoming more likely that we could bring individual cryopreserved organs back to life, but were less convinced by the idea of freezing whole bodies. So I decided to visit Alcor Life Extension Foundation, the world's biggest cryonics facility, in Scottsville, Arizona, to find out what happens when a body is put on ice.

Alcor's lobby has the feel of a doctor's waiting room, except that lining the walls are portraits of men, women, children and the occasional dog. The people in the pictures are preserved there, some alongside their beloved pets.

Aaron Drake, head of Alcor's medical response team, says the company has more ›

Cool design

Cryopreservation typically happens at -196 °C using liquid nitrogen, but this can damage tissue. A new storage system called the Temperature Control Vessel works like a self-cooling thermos. It keeps the body at -140°C to reduce damage



WHAT IS DEATH?

Death has been redefined several times over the past century. It was once considered the cessation of a heartbeat and breathing. Today it includes other scenarios, such as the cessation of brain activity. But even that's not good enough for some.

"Death is a process, not a switch," says Max More, president and CEO of the Alcor Life Extension Foundation in Scottsdale, Arizona. "If you go back 100 years and someone falls over in the street and stops breathing, doctors would say 'this person is dead'. Today we can do CPR and defibrillation to restart their heart and they can be brought back to life. So when that doctor declared them dead, were they? With today's standards, no they weren't." Instead, says More, what we're really saying is "given today's technology and the medicine I have available to me right now, there's nothing more I can do for you".

A definition that emerged in the 1990s in response to this problem is the information-theoretic definition of death. It states that a person is dead only when the structures that encode memory and personality are so disrupted that it is no longer possible in principle to restore them.

Therefore a person who is cryogenically frozen, with brain structures preserved in a state close to what they were before the pronouncement of clinical death, is not by this definition, actually dead. So if the people frozen at Alcor aren't dead, what are they? "There's no good word for what they are," says More (see Interview, page 30). "Some people say they are de-animated."

than 1000 clients signed up worldwide – 99 per cent are healthy, but 1 per cent have a terminal disease. Some of them want to freeze their whole body, others – known as "neuros" – opt for just the head.

Drake admits that the techniques his firm uses aren't perfect, which is why they continue to research the process. Recently, Alcor scientists placed acoustical devices on the brains of neuros as they were lowered into liquid nitrogen, listening as the heads cooled to -196 °C. The colder they got, the more frequently the team heard acoustical anomalies, which they attribute to micro-fracturing of the tissue. "That's damage happening," says Drake. It's difficult to say what effects this might have. "It's not universal or consistent, but it's something we know doesn't happen at around -140 °C."

The problem is, to store a person at -140 °C, you have to keep them warmer than nitrogen's boiling point, which is incredibly hard to do – certainly much harder than placing a body in a giant thermos full of liquid nitrogen, letting it boil and occasionally topping it up.

But at Timeship, Valentine thinks he's cracked the problem. After years of experimentation, he has designed a system called a Temperature Control Vessel (TCV), a dewar that houses cryogenically preserved bodies, heads or tissues. Inside the dewar are moving rods that can be dipped into a pool of liquid nitrogen whenever a sensor notes that the temperature has risen from -140 °C. This would provide a relatively autonomous way of maintaining the contents at an ideal temperature (see "Cool design", page 29).

Each TCV can carry hundreds of samples of tissue and organs, or four bodies and five heads.They are designed to be stacked together in a tessellating pattern that forms the neighbourhoods within the main building.

This should reduce some of the damage to brain tissue that the Alcor team heard. But even with that technology, is there any hope of reanimating a brain?

Facing the future: portraits of people preserved at Alcor watch over the "animated" living

MURRAY BALLARD

There is some evidence to suggest that certain properties of the mind – memories, for instance – can survive cryopreservation. In 2015, researchers trained worms to recognise a smell, then froze them. On thawing, the worms retained the smell memories. And this year, Fahy's team cryopreserved a rabbit brain in a near-perfect state. Although the group used a chemical fixative that is not yet used in human preservation, the thawed rabbit brain appeared "uniformly excellent" when examined using electron microscopy.

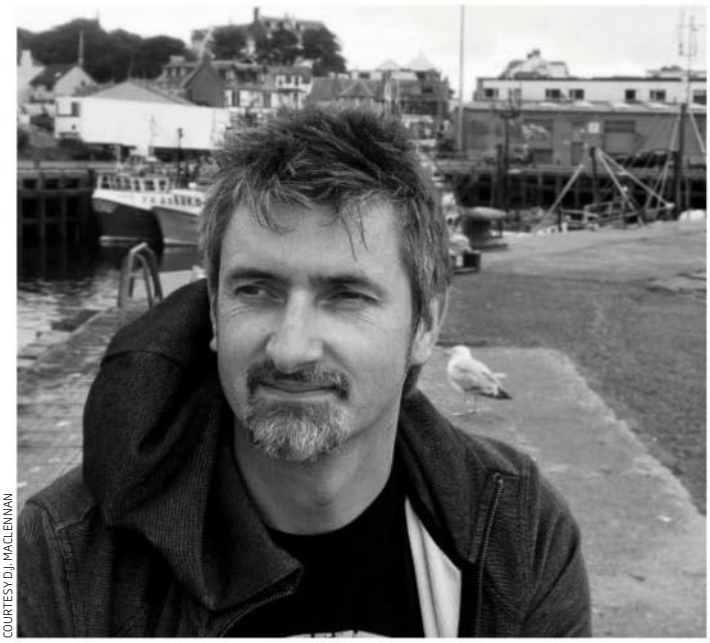
"These kinds of experiments show that it's not such a massive leap of faith to think that we could preserve the human mind," says Max More, president and CEO of Alcor. But not everyone is convinced. Even if you could preserve the delicate structures of the human brain, the cryoprotectants themselves are toxic. "No matter how smart scientists are in the future, you can't change mush into a functional brain," says Caplan, "and I just don't think that what we're able to do right now to preserve the brain is good enough to ever bring it back to life."

There are precedents for the idea that the human brain can be revived after being cooled, however. In 1986, two-and-a-half-year-old Michelle Funk fell into an icy creek where she was submerged for just over an hour. Despite showing no signs of life, doctors spent 2 hours warming her blood through a heart-lung machine. Eventually, she recovered fully. Her doctors figured that the sudden cooling of her brain must have slowed the organ's need for oxygen, staving off brain damage.

Funk's recovery was so remarkable it spurred researchers to repeat the scenario experimentally in pigs and dogs – cryopreserving them for hours before bringing them back to life. The same procedure is now being tested in humans in a groundbreaking trial by surgeons at UPMC Presbyterian Hospital in Pittsburgh, Pennsylvania. There they are placing patients in suspended animation for a few hours, to buy time to fix injuries that would otherwise be lethal, such as gunshot wounds. The technique involves replacing the person's blood with a cold saline solution and cooling the body. They will then try to fix the injuries and bring the patient back to life by slowly warming the body with blood.

That's not so different from what goes on at Alcor, says More. "What we're doing is trying to stretch the time in which the person is suspended. It's just an extension of emergency medicine." I ask More whether he really believes that his members will be brought back to life. "I don't know if it will ever

"WHAT WE ARE DOING IS JUST AN EXTENSION OF EMERGENCY MEDICINE – WE ARE STRETCHING TIME"



COURTESY D.J. MACLENNAN

Head start: D. J. MacLennan pays £50 a month to get his head frozen after death

happen," he says, "but we're breaking no laws of physics here. Who is to say that in 100 years we won't have the medical tools – some kind of nanotechnology perhaps – that can fix cells at an individual level and repair what's necessary to revive someone in good health."

This is the central argument in favour of cryonics – the possibility, no matter how slim, that it offers a chance of survival. "We think of cryonics as a scientific experiment," says More. "People that are buried or cremated are our control group, and so far, everyone in the control group has died."

Facing the future

It is an expensive experiment, however. Cryopreserving your body will set you back up to $220,000, payable on death – often via life insurance, with Alcor as the beneficiary.

"People often say that the money would be better spent on family or given to charity," says Ole Moen, a philosopher and ethicist at the University of Oslo, Norway. "But what's strange about this is that nobody complains when people spend money on expensive cancer treatments or long-term care – people drain the public healthcare budget trying to stay alive all the time," he says. "So why complain when people want to spend their own money trying to live longer via cryonics?"

If you're happy to fork out, there's the big question of what kind of future you'd wake up to. "Even if you could get this technique up and running by some magical future science I believe you'd be a freak – you'd be so far out of it culturally, so lost, that you'd be at risk of being driven mad," Caplan says.

With so many big unknowns, I leave Alcor and Timeship undecided on the utility of cryonics. What's clear, though, is that the underlying research into cryopreservation is worthwhile. Whether it's to help me have children, fix a future tennis injury or potentially even provide me with a new heart, I'd be first in line to freeze cells and tissues today that might help my future self live longer, and healthier.

On my way out of Alcor, I ask Drake whether he wants to be frozen, given that he has cryopreserved so many others. "Yes," he says. "Not because I want to be immortal, I don't think that's possible. I just want to see if all this work was futile. I was the last person these people saw before they took their last breath. Will they see me again? Will they thank me? I don't know if that will ever happen. But wouldn't that be nice?" ■

Helen Thomson is a consultant for *New Scientist*

WHY I SIGNED UP TO GET MY HEAD FROZEN

Taking out insurance to freeze your head after you die is the responsible thing to do, says D. J. MacLennan

Ever since I learned that people eventually died, I have had this fear of death churning away in the background. As a child I was always thinking "isn't there something we can do about this?"

I considered cryopreservation for many years and then signed up as a neuro in 2007, which means I'll only have my head preserved. It made perfect sense to me that the mind arises as an emergent property of the brain and that it might be possible to preserve that.

I don't know whether it will be possible to bring someone back because it's hard to know what kind of repair work you would have to do to correct any deterioration. So I don't think of how it might work, but of what kind of values might be around at the time.

