New Scientist

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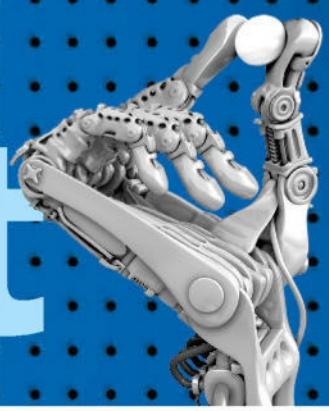

GAME OVER?

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RED ALERT Early cancer warnings are written in blood

WE KNOW THEY'RE OUT THERE

11 things we're sure exist – but have never seen

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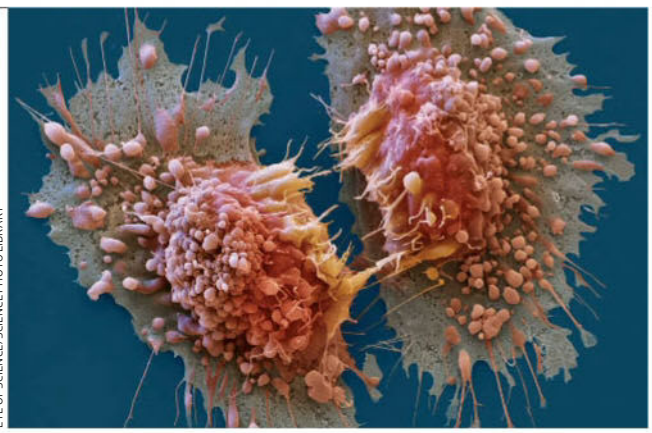

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Entries for $250,000 Ryman Prize now open

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Gabi Hollows and Nobel Laureate Dr Erwin Neher at the presentation of the inaugural Ryman Prize

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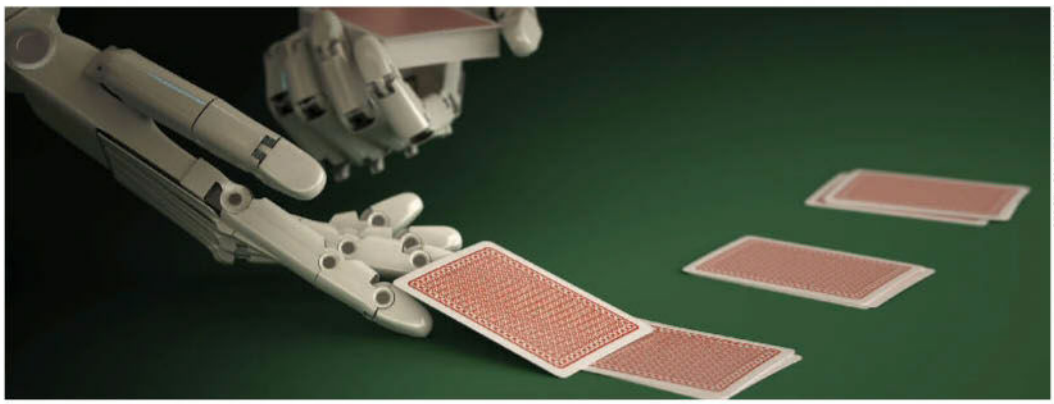


SERGEY SOLDATOV/ALAMY STOCK PHOTO

Time to raise the game

What should we teach computers to take on next?

This week, Google's AlphaGo beat a grandmaster at the complex game Go – an artificial intelligence milestone (see pages 9, 20 and 21). Here's what the experts say AI's next big challenge should be.

No-limit poker: Go represents the ultimate in games where all the information is available to the players. But AI still struggles with games where information is incomplete – like poker, where a player doesn't know what card is coming next.

"Computers have beaten the best people at heads-up limit Texas Hold'em, but not yet at no-limit, a much more complicated game," says Peter Stone at the University of Texas at Austin.

***Diplomacy*:** "AlphaGo doesn't know the meaning of any of the symbols it is so adroitly manipulating: it doesn't even know that it is playing Go," says Mark Bishop at Goldsmiths, University of London. So he suggests the strategy board game *Diplomacy*, in which players pose as European powers competing for land and resources.

Diplomacy embodies many of the obstacles between current and true AI. "Interestingly, it is a game that in theory a computer could play very well, as moves are communicated in writing," says Bishop. But it would have to pass the Turing test – humans could team up against the AI if they figured out which player it was.

***StarCraft*:** In Go, there might be about 300 possible moves at any time. In *StarCraft*, a strategy video game with hundreds of pieces, there might be 10^{300}. "You can't even examine all possible moves in the current state, let alone all possible future move sequences," says Stuart Russell at the University of California, Berkeley.