When you sign up, there's a fair bit of legal paperwork and the finances to sort out. I pay for mine through a life insurance policy that pays Alcor upon my death. It's about £50 a month.

I discussed it with my wife for several years, but didn't tell anyone else until I'd signed up.

I don't think we should rest on our laurels and be satisfied with our lot. How do we know that we should be happy with this amount of life? Imagine the regret in the future if this is something that works out and we realise we've got all these people that we've lost that we could have saved?

I don't agree with people who say it's unethical. Where's the wisdom in losing the accrued knowledge of someone who's lived for decades? I think death is a terrible thing. Giving yourself the option, however minute, of keeping hold of all that knowledge and experience is surely the responsible thing to do.

D.J. MacLennan is the author of *Frozen To Life: A personal mortality experiment*. Read a longer version at bit.ly/headfreeze

The man who freezes time

When you earn your crust preserving people who hope for life after death, you receive a lot of flack, but it's worth it, says **Max More**

PROFILE
Max More is CEO and president of Alcor Life Extension Foundation in Scottsdale, Arizona, a non-profit research centre that focuses on cryopreservation of whole human bodies and brains

The Alcor Life Extension Foundation has hundreds of clients who have signed up to be frozen. Is the ultimate goal immortality?
I don't like the word immortality – that's not what we're offering. If you lived forever, I'm sure it would get awfully boring. What we do is freeze people with the expectation that one day it will be possible to bring them back to life into a world in which we can control the ageing process. Then we can stop it or reverse it and decide what age we want to be biologically. You won't die of old age, but that doesn't mean you'll be immortal – you could be killed, have a fatal accident or choose to die.

How can you be so confident that it will ever be possible to bring frozen people back to life?
I don't know if we will be able to bring people back, but there's no reason why we shouldn't be able to – it's just a matter of time. There's nothing here that violates the laws of physics. It just requires a better understanding of this incredibly complex machine that is our body and brain, and very fine medical tools that can repair cells. We've extended average lifespan by figuring out how to fix people, it's inevitable that for some of our patients it should be possible to undo the damage that caused them to die – old age, a heart attack, cancer. We have to assume it will happen at some point.

What happens at Alcor when someone dies?
Ideally they have already relocated somewhere close by. When they are nearing death we arrive, and within seconds of being pronounced dead, we start our procedures. We cool the body and then transport it back to Alcor to begin the process of replacing their blood with drugs that prevent ice formation as they freeze. That minimises damage to cells in the body. We store four people in each container, which is filled with liquid nitrogen.

What if you can't get to someone that quickly?
There are situations in which our members die and aren't found for 24 hours. That's really bad; there will certainly be decomposition. Are they beyond revival? We let our members draw that line because we don't know. Most people say "no matter how or when you find me, go ahead and do the best you can".

Do people's families ever object?
We had one case where the family didn't approve and so didn't tell us that the person had died. A year later we tried to contact him and they said "oh, he died, we buried him". We got a court order and had him exhumed because it was in his contract – he said "no matter what I want to be cryogenically preserved". We had to send a clear message – don't interfere with the wishes of our members. We have to protect their rights.

Is cryonics becoming more widely accepted?
I do believe that we are becoming more accepted by the medical community – particularly since they've started using cooling processes to help in surgery. I think cryonics is just an extension of emergency medicine.

Would you say that the people you have frozen are dead?
They're not dead and they're not alive. They are in a third state that we don't have a good word for. We talk about them being de-animated. I don't particularly like that word because it makes me think of a horror movie, but that's what we're doing. We are slowing down the metabolic process, we are taking away animation. They're not alive because you need metabolism to be alive, but if by dead we mean irreversibly, irretrievably, permanently beyond recovery, then no, we don't consider them to be dead.

Have you ever managed to bring back to life anything that was cryopreserved?
Yes, we trained worms to find food by following a specific chemical gradient. We cryopreserved them and then rewarmed them. We proved that they retained their

MURRAY BALLARD/MURRAYBALLARD.COM/

memory of how to find the food after being brought back. We have slides of brains from vitrified animals where you can see all their membranes and synapses are intact. These show that this isn't a big leap of faith – we are actually preserving all the structures that are relevant for memory and personality. It's a reasonable projection of future capabilities.

What do you make of religious objections to cryopreservation?
I think those arguments are rubbish. Show me any holy book that says "thou shalt not cryopreserve". If they get cancer, do they say "It's god's will, I better just die"? No, they go to hospital and spend huge amounts of money extending their life. In fact, don't most religions say you were given this body and should take care of it so you can do more good work? Isn't there in fact a duty to be cryopreserved if there's a chance of it working, rather than rushing off selfishly to your reward?

Why isn't cryopreservation more popular then?
Because it's unfamiliar. People see it on TV and they think we're going to be reviving zombies with no soul or they think the future will be horrible. In reality, if this ever did work, any future that we will wake up in should be pretty good – at least as good as today and probably better. Why? Because if we screw ourselves over and run out of resources we're not going to be spending money on bringing people back. So any future in which we return has to be one that's sufficiently wealthy and civilised to have been able to achieve that feat.

What are the biggest criticisms you face?
The most common is not religious or ethical, but the idea that cryopreservation is only for rich people. It costs $200,000 to preserve a whole body, which sounds like a lot, but most members pay for it using a life insurance policy. It pays for your treatment and storage. Most people have life insurance, it's very affordable. I signed up as a neuro when I was a poor student.

> "Everything that matters to me is in my head – that's what I want to keep"

What's a neuro?
A neuro is someone who only has their head cryopreserved rather than their whole body. My decision was based on the fact that if we develop the technological capabilities that are able to go into a hundred billion neurons and repair damage, then regrowing a body should be pretty easy by comparison. We're already growing organs. Also if I die at 93, my body is going to be a mess – why waste all that money storing this piece of junk when it's going to have to be regenerated anyway. Everything that matters to me is in my head – that's what I want to keep. If it doesn't work, it doesn't work. But this option gives me more chance of living again than any other options we now have.

How long would you want to live for?
I don't know. Come back in 1000 years and ask me then. Why should I accept an arbitrary end that I haven't chosen for myself? We die because our bodies aren't designed to live indefinitely, because nature doesn't care about that. All evolution cares about is giving genes to the next generation. Once you pass reproductive age you can start rotting. There's no reason why we can't say "we have other ideas, we want to stay healthy and keep producing and creating and loving and all the good things that life allows". ■

Interview by Helen Thomson

MODERN TOSS

The emperor's new loos

Wherever the Romans went, their baths and toilets followed. But did it usher in a cleaner, healthier age? **Stephanie Pain** digs the dirt

IF THERE'S one thing most people know about the ancient Romans, it's that they spent a lot of time in the bath. As the Roman Empire expanded, public baths proliferated across the newly annexed territories. From plain and practical to polished-marble luxury, baths provided both colonists and colonised the means of a daily soak. Less well known is the Roman passion for another hygienic innovation: the public convenience. Wherever the Romans went, they took their toilets.

What did all that washing and flushing do for the health of less fastidious folk who came under Roman rule? "Given what we know now about the benefits of sanitation, you might safely assume this would lead to an improvement in people's health," says Piers Mitchell, a doctor and palaeopathologist at the University of Cambridge.

But hard evidence was lacking, so Mitchell went in search of it. He scoured records of Roman remains from towns and graveyards to fossilised faeces, for parasites such as intestinal worms, lice and fleas. What he found was precisely the opposite of what he expected.

According to legend, Rome was founded in the 8th century BC. Two centuries later work began on the cloaca maxima, or great sewer, which eventually became part of an immense network of drains and underground sewers. Work on the first of the city's remarkable aqueducts got under way in the 4th century BC. By the end of the 1st century there were nine, carrying more than enough water for drinking, bathing, flushing the streets clean and holding mock naval battles in a purpose-built lake.

By now Rome was the world's biggest city, with a population of a million, mostly living in squalid tenements in dirty narrow streets. Yet most people had access to public baths and toilets: the much-travelled Romans had acquired the technology from their Greek

neighbours centuries earlier and built bigger, better and more of both. To most Romans, personal cleanliness was a matter of pride and bathing a daily ritual. The city now had 200 public baths of varying sizes and degrees of luxury – places to relax, socialise and wash off the day's dirt. Toilets were ubiquitous; private houses and tenements had latrines that seated several at a time, while some public lavatories could accommodate as many as 50. The authorities, keen to keep the city clean, introduced laws requiring human waste and rubbish to be removed outside the city.

As Rome's tentacles stretched ever farther across Europe, so did its plumbing technology, waste-removal regulations and passion for bathing. Eventually even the empire's extremities had baths and toilets, and the unwashed "barbarians" of the north were finally introduced to the pleasures of washing.

But just how did this affect public health? "It's difficult to study the prevalence of most infectious diseases because they don't leave much evidence," says Mitchell. "But what you can track are parasites." They often leave clearly identifiable traces. Intestinal worms have eggs with tough chitinous walls that can survive millennia in coprolites – preserved faeces – and persist at burial sites in soil within the pelvic region of long-vanished bodies. The more delicate cysts of parasitic amoebae, such as those responsible for dysentery and giardiasis, rarely survive intact but can be identified from proteins unique to each species. External parasites such as fleas, lice and ticks also survive at archaeological sites, clinging to fragments of ancient cloth, the teeth of combs and in soil from graves. More than just a nuisance, they can transmit bacteria responsible for potentially fatal diseases such as typhus and plague.

To establish how baths and toilets affected the health of Britons, Gauls, Germans and other Europeans who had never seen either before the Romans arrived, Mitchell dug out every reference to parasites found at archaeological sites before, during and after the Roman period. Scouring records from more than 50 sites, he mapped changes in the distribution of species over the centuries.

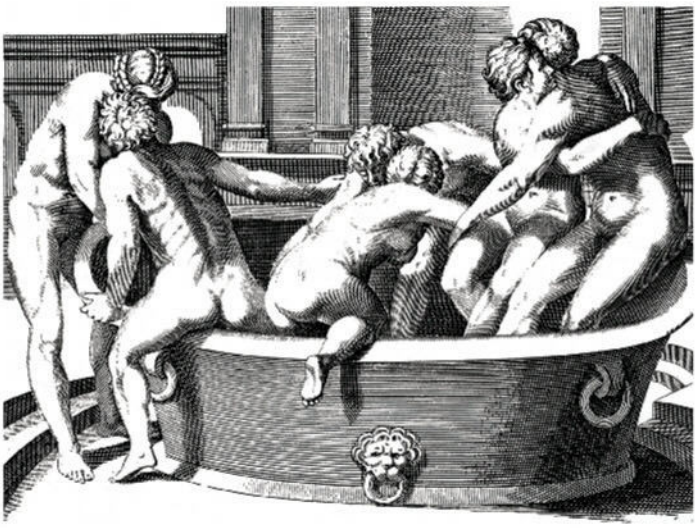
When the Romans invaded, the dominant internal parasites were roundworm (*Ascaris lumbricoides*), whipworm (*Trichuris trichiura*) and *Entamoeba histolytica*, the amoeba that causes dysentery. All three are spread in food or water contaminated with human faeces. With the adoption of toilets and baths, Mitchell expected to see them decline. They didn't.

Of the 12 species of internal parasite found in Roman remains, including a variety of tapeworms, flukes and nematodes, those linked to faeces continued to be the most widespread, especially whipworm, the most widely found intestinal parasite in the Roman Empire. "For all their sophisticated sanitation, under the Romans intestinal parasites did not decrease," says Mitchell.

Despite the building of baths, fleas and lice – head, body and pubic – also clung on, their numbers undiminished. And there was another surprise. Mitchell expected to see some evidence of more exotic parasites, brought to the northern territories by much-travelled Roman soldiers, officials and traders from warmer parts of the empire. Instead, he saw traffic in the opposite direction. Before the Romans, the fish tapeworm had a limited distribution in what is now France and Germany. During the Roman period, it spread as far as Poland in the east, Britain in the north and Israel in the south.

Why didn't Rome's sanitation revolution make a dent in Europe's dirt-loving parasites? Closer inspection of Roman baths and toilets provides plenty of clues. Take baths. The Romans and their subjects certainly did. Bathing was a communal activity: the largest known baths could take 3000 people at a time, clean and dirty, healthy and sick. No one used soap. People preferred to be slathered in oil and scraped clean with a curved implement called a strigil. Writers of the time complained about scummy water contaminated by oil and excrement. "No one knows how often the bathwater was changed," says Craig Taylor, an archaeologist at the University of Alberta, Canada.

This meant there was a significant risk of ›



INTERFOTO/SAMMLUNG RAUCH/MARY EVANS

Good, clean fun? Sharing a bath could mean sharing fellow bathers' pubic lice (below) and eggs from intestinal worms

"Anybody urinating here will incur the wrath of Mars"

Forum arch, Thigibba, Tunisia

"To the one defecating here beware of the curse"

Outside a house in Pompeii

"Shit with comfort and good cheer, so long as you don't do it here"

Vesuvian Gate, Pompeii

EYE OF SCIENCE/SPL

contracting something nasty. Celsus, a 1st-century writer on medical matters, warned of the dangers of gangrene from bathing with an open wound. The intact could also leave with more than they bargained for. Traces of excrement combined with warm bathwater would have encouraged the spread of roundworm and whipworm eggs if bathers swallowed any water, says Mitchell. Eventually there was some recognition that sharing a bath with the unwell might be unwise: the 1st-century emperor Hadrian ordered that the sick and healthy should bathe at different times – the sick first.

The persistence of fleas and lice is more puzzling; you would think that regular baths would get rid of them. Perhaps bathing wasn't as popular in the northern reaches of the empire, or perhaps Roman hygiene was lacking in another area. "We don't know how often they washed their clothes or whether they boiled them," says Mitchell. "If they put clean bodies into dirty clothes they'd still have ectoparasites."

If baths were dirty, toilets were worse. Those in private homes and tenements were often sited in the worst possible place: in or next to the kitchen. Most emptied into cesspits, which was considered preferable to linking to a sewer. "Roman toilets didn't have traps, so where they were connected to the sewers there were problems of smells coming back into the home, and the possibility of vermin," says Taylor. In Rome itself, the river Tiber regularly flooded. When it did, anyone connected to the sewers could expect a deluge of filthy water and worse to pour into their homes.

Public latrines had more mod cons. A continuous stream of water ran through a trench beneath the seats, flushing waste into a sewer. At least some provided the Roman equivalent of toilet paper – a sponge on a stick, with a water-filled channel in the floor to rinse it in. Later designs could be positively luxurious, with carved marble armrests between each seat, painted walls and washbasins (but no soap). Nevertheless, people often chose to relieve themselves elsewhere, as the graffiti in ancient Roman cities attests (see page 35).

A visit to the latrine was probably unpleasant and only for the desperate, according to archaeologist Ann Olga Koloski-Ostrow, author of *The Archaeology of Sanitation in Roman Italy*. She has looked into more Roman lavatories than most. Aside from the total lack of privacy, she notes, they were almost invariably dark, smelly and potentially dangerous. Noxious gases built up in the trench below and sometimes exploded, sending flames shooting up through the toilets. Rats could bite unwary visitors. The sponges were almost certainly shared. It's no wonder many public toilets included a shrine to the goddess Fortuna.

BOTH: DEAGOSTINI/GETTY

A visit to the communal toilet could be risky, with noxious gases and rats escaping from the sewers beneath

That's not all. The seemingly hygienic habit of removing faeces from Roman towns and cities may have contributed to the spread of disease, too. Every day, cartloads of waste from cesspits trundled out of Rome itself, where much of it was sold to farmers to fertilise their crops, a practice that was probably adopted across the empire. "It's possible that sanitation laws requiring the removal of faeces actually led to reinfection of the population, when they ate locally grown produce contaminated with parasite eggs," says Mitchell.

So should we write off Roman sanitation as a failure? Not at all, says Mitchell. "We are looking at things from a modern perspective. You have to see things the way the Romans would see them." Piped water, sewers, baths and toilets were probably never intended to improve health. The cloaca maxima was built to drain mosquito-ridden marshes around Rome. Later sewers were intended mainly as storm drains. And having piped water instead of collecting it from the river in a bucket would have been seen as "practical and time-saving", says Mitchell. Besides, the Romans didn't understand the link between good hygiene and health. "They didn't know about microorganisms and they didn't know how parasites spread," he says.

One mystery remains. Why did the fish tapeworm migrate across the empire? Mitchell offers an intriguing explanation. These parasites are found in fish species that spend all or part of their life cycle in fresh water. Cooking kills the eggs, and before the Romans came, most infections probably arose from eating dried, pickled or smoked fish. The Romans, however, liked to perk up their meals with lashings of garum, a malodorous mix of raw fish and herbs left to ferment in the sun. Demand for the stuff was huge, and a product that originated in the Mediterranean was soon being made in more northern regions, where fish tapeworms were much more common. The stinking liquid was packed in sealed jars and traded round the empire – and the parasite went with it. ■

Stephanie Pain is a consultant for *New Scientist*

A BRIEF HISTORY OF LOOS

3200 BC
The oldest known citywide sanitation system is built in Shahr-e Sukhteh, on the banks of the Helmand river in south-east Iran

2900 BC
The Minoans of Crete install what was probably the first ever flush toilet, complete with wooden seat, at the Palace of Knossos

2500 BC
The Indus Valley civilisation has advanced sanitation, including flushing toilets connected to brick-lined sewers

500–200 BC
Public conveniences are built in several Greek cities, including Athens

150 BC
Public latrines proliferate in Roman Italy, becoming common throughout the empire by the early 1st century BC

HOT *ICE*

An invisible threat is making planes fall out of the sky. **David Hambling** reports

SHORTLY after leaving Rio de Janeiro on its way to Paris in 2009, Air France flight 447 flew over a band of thunderstorms. It was an unremarkable event that at first resulted only in light turbulence. But, as anyone familiar with the headlines knows, things got much worse. It ended in one of the deadliest air disasters in recent history, killing all 228 people on board. The wreckage took two years to retrieve from the bottom of the Atlantic Ocean.

When the black boxes were finally pulled out, multiple culprits were identified, including pilot error and faulty software. However, one apparently minor detail is beginning to take on new significance: ice blockage in a sensor called a pitot tube, which measures air speed.

That shouldn't have happened at 35,000 feet. According to our understanding of weather, it is not possible for ice to form at this altitude.

Flight 447 is not alone. It is the grisliest example of a stealthy phenomenon that has been pulling planes out of the sky for the past half-century. Aerospace companies, researchers and government bodies have joined forces to try to understand a threat whose reach is only starting to become clear. As a picture has emerged, though, it has also become apparent just how hard it will be to keep aircraft safe.

Rumours of planes falling out of the sky for no apparent reason have been around since the 1950s. Some research was done back then, but seems to have been lost. It wasn't looked into again until 1994, when American Eagle flight 4184 flew into "unknown icing conditions" over Indiana and ploughed into a soybean field at full speed, killing all 68 people on board.

The US Federal Aviation Administration (FAA) launched an investigation, and

"People didn't know what was going on. There were wild theories."

subsequently identified 32 other incidents bearing a particular signature: a sudden engine shutdown at high altitude, weird sensor malfunctions, and a mysterious heavy "rain" spattering the aircraft's windshield. And all despite clear skies, temperatures too cold for liquid water to exist, and with no radar indications of any weather anomalies.

"People just didn't know what was going on," says Walter Strapp, a cloud physicist with Environment Canada. "There were wild theories about water being wafted high up into the atmosphere."