"These twists on gaming go beyond the mathematical challenges being breached by current AI"

Instead, the AI would have to consider its actions and goals on a higher level, then work out a plan to get there – requiring reasoning methods applicable to a wider range of real problems.

***Dungeons & Dragons*:** "What we're seeing with AlphaGo is not trying to prove or disprove a humanlike sense of reality or believability, but instead is purely goal-centred – to win the game," says Julie Carpenter at the University of Washington in Seattle. She says it would be interesting to throw AI at something like a role-playing game. There, the machine's goals wouldn't be as obvious. It would need to rely on skills like social communication and higher-level situational awareness in order to succeed.

Cheating: Human players can read their opponent's faces and body language for clues about what to do next. They can also get ahead by using deceptive tactics, like misdirection. Could a robotic hustler ever successfully spot these false behaviours – or even cheat without being detected? "These twists on gaming go beyond the largely mathematical challenges that are currently being breached by current AI," says Ronald Arkin of the Georgia Institute of Technology in Atlanta.

The real world: "I'm not particularly interested in seeing AI pitted against other games," says Murray Shanahan at Imperial College London. That's useful for testing an algorithm or new learning methods, he says, but the true frontier is the real world. "When machine learning is as good at understanding the everyday world as it is at Go, we'll be well on the way to human-level artificial general intelligence." ■

HOWARD WALKER

Disputing "shaken baby syndrome"

Doctor misled courts

A BRITISH doctor who has been an expert defence witness for parents accused of killing their children has been found guilty of charges including giving misleading evidence in court.

The Medical Practitioners Tribunal Service said that Waney Squier, a pathologist at John Radcliffe Hospital in Oxford, UK, had failed to work within the limits of her competence, failed to be objective, and failed to heed the views of other experts. The MPTS examined her conduct during six child abuse cases and one appeal.

Squier is one of several researchers who have challenged a long-standing belief that a trio of head injury symptoms provide unequivocal evidence of abusive behaviour. Squier has argued that the symptoms can have innocent causes, such as choking.

"The impact of her research in blunting the false prosecution of innocent caregivers is beyond value or measurement to those impacted," said Steven Gabaeff of the American Board of Emergency Medicine in his submission to the tribunal.

In 2010, another pathologist challenging the triad, Marta Cohen at Sheffield Children's Hospital, was examined by the UK General Medical Council but cleared of wrongdoing. The GMC will make a final decision by 24 March on whether Squier should lose her licence to practice.

"I suspect there will be no one in England willing to dispute allegations of shaken baby syndrome now the finding against [Squier] is unfavourable," says Edward Willey, a forensic pathologist in Florida.

Hottest February

HOT stuff. February 2016 was 1.35 °C warmer than the 1951 to 1980 average for the month – the biggest monthly temperature anomaly in NASA's record, which goes back to 1880, according to figures released by the agency.

"Parts of North America and Eurasia saw temperatures more than 4 °C above the February average"

It eclipses the previous biggest anomaly, seen in January 2016, which was 1.13 °C above the January average. The Arctic had the largest anomaly, with parts of North America and Eurasia seeing temperatures more than 4 °C above the February average.

The warmest global surface temperatures were recorded in July 2015. However, it is possible that will be exceeded in 2016, with the UK Met Office predicting average global surface temperatures reaching around 1.1 °C above pre-industrial levels.

Even though some of this heat is coming from the extreme El Niño event, much of this is down to global warming driven by rising atmospheric CO_2 levels.

CO_2 levels reached record levels of 404.02 parts per million in February, according to preliminary records from Mauna Loa, Hawaii. Global average CO_2 levels rose by a record 3.09 ppm in 2015, smashing the previous record annual rise of 2.82 ppm, in 1998.

Ralph Keeling at the Scripps Institution of Oceanography says the long-term trend is that more and more CO_2 is entering the atmosphere, and the rate of growth continues to increase.

Mozzie trial closer

FLORIDA is edging towards unleashing genetically modified mozzies. The insects are able to slash the wider mosquito population through mating, and so can forestall diseases that the insects transmit.

A proposed trial release would have no significant negative impact on the health of people, animals or the environment, the US Food and Drug Administration provisionally ruled last week. The FDA is now accepting public feedback ahead of a final verdict.

UK firm Oxitec and the Florida Keys Mosquito Control District hope to release mozzies modified so that their offspring fail to reach adulthood. "We have a mosquito-rearing facility in Marathon, Florida, that's ready to go," says Matthew Warren of Oxitec.