In most of these cases, pilots were able to restart the engines when they fell below ›

"The more we look for crystal icing as a culprit in crashes, the more we find it"

10,000 feet (3000 metres). The passengers survived, albeit badly shaken. In one case, the engine died entirely, but the pilot managed a deadstick landing.

The FAA's investigation determined that the engine trouble was caused by a kind of icing – though one that doesn't make much sense, because it affects only the hot parts of an aircraft.

In general, aircraft icing is well understood, happening when supercooled droplets of water strike the cold surface of the aircraft and freeze. This rarely catches pilots by surprise. "It's pretty obvious," says Dan Fuleki, who studies aircraft icing at the National Research Council Canada. "Pilots can see the ice building up on their windshield wipers." This only happens below 22,000 feet, and freezing rain is also clearly visible on radar. What's more, planes are equipped with sensors and their wings can spray de-icer.

None of that is true for crystal icing.

Unlike normal icing, crystal icing happens at altitudes where water should not be liquid. The culprits are plumes of crystals around 40 micrometres across, no bigger than grains of flour, which are invisible to weather radar that pick up normal precipitation.

Because they're solid, these crystals bounce off the wings and other areas equipped with sensors and defences. But when they land on the warmest parts of the plane – such as the engine or pitot tube – they melt. This also happens in contact with the heated windscreen, where they can cause the weird "rain" sometimes reported.

Once a layer has partially melted, it accretes more crystals. When these layers accumulate in the engine, they can stall it, or break off in solid chunks that damage the engine (see diagram, right).

Ice build-up in the sensors leads to more insidious damage. On flight 447, the ice crystals blocked the pitot tube, which started giving false readings, showing the plane flying too slowly. This caused the autopilot to disengage, which along with other malfunctioning sensors confused the pilots to the extent that they went against their usual training. Thinking they were losing altitude, they angled the aircraft upward so severely that the engines stalled.

The more we look for crystal icing as the culprit, the more incidents fit the bill. A 2011 NASA report revised the FAA's previous estimate, concluding that since the 1980s, crystal icing was probably implicated in 140 other events. The frequency of the problem, they warned, is "alarmingly high".

So it seems like high time to redesign aircraft engines to help them withstand crystal icing. That was why NASA joined a multinational programme in 2006 that included the National Research Council Canada, Airbus, Boeing and many others.

But before they could redesign the engine, they needed to understand how hot engines get iced up. That meant recreating the exact conditions in a lab at NASA's Glenn Research Center in Cleveland, Ohio – although "lab" may be underselling a facility that can simulate the frigid temperatures, several-hundred-mile-an-hour winds and shockingly low pressures that an airliner withstands at 30,000 feet.

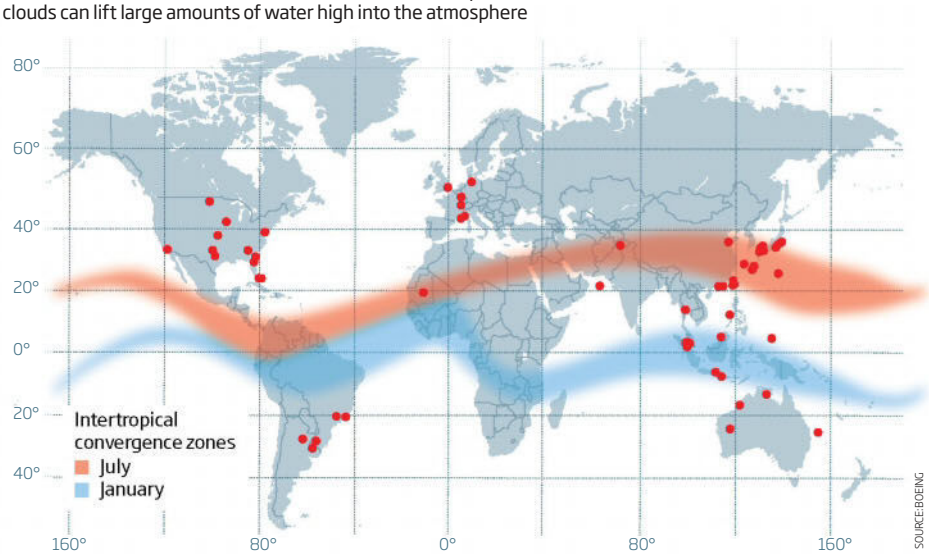
After years of work, icing cloud specialist Judy Van Zante and aerospace engineer Ashlie Flegel designed an array of "ice bars" that can minutely adjust the size and concentration of ice crystals spraying through an engine until they start to build up on the hot blades.

Things did not go as planned. One challenge became apparent when they turned on the ice-cloud generator. The crystals acted like a sandblaster, destroying the sensitive measuring equipment. And because the crystals also carry static electricity, even the surviving instruments misread wildly. "We had to design and build some more robust instruments," Van Zante says.

Their work has revealed a complex pattern of ice accretion: ice crystals may shatter on first contact, for example, creating a cloud of smaller particles. Turning the lab data into a working model is going to be a major multi-

Something in the air

Boeing has mapped 67 confirmed incidents of power loss related to crystal icing in aircraft since 1990. The incidents seem to be concentrated in warmer parts of the world, where convective clouds can lift large amounts of water high into the atmosphere



SOURCE: BOEING

LEFT: EPA/EMMA FOSTER/ALAMY; RIGHT: REUTERS

Crystal icing is implicated in a growing number of insufficiently explained crashes

physics headache. For now, they have scaled back their focus, with plans to build a simpler model that will assess the risk of icing.

"A full three-dimensional model is probably 10 years away," Flegel says. After that, turning the model into an engine redesign will take at least another decade.

We need much more immediate help to keep planes in the sky, with some understanding of the weather conditions that lead to ice build-up in the engine.

Invisible killer

Boeing had previously identified a possible association between crystal icing and so-called decaying convective storms. These are not showy, with thunder or lightning, but put a great deal of water into the air – up to three times as much as an ordinary rainstorm. We don't fully understand them yet, but one thing that's clear is that these storms require heat, which goes some way to explaining why reported incidents seem to have clustered loosely around warmer latitudes (see map, left).

Tom Ratvasky, also at Glenn, and his colleagues decided that the best way to get to the heart of the matter was to fly a plane directly into such conditions and see what happens. They equipped a jet with a suite of weather and moisture sensors and flew it through likely hotspots looking for trouble.

They found it. Deliberately flying the jet into so-called "high water ice conditions" (HWIC) quickly caused readings from the air temperature probe to jump from well below freezing up to zero – a sign that ice was building up on it.

Crucially, Ratvasky was able to confirm the association between HWIC and convective storm systems, and identify the mechanism: the strong updraught from the storm sweeps water vapour to much higher altitudes than normal. The effect does not seem to appear when the convection is strongest, but when the storm is dying down, for reasons we don't yet fully understand.

The hope is that all the data gathered will yield a distinct signature that corresponds to HWIC. This will enable "nowcasting" – using satellite data to predict where aircraft are likely to encounter dangerous conditions. Researchers are also working on modifications to existing radar that allow them to detect crystal-icing conditions.

That's a few years away, but at least it's closer than a full engine redesign. What's more, the team managed to establish a makeshift HWIC detection method: by pointing the aircraft's weather radar downwards, you can see if you are flying over patches of heavy rainfall and should consider changing course.

Even better, Fuleki and his team have cleverly hacked existing instruments to create two sensors. The first, a beer-can-sized device called the particle ice probe, is mounted outside the aircraft and detects the presence of small particles by the way they change the air's electrical characteristics. It was originally designed to detect debris from the engine, but the team modified it to distinguish the particular signal of ice crystals.

The other device – an ultrasound ice-accretion sensor – directly measures ice inside an engine. A series of dime-sized sensors sends ultrasonic pulses whose reflection changes as ice builds up. Both devices are advanced enough that Fuleki is now in talks about turning them into commercial products.

Even when planes get the new sensors and radar, however, we're not out of the woods. For one thing, we are still not done tallying up the true toll of crystal icing. Speculation is building on its role in yet more unexplained crashes, such as that of Air Algérie flight 5017 in 2014, which killed 116 people.

We know about flight 447's blocked pitot tube because of the flight recorder, but with some other incidents we may never know for sure. Sometimes there is characteristic physical damage, but aside from that, all traces of crystal icing tend to vanish below 10,000 feet, whether the plane survives or not.

There's even a chance the problem could get worse. "The warmer, moister world predicted by climate change will have more convective instability, " says Sue Gray, a meteorologist at the University of Reading, UK. "These systems will be more vigorous and more frequent."

And according to a recent analysis by Rolls Royce engine labs, these increases in extreme weather could make the conditions in which crystal icing flourishes more frequent. In a presentation, Rory Clarkson, an engine specialist with the company, offered an inconvenient but undeniably safe answer: "Restrict operation during severe weather." ■

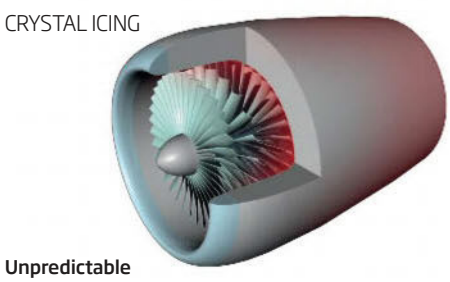
David Hambling is a writer based in London

Knowns and unknowns

Crystal icing is deadly because unlike normal icing, it is hard to detect or predict, and we have no defences against it

Easy To Avoid

- Only happens below 22,000 feet (6700m)
- Radar can detect weather conditions, so they can be avoided
- Only builds up on cold surfaces like wings
- Activates alarms and defences like anti-icing spray



Unpredictable

- Happens as high as 35,000 feet (10,000m), where ice was thought impossible
- Ice is invisible to pilots & radar
- Builds up in engines and hot parts of plane
- No sensors or defences can detect or avert it – though that may change (see main story)

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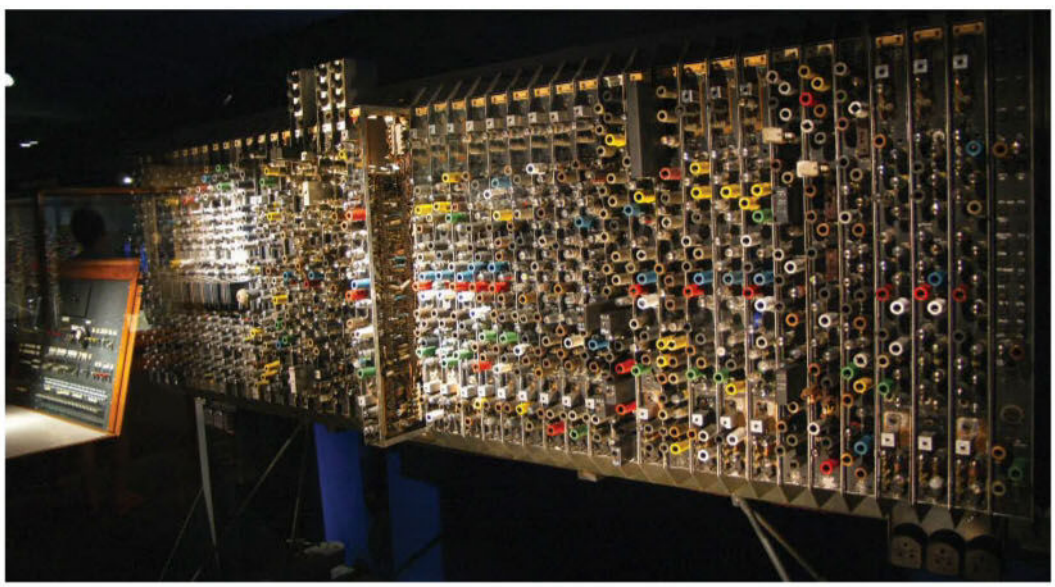
Are we Turing machines?

What is the true legacy of AI visionary Alan Turing? **Jonathon Keats** explores

Turing's Vision: The birth of computer science by Chris Bernhardt, MIT Press, $26.95/£19.95



MARK DUNN/ALAMY

IN 1935, Alan Turing set out to build a reputation by outflanking the world's leading mathematician. Turing was 22 years old, and a new fellow at Cambridge. His target, David Hilbert, was the venerated University of Göttingen professor who had single-handedly set the research agenda for 20th-century mathematics.

Hilbert was no match for the British upstart. In his book *Turing's Vision*, Chris Bernhardt deftly shows how Turing dashed one of Hilbert's great ambitions with a masterful proof – in the course of which he inadvertently invented the modern computer.

The title of Turing's paper, "On Computable Numbers, With an Application to the Entscheidungsproblem" (which means "decision problem"), is hardly inviting, and reading it takes advanced training. This may explain why, as Turing's fame exploded, most popular writing focused on his wartime codebreaking, his post-war writing on artificial intelligence – or his persecution and prosecution for being gay and posthumous royal pardon.

But what Bernhardt's book lacks in drama, it makes up for in lucid explanation. *Turing's Vision* allows careful readers to appreciate the proof that made Turing's name and, as a bonus, to understand the basics of modern computers.

The Entscheidungsproblem was part of Hilbert's work to show that the basic axioms of mathematics are logically consistent. To that end, Hilbert sought an algorithm – a computational procedure – that would indicate whether a given mathematical statement could be proved from those axioms alone. Turing decisively showed that there was no such algorithm.

To do that, Bernhardt explains, Turing had to first establish a working definition for the term

"Turing proved that there was no mechanical set of rules for the solutions of all mathematical problems"

algorithm – to define what it means to compute. Turing looked at human "computers" – people who made computations. The task involves writing symbols on paper, he noted. "The behaviour of the computer at any moment is determined by the symbols... he is observing and his 'state of mind'."

Breaking down apparently complex cogitation into simple arithmetical procedures, Turing made computation explicit and eliminated the human element. "Turing's fresh insight was to define algorithms in terms of theoretical computing machines," writes Bernhardt. "Anything that can be computed can be computed by a Turing machine."

That's why the machines were central to Turing's paper. To show there were algorithms that Turing machines would run indefinitely and inconclusively was a way of showing Hilbert was mistaken. Turing proved "that there were questions that were beyond the power of algorithms to answer". His triumph was spectacular, and devastating to those who believed (as Hilbert did) that all problems could be solved.

Yet as crucial as the theoretical machines were to Turing's proof, they turned out to have even more impact in their own right, providing a conceptual model for

Turing's theoretical machines were turned into room-sized reality

modern computers. The influence was direct, informing John von Neumann's pioneering 1945 design for electronic computers, and the room-sized machines that applied his architecture. Like Turing's machines, the computers used ones and zeroes to encode programs and data. This remains essential to high-level languages and networks, so in learning about Turing machines, readers pick up principles of computer science.

There are also philosophical ramifications today. Having based computers on human behaviour, Turing noted that people are really Turing machines. Computers are our mirrors: whether we marvel or shudder at the latest AI, we're merely looking at ourselves. ■

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

So near, so far

Low ambition is no bad thing for virtual reality, finds **Julian Richards**

The Alternate Realities Summit, Sheffield Doc/Fest, UK, June 2016

YOU are in the bath and the soap slips out of your hand, leaving a smell on your skin that reminds you of your grandmother's bathroom. A mere 26 words have done what state-of-the-art virtual reality technology still can't: made you feel somewhere else, like you can touch and smell things that aren't there, triggered by real memories.

So what is VR good for? That was the question exercising some top practitioners recently at Sheffield Doc/Fest, a documentary film festival in the UK. They were mostly sceptical, but the work on offer demonstrated some effective ways to hook the technology to hearts and minds.

The production that had the biggest effect on me was also one of the simplest. *Home: Aamir* uses a sequence of 360-degree video scenes shown in a headset with a voice-over to describe the journey of a refugee from Sudan trying to get to the UK. Its creators used six small GoPro cameras to film at the unofficial Jungle migrant camp in Calais, France, and other stages of Aamir's terrifying odyssey. His words are spoken by an actor.

There was no way to interact directly, but the basic all-round video left me free to look about as I would in reality, lingering on things that caught my eye while listening to Aamir's words. A 2D documentary using similar images and text would have shown only what the film-makers presented through their unalterable choices of frame, composition and sequencing. The 360 video allowed freer, less aestheticised views.

For me, the two least successful productions were also the most ambitious. Both put you in a high-resolution animation, wearing a virtual spacesuit, with virtual hands to grip virtual objects when you press controls in your real hands. But the interaction is still frustratingly limited.

Mars 2030, a collaboration with NASA, lets you survey a Martian landscape. But to take even a small step in it, you use the controls rather than your legs. Realism took a further knock when I walked right through another astronaut, although I felt a lurch in my stomach as I did so. That happened again as I drove a rover recklessly down a slope, but later, driving off a cliff, my stomach was already getting less impressed.

The second epic was the BBC's *Home – An Immersive Spacewalk Experience*. This takes you to the International Space Station, where you move around by swinging gibbon-like between virtual handholds. Like the Mars simulator, it manages to gamify an experience, but reading astronauts' accounts gives me a much richer sense of life in microgravity – detailing the nausea, loss of taste and disorientation that current technology just can't replicate.

"Can immersive media increase empathy as it lets us feel present with others in a virtual scene?"

Such text-based "VR" goes back millennia, a fact acknowledged in a session called "VR: The Machine to Make Us More Human?" In other words, can immersive media increase empathy as it lets us feel individually present with others in a virtual scene?

The panel responded with refreshing quantities of cold water. Clint Beharry, who explores such phenomena at the Harmony Institute in New York, pointed out that radio also creates immersive experiences, while books are so immersive he frequently misses his subway stop while reading.

Tony Prescott, a psychologist and director of the research centre Sheffield Robotics, went further: life is immersive, yet we forget most of it. Why should immersive technology make a difference?

One way forward may lie in something common to the two Home pieces: theatre. *Aamir* was made by the UK's National Theatre, and Tom Burton, who co-directed the spacewalk experience, has worked in immersive theatre, which blurs distinctions between venue and set, actors and audience.

The speakers agreed that this type of expertise is needed to make VR work. For example, one big challenge in 360-degree video is to direct the viewer's attention. Burton's answer is to look to the devices of theatre and magic, and psychology's insights, to learn how to make us see what's not there, and not see what is. ■

A VR experience of the Jungle migrant camp lets your eyes wander

HOME | AAMIR, SURROUND VISION AND ROOM ONE, NT IMMERSIVE STORYTELLING STUDIO.

The terrifying face of a new sublime

A hunt for aesthetics in the Arctic hints that we should unfreeze an 18th-century concept, finds **Sumit Paul-Choudhury**

JIM RICHARDSON/NATIONAL GEOGRAPHIC CREATIVE

IT IS forbidden by law to die of natural causes in Longyearbyen, the world's northernmost town – because the rock-hard permafrost makes it impossible to bury you. Nor can you be born here, due to the peculiar legal status of the Svalbard archipelago, a thousand kilometres north of Norway.

Forty-two nations, including the unlikely Arctic powers of Afghanistan and Venezuela, have the right to settle and exploit its resources: from whales in the 18th century, to furs in the 19th and coal in the 20th. Now, with coal on its way out, Svalbard is presenting itself as a location for scientific research, ecotourism and the arts. As such it may find itself at the nexus of a new global reality.

"With the melting of the ice and thus new trade routes, Svalbard and places like it are really at the cutting edge of geopolitics," says Katya Garcia-Antón, who runs Norway's Office for Contemporary Art. That's why OCA last month brought artists and scientists there to discuss representations of the fast-changing global north.

It quickly became apparent that there are few simple narratives to be had. Early panels at Thinking at the Edge of the World focused on Arctic indigenes' relationships with the land, and the value they place on it – attitudes that might be instructive when it comes to global stewardship of resources.

But Svalbard has no indigenous people, and its historic resources are increasingly worthless. So how do you represent the value – be it economic, cultural or ecological – of a place that belongs to everyone and no one, that's both untamed wilderness and Anthropocenic canary, whose fate is both utterly solitary and entirely global?

Delightful horror

Part of the problem is that our impressions of such places don't correspond with current realities. The "frozen wastes" of popular imagination don't cut it today. Another part is that what we find pleasing isn't always what's wise: a neat lawn is an ecological horror.

Lisa Phillips, director of New York's New Museum, which focuses on the dynamics of the 21st century, suggested that our aesthetic values might be out of date, failing to reflect today's ethics. What might a more appropriate aesthetics be like?

In 1688, literary critic John Dennis took a Grand Tour of Europe, as was de rigueur for gentlemen of his station. During his passage of the Alps, he wrote that he experienced "a delightful Horrour, a terrible Joy and at the same time that I was infinitely pleased, I trembled". A term used in transcendent literature seemed appropriate: such experiences were "sublime".

The sublime caught on, with other adventurers extolling the terrible beauty of the wilderness. In 1757, the philosopher Edmund Burke defined it as an aesthetic category distinct from beauty, and it became a potent concept in 19th-century Romantic literature and art, in part as a reaction to early industrialisation.

Today's visitors to Svalbard, Europe's largest wilderness, might also be in search of the sublime, knowingly or otherwise. But the experience is not the same as it was for earlier adventurers. Gaze at the Arctic ice, and you become uneasily aware that it is vanishing, even if you can't see that directly – and that your own presence is contributing to its thaw.

Longyearbyen's residents attest to that thaw: the port opened months earlier than usual this year; last summer was sweltering; a polar bear had to be rescued from the bay's thinning ice. "The landscape has changed dramatically over the 30 years I've been here," says Kim Holmén, international director of the Norwegian Polar Institute.

Many attempts to capture this have translated climate models into graphical or sculptural forms. The effects can be stimulating to the eye, but less often to the mind. Straight depictions of its effects can be misleading, hence the furore over all those photos of gaunt polar bears: are they tragic

DE AGOSTINI PICTURE LIBRARY/GETTY

A Romantic view of the Arctic's terrifying beauty: *The Sea of Ice* by Caspar David Friedrich (1823)

The Global Seed Vault: the cutting edge of the Arctic sublime

victims or unlucky individuals? The sentimental imagery beloved of tree-huggers is unhelpful, too.

Climate change – its impact, complexity and persistence – is hard for human brains to parse. In his 2013 book *Hyperobjects*, the philosopher Timothy Morton described how "things that are massively distributed in time and space relative to humans" defy our intuition. Global warming is one such hyperobject: a panel about the ocean hinted at others.

Hidden depths

Anchorage Museum director Julie Decker talked in Svalbard about *Gyre*, a 2014 show based on how plastic pollutants travel the seas. "Alaska has a reputation as a pristine wilderness," she said, "but we send trash around the world and receive the trash of the world on our shores." It is also found, like handfuls of candy, in the entrails of animals and birds.

Presenting this in a way that doesn't simply induce despair is tough. Part of the problem is that we are used to durability being of a piece with artisanry and scarcity. Our aesthetics are off: we don't readily grasp that cheap, mass-produced junk will circle the globe and last almost forever.

Camilla Svensen, a marine biologist from the University of Trømso in Norway, described the challenges of understanding food webs based on plankton, which are more abundant in the oceans than insects are on land. "The complexity is so huge: it's like opening doors and doors to ever more universes," she said. Hardly anyone has personal experience of this vast marine biomass, for all that we are its beneficiaries. Our efforts to manage the land, of which we at least have somatic knowledge, are fraught enough – how are we to manage the oceans, or for that matter the atmosphere or the ice? A return to the sublime in art might help us process them – but what does the 21st century version look like?

"Part of the problem is that we can't conceive that our junk will circle the globe and last almost forever"

Véréna Paravel, maker of 2012 documentary *Leviathan*, fixed cameras to a North Atlantic fishing trawler, and to its crew. "We were trying to diminish the men, or at least to portray them in a way that subsumed them in something larger," she said, to achieve a "self-portrait of the sea". The result is a visceral, occasionally poetic and frequently alienating film that captures both the hostile majesty of the seas and our impact on it. As Holmén said: "The ocean is very big, but we are also very big."

The film's imagery is at once appalling and beautiful: fish guts splatter, scavenging gulls wheel in the boat's wake, torrents of scarlet blood and tumbling starfish are discarded as by-catch. Delightful horror and terrible joy, indeed.

The backup plan

Back in Svalbard, a tiny portion of the abandoned coal mines in the mountains around Longyearbyen has been converted into the Global Seed Vault, a geometric concrete wedge driven into the permafrost. It holds 864,309 seeds as a "backup" against agricultural doomsday. Stand next to it, and you can hear the regular whooshing of air intakes, like the breathing of some gigantic, slumbering beast.

Last winter, the vault saw its first withdrawal: barley, wheat and grasses to replenish a gene bank damaged in the Syrian civil war. That was much earlier than expected: the vault is designed to last centuries, the permafrost protecting its cargo even if the power goes out, the climate heats up and the vault stops breathing.

Perhaps it's not surprising that it was an artificial disaster, not a natural calamity, that prompted the move. With climate change continuing to surprise, in mostly unpleasant ways, the permafrost's guarantee no longer seems so rock solid. Perhaps one day there will be bodies buried in it, as a new Svalbard emerges from the ice.

In an age where old certainties are collapsing, we need to find values and aesthetics more fitting for the times – or to renew old ones. Perhaps it's time the sublime made a comeback. But if it does, it will have to include not just the horrors and joys of nature – but of humanity too. ■

The writer travelled as a guest of OCA

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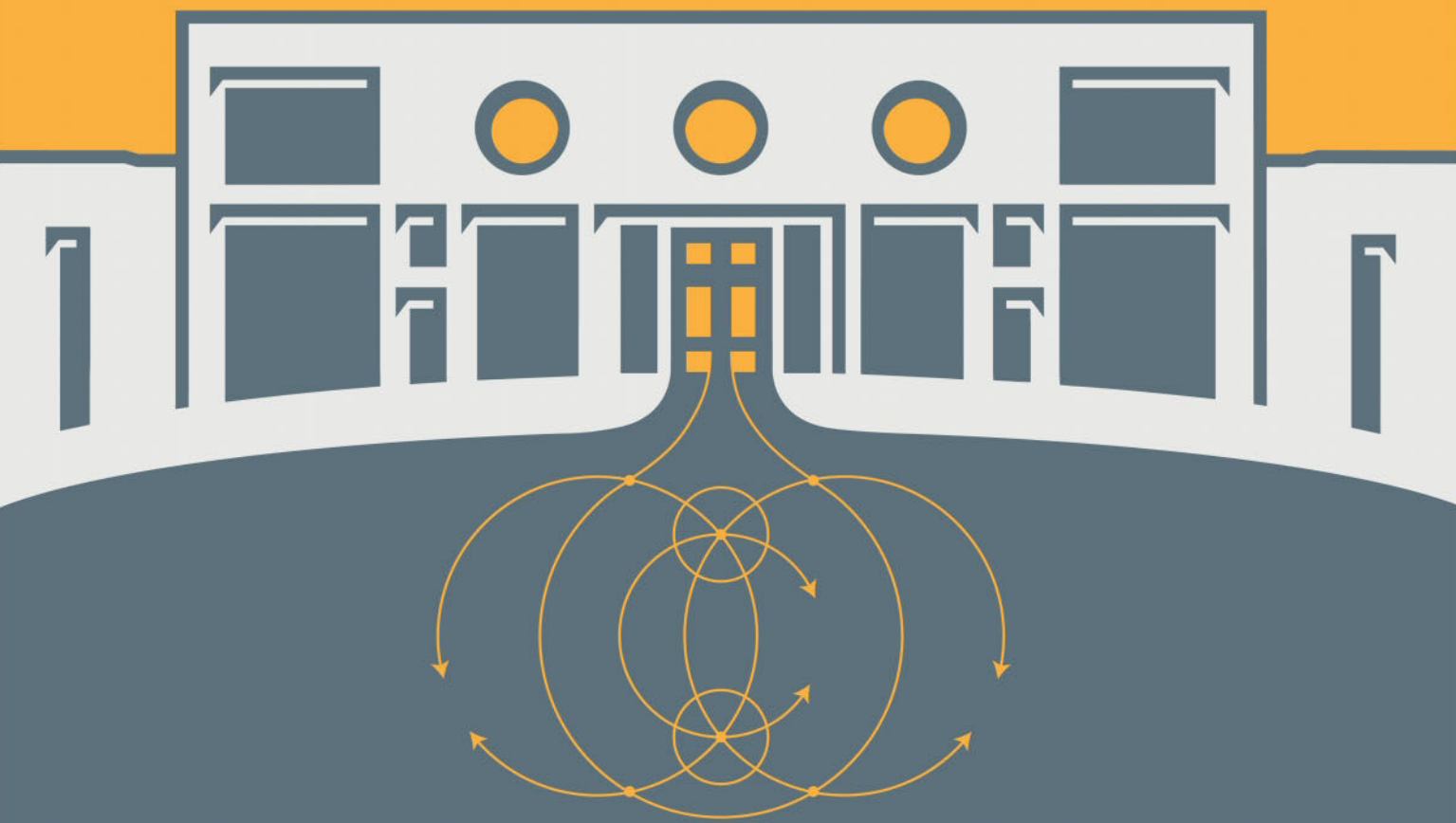

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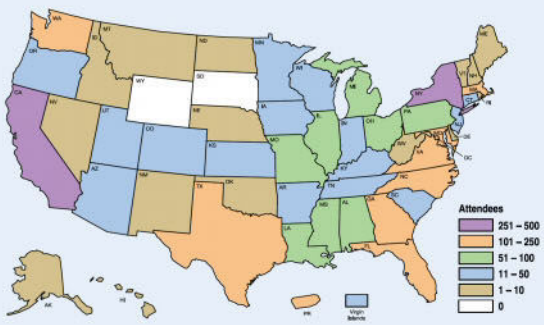

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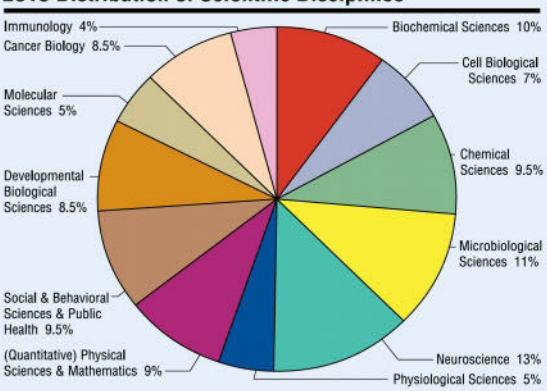

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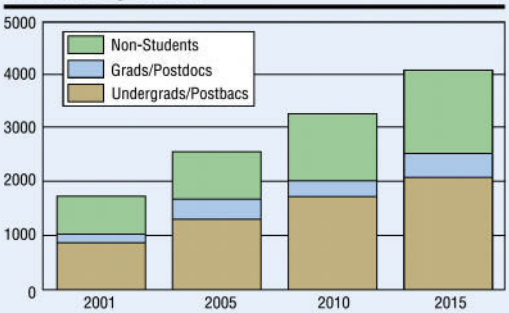
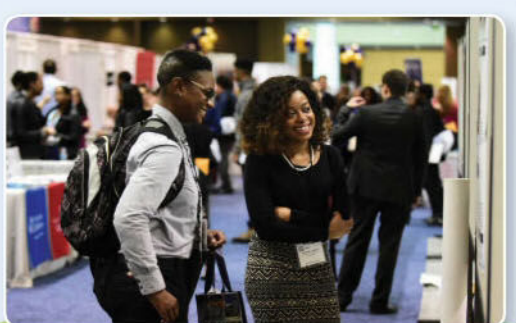


"It was a great opportunity to see the extraordinary research being conducted in the country and also to encourage and offer thoughtful advice to the future scientists."
FACULTY/JUDGE



"I love ABRCMS because of the vast amount of opportunities it has to offer. I meet so many new people who broaden my perspective of different areas of research. It's great to see people from all walks of life who possess the desire to be involved in science."
STUDENT ATTENDEE

Important Deadlines:

Judges' Travel Subsidy Application: ..... **July 12, 2016**
Travel Award Application: ..... **August 26, 2016**
Abstract Submission: ..... **September 9, 2016**
Discount Registration: ..... **October 12, 2016**

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EDITOR'S PICK

Love of change is natural too

From David Smallwood

I have to disagree with your generalisation that "fear of change is a natural impulse" (18 June, p 5). Our neurology is geared to notice difference, not to fear it.

Many people spend their lives craving change. There are those who constantly change jobs and friends, move houses, pursue different interests and always go on holiday somewhere different.

Of course, if you are the kind of person who has had a similar job all your life, always lived in the same place, been married once, keep in touch with friends from university and have a timeshare that you go to on the same dates every year, then none of this will make sense.

A spectrum of preference drives our behaviour, extending from craving change to wanting everything to stay the same. What is important is to notice where you are on that spectrum.

Castlemorton, Worcestershire, UK

To read more letters, visit newscientist.com/letters

The deception of free will

From Peter Basford

Nicolas Gisin seeks to rescue free will (21 May, p 32). But the fundamental question is: of what constraints could free will be free?

Our decisions are certainly constrained by our intelligence, personality, the information we have, upbringing, culture, peer pressure; and by any effects from brain injuries, drugs, food influences or parasites we may have. In other words we do what we do because we are who we are.

We feel "free will" simply because our self-awareness gives us a limited experience of our decision-making process within those constraints. If a demon with a perfect model of our brain and the factors influencing a decision could predict it, we would still have to actually live the moment in which we "made" it.

Potters Bar, Hertfordshire, UK

From Chris Brausch

I must assume that Gisin is no adherent to any many-universes theory. As I understand it, if a particle has a 50 per cent probability of "collapsing" into one of two states on measurement, the observer's physical brain will recognise this new state as A in 50 per cent of "worlds", and as B in the other half. The collapse seems random because the observing brain heads off into its newly created universe, oblivious to the almost identical brain that firmly believes the particle assumed the opposite state.

In this picture there is no randomness and no need for free will. Of course, this may be just an idea that some capricious and haphazard mind dreamed up.

Katikati, New Zealand

From Nial Wareing

Gisin presents free will as either a mysterious concomitant of consciousness or an illusion. There may be another possibility, involving probability, pointed to by game theory.

Free will arises in situations where there are a set of possible actions and somehow we choose one, apparently consciously "deciding" which. Humans are constantly presented with situations in which we need to make a decision but lack complete information about all the relevant factors involved. In game theory, with such imperfect information the correct approach is to pursue a "mixed" strategy: for example, if there are two alternatives you might calculate that it is optimal to select the first 20 per cent of the time and the second 80 per cent.

No one suggests we do game-theoretic calculations in our heads; but an unconscious mechanism might "decide" probabilistically, with the weights adjusted based on experience.

If such a mechanism did exist, it would be acted on by evolution. In this picture, the awareness of free will is just the later manifestation into consciousness of the unconscious probabilistic determination.

Tetbury, Gloucestershire, UK

Data fudging begins at school

From Bill Courtney

A teenage reader related the creation of false experimental data by school science students (Letters, 4 June). I can assure younger readers that there is nothing new about this.

Back in 1964, my A-level physics practical examination required finding the local acceleration due to gravity, g, using the swinging pendulum method. At that time both metric and imperial units were on the syllabus.

Knowledgeable students were aware that g could be taken as either 981 centimetres per second squared or 32 feet per second squared. When we left the exam room, one of my friends boasted that he would probably be awarded full marks for this practical paper. Instead of "wasting time" doing the experiment, he had used his slide rule to create a beautiful straight-line graph. This might have impressed the examiner, had the value not been hopelessly inaccurate because the poor lad had got his imperial and metric units muddled up.

He failed the A-level physics exam and I have no idea what his subsequent career was.

Altrincham, Cheshire, UK

Speech feedback lacks language

From Bob Ladd

The idea that wearable technology could provide instant feedback to improve pronunciation in a foreign language is far-fetched (7 May, p 24). The SayWAT system you describe detects socially significant global features of speech, like overall volume. This is basically an acoustic task.

Alerting language learners "when they mess up a specific sound, like tones in Chinese or the Rs in French" would not just need more computational power: the device would have to know what you were trying to say. It will be decades before speech and language technology is ready to do anything like that.

Edinburgh, UK

How to get back there from here

From Harry Dewulf

Colin Stuart gives us yet another revision to the hypothesised process of the formation of our solar system, based on modelling its evolution (23 April, p 30). I wonder whether, even in a deterministic universe, it is really possible for the current state to

"I have done 'meaningful' jobs for 46 years: retired, I finally have control over my own life"

Penny Steevens isn't convinced by the argument that going to work is good for you (25 June, p 29)

have been arrived at in only one way. Surely there must, given the timescales involved, be millions of different initial states, any of which could have resulted in the current state, making all such speculation a little redundant?
Houdelaincourt, France

The editor writes:

■ It is surprisingly difficult to get a set of initial conditions that exactly reproduces what the solar system looks like. So while there's no guarantee you have found a unique solution if the model ends up with what we observe, it's quite likely. You can be more certain by re-running the algorithm.

How small fingers could evolve

From Max Starkey
Andrea Stevenson derides the idea of future generations evolving smaller fingers through smartphone use (Letters, 14 May). This ignores the ubiquity of smartphones in the dating rituals of today's youth. Those with big fingers may indeed fail to reproduce, leaving only those with dexterous small fingers…
Avignon, France

Prospecting for prime patterns

From David Jenkins
Jacob Aron discusses patterns in prime numbers (19 March, p 12). This prompted me to wonder whether the patterns would persist if you considered the last two digits in a prime number rather than the last one. For instance, 1097 is a prime number: what are the chances of the following prime ending in 97?

I checked all numbers up to 10 million and found 664,579 prime numbers. Of those I found one case of a prime ending in 11 being followed by another one, no cases at all of a 77 being followed by another 77 but 3577 cases of 01 being followed by 07. These are just a few examples. When you plot them out as a scattergram, a complex pattern emerges.
Carlton, Bedfordshire, UK

Your label does not compute

From Jonathan Wilkins
James Ball's photographs offer a fascinating reminder of life before the ubiquity of powerful and portable computing (28 May, p 26). They are also a tribute to the endeavours of those who preserve and operate the precursors of the computers of today.

However, for the record, the image you labelled as an ICL 7500 system showed an operator's console for a New Range (2900 series) mainframe computer, which was indeed based upon the 7500 series and is surmounted by a 7561 visual display unit.

I am documenting this system at bit.ly/NS_ICL.
Deganwy, Clwyd, UK

Milk of synthetic human kindness

From Brian Horton
Chris Baraniuk discusses making synthetic wine (21 May, p 8).

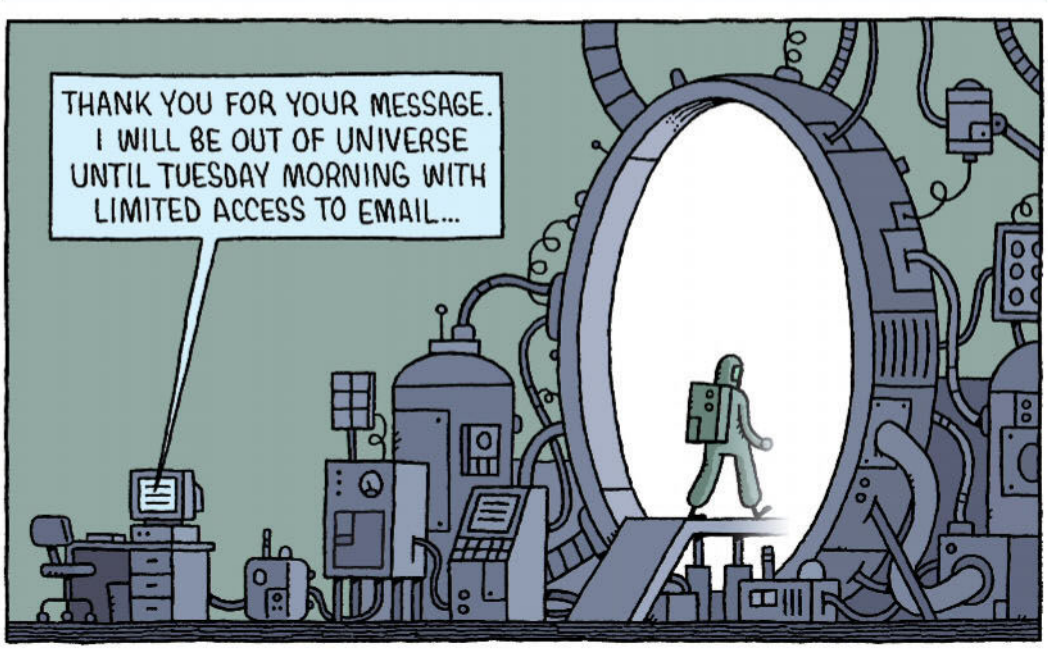
Instead of replacing attractive vineyards that take carbon dioxide out of the air, then producing a product that real wine drinkers will never want, they should instead explore making synthetic milk.

This would replace cows that turn valuable grain into methane and will produce something that people actually need. It may not be a big money-maker, however, since around here milk is cheaper than bottled water.
West Launceston, Tasmania, Australia

The spectre of clinical nightmares

From John Bradshaw
Bryn Glover describes his recurrent nightmare featuring an indescribable taste or smell (Letters, 21 May). This is a clear and classic example of a minor temporal lobe seizure. And that raises the interesting question: are some or all recurrent nightmares clinical phenomena? Even normal dreams may perhaps share aspects.
Clayton, Victoria, Australia

TOM GAULD



For the record

■ **A clarification: the purple sector in the first of our diet plate illustrations would better be labelled "Added fats" (11 June, p 28).**

■ **A "king tide" is simply a colloquial term for a very high tide (11 June, p 6).**

■ **Katy Gonder of Drexel University in Philadelphia discovered a subspecies of chimpanzee in 1997 (11 June, p 33).**

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PAUL MCDEVITT

SHAKESPEAREAN actor and big friendly giant Mark Rylance has been keeping Prince Charles up to date on alien activities, reveals the *Sydney Morning Herald*. "I'm his crop circle counsellor," the Oscar winner told Stephanie Bunbury. "I send him my crop circle calendars and magazines that I buy and keep him informed".

No word yet from the prince on whether the cereal farms producing his Duchy Originals biscuits have been plagued by alien vandals. Is this why the royals are so often seen patrolling their estates, shotgun in hand?

TENSIONS in Hampstead, London, are boiling over as residents face the installation of internet-linked water meters in their homes. But it's not the prospect of per-litre water tariffs that has some of them frothing.

A leaflet hand-delivered to homes in South Hill Park claims that the electromagnetic emissions from smart meters can strip the lead from pipes and poison the water. The document also claims the meters are "making us all electro-sensitive" and "cause trees, plants and bees to die, allegedly". Further information, we are told, can be found "on YouTube".

Is there something in the water in north London?

FEEDBACK often reaches for a trusty tin foil hat to deflect alien mind control signals, electrosmog from smart meters and unwanted company. However, the efficacy in two of these categories is open to question, says Eugene Girardin, because we are using aluminium foil. "Surely, to screen radio waves you have to use ferromagnetics (iron or steel) to exclude the magnetic component," he says. Do our shiny shields leave us open to electromagnetic attack? How can Feedback build a better version? Answers on a postcard please – or by radio mind wave.

Monica Backes writes: "Regarding Patrick Fenlon's note on truncated sentences, for many years a broken sign outside the city of Plymouth, UK, welcomed visitors to 'The City of Disco'."

WESLEY PAWLOWSKI is left paralysed with indecision by the instructions printed on the side of a bag of white sugar. These caution him: "This packaging material is not recyclable in Australia. Please dispose of thoughtfully."

"I have spent some time deciding on how thoughtful I need to be, but I cannot decide on whether to bury it, burn it or send it overseas," says Wesley. "It appears to be made of paper, so what is the problem?"

To which Feedback replies: we think that's quite enough thought devoted to a paper bag.

FURTHER to the observation by Chris Smith that Anchor mature cheddar needs to be zip-sealed to stay fresh despite being "Slowly Matured / Since 1886" (14 May), Andy Howe offers a dairy product that appears to have inverse properties. His carton of Elmlea cream alternative boasts that the product "Lasts longer once opened".

If this is the case, "I wonder why they sell it in sealed tubs?" says Andy.

IN LIVERPOOL, the local NHS Clinical Commissioning Group has turned off the tap funding homeopathy, a decision the organisation's governing body came to after considering public opinion, national guidance and the niggling fact that homeopathy doesn't work.

Understandably this is bad news for the small number of patients currently receiving treatment, but Feedback expects they can take heart knowing that, as the homeopathy budget dwindles to an infinitesimal balance, its purchasing power will increase accordingly.

PREVIOUSLY, our attention was drawn to the perils of automatically shortened text. Hillary J. Shaw writes that he used to purchase a weekly geology magazine named *Treasures of the Earth*, which came with a small mineral sample attached to each copy. However, "when I bought this magazine at the newsagent, the printed receipt invariably read 'Treasures of the Ear'."

FROM Australia, Tom DuFresne reports: "In my 20 years as a zookeeper, often a pretty smelly job, the best smell of the day was always the tiger's paws."

Tom claims that these smell like chocolate, a story that sounds to Feedback like the kind of prank seasoned zookeepers might play on work-experience staff.

Feedback doesn't plan on confirming whether tiger paws smell like bundles of chocolate coated sickles – maybe one of our braver readers will.

MORE odd smells from a land down under: Sarah Eccles in Canberra reports that the male koala "has a scent patch on his chest that smells just like passion fruit".

IN REGARDS to smelly trees (21 May), Chris Whitfield writes to tell us "Stercula was the Roman god of the privy, and his name is given to a group of trees, the Sterculia family, also known as stinkwoods."

Chris says that a Roman working with the wood might have exclaimed *quid olet sed redolet non sed rosae*: "The smell that arises is no smell of roses."

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.

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.

■ As an extreme analogy, consider the difference between a freshly purchased ream of paper and pages in a recycling bin. When all the sheets are flat and uniformly aligned, they take up less space than when tossed randomly into a recycling bin after being used and crumpled.

When layers of fabric (or paper) are arranged flat against each other, then there is nothing to prevent them coming into close contact over their entire surface, expelling most of the air and closing the gaps it has created.

"Even when you compress the fabric mass under high pressure, there is a limit to how thin it can become"

As soon as fabric is crinkled (or paper is crumpled), then irregular cavities are formed between the layers and the total depth of fabric at any point varies depending on the number of folds. This means that even when you compress the mass under high pressures, there is a limit to how thin it can become – air cavities remain in your luggage.

So you may be able to minimise the problem with a bit of pressure, but you won't be able to reduce it to a smaller volume than that taken up by neatly folded clothes under the same pressure.
Simon Iveson
University of Newcastle
New South Wales, Australia

■ The explanation is related to the difficulty in folding a sheet of paper more than six times. It isn't the number of sheets that makes it difficult, but the thickness of the folds that limits the process. A six-times-folded sheet creates a stack of 64 sheets, but the folds mean this stack is thicker than 64 separate sheets.

Similarly with clothes, if you bundle them up you have many folds, each of which takes up more space than two pieces of cloth. Alternatively, you can strategically alternate folds in successive layers so that each piece of clothing has only one fold and that fold is at the opposite end of the suitcase to the fold in the piece of clothing above or below it.

I pack nearly all the suitcases in our household because I can get so much in – it may be down to nominative determinism though.
Adrian Foulds
Glasgow, UK

This week's questions

BLOB OF THE GAPS

I live near Lake Clifton in Western Australia, home of these rare round thrombolites (see photo).

I have always wondered what the grey "rocks" in between the thrombolites are. The one in the centre of the photo has the appearance of a fracture face on a piece of shale. I clambered down to get one of them only to find they were soft and almost jelly-like in consistency. They were just about floating, bobbing with the water action, although some were submerged. Can someone identify them?
Willy Stobart
Dawesville, Western Australia

CROCKED CROCI

This year the carpets of crocuses in Glasgow were magnificent, although they were probably out a little later than usual. Over the past few years I have noticed that there are far fewer yellow flowers – and this year there are large carpets with only blue and white flowers. Has anyone else noticed this in other parts of the world and does anyone know why the yellow crocuses might be in decline?
Sue Kinn
Glasgow, UK

PARTICULAR PARTICLES

We are told that particles PM_{10} and $PM_{2.5}$, from sources such as diesel engine exhausts, are dangerous because they are so small they penetrate deep into the lungs. But the lungs secrete mucus, which is constantly being swept out to keep them clean. Why are the tiny particles not removed with the mucus?
Barry Cash
Bristol, UK

GRAIN TRAIN

I was weighing sugar into a plastic jug that had been recently washed and dried. There was too much sugar so I spooned some out with a teaspoon. The sugar sprayed off the spoon and coated the sides of the jug. Why?
Jean Hill
Hull, UK

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