The approach has proved successful in trials in South America. The species being targeted is *Aedes aegypti*, which is known to spread Zika and dengue virus, as well as yellow fever. None of these are major public health issues in Florida yet, and the plan is to keep it that way.

ZUMA/REX/SHUTTERSTOCK

Higher seas coming your way

Sea change in US

IT'S that sinking feeling. Sea level rise could force three times as many people in the US from their homes by the end of this century as had been thought, according to an analysis of population trends.

Until recently, most studies that predicted the risks associated with sea level rise used current population numbers, says Mathew Hauer at the University of Georgia. The problem with that, he says, is that the predictions

have become "outdated almost immediately" as US coastal communities continue to grow.

So his team combined projected population growth with predicted sea level rise based on the scenarios of the US National Oceanic and Atmospheric Administration (NOAA).

They found that a 1.8-metre rise by 2100, near the top end of NOAA's predictions, could lead to 13.1 million people being displaced – more than three times as many as indicated by current populations. Most affected will be south-east states such as Florida (*Nature Climate Change*, doi.org/bddb).

Drug trial answers

AN EXPERIMENTAL painkiller that killed one volunteer and severely injured five others in a clinical trial may have acted on parts of the brain that it wasn't supposed to, a committee investigating the incident has concluded.

The trial, which took place in Rennes, France, was looking at a drug called BIA 10-2474 on behalf of the Portuguese company Bial. Ninety people received the drug and the six who were adversely affected received the highest dose. By the time their symptoms began showing they had ingested between 250 and 300 milligrams, in 50 mg increments.

BIA 10-2474 works by blocking an enzyme that normally breaks down a painkilling neurotransmitter, preventing it from building up in the brain. The investigators suspect that at the high doses given – in some cases, 40 times higher than that needed to block all the enzyme – the drug may have disrupted other enzymes or activated other molecules in the brain.

The committee has called for a ban on drug doses vastly in excess of those needed to achieve the intended effect.

Maths 'Nobel' win

HIS work was one of the most stunning results in modern mathematics – and now he has won one of the biggest prizes in the field. Andrew Wiles of the University of Oxford, who in the 1990s cracked the long-standing mystery of Fermat's last theorem, has been awarded the 2016 Abel prize.

The Norwegian Academy of Sciences and Letters chose to award Wiles the prize, often called the Nobel of mathematics, "for his stunning proof of Fermat's last theorem by way of the modularity conjecture for semistable elliptic curves, opening a new era in number theory". The prize is worth 6 million Norwegian kroner (almost £500,000).

"It feels fantastic, a great surprise, and very exciting," says Wiles.

In 1993, Wiles published a lengthy proof of a seemingly simple theorem posed by the 17th-century mathematician Pierre de Fermat, having worked on the problem in secret for seven years. A new, complete version was published in 1995.

"I think it has gone better than I could have hoped," he says. "There are still lots and lots of challenges, but it has come to be an ever-expanding part of number theory."

Gun control funding drought

THE US needs to fund research into gun control properly. Last week, a modelling study found that if three state gun laws were enacted across the US, firearm deaths would fall by 90 per cent. It sounds like great news, but the study has come under fire.

The laws include background checks on those buying ammunition, checks on people buying guns privately, and using "fingerprinting" technology to enable a bullet to be traced (*The Lancet*, doi.org/bdcj).

The trouble is the model also found that laws requiring child-proof locks on firearms increase mortality. This just doesn't make sense, says Jeffrey Swanson at Duke University in North Carolina. Neither does the link between bullet fingerprinting and lower gun crime, as manufacturers have yet to introduce the technology.

In the 1990s, a bill was passed that heavily discouraged national funding bodies supporting research into gun control. President Obama has made moves to undo this but many bodies haven't funded gun research in years. The impact can be seen in the latest study, says Swanson.

It was carried out by a small group of researchers working in their own time with no external funding. He worries that their confusing findings may be misinterpreted by those who are against gun laws. "Investment needs to match the gravity of the situation," he says. "I'm a strong supporter of research in this field, but you have to do it right."

SERGEY SOLDATOV/ALAMY STOCK PHOTO

How safe?

60 SECONDS

Next stop, Mars

Europe and Russia's joint mission to the Red Planet is under way. The ExoMars Trace Gas Orbiter launched from the Baikonur Cosmodrome in Kazakhstan at 0931 GMT on 14 March. It should arrive on 19 October, when it will try to understand Mars's atmosphere and search for hints of biological and geological activity.

Brain trauma admission

"The answer to that question is certainly yes," said Jeff Miller, the National Football League's health and safety policy chief, at a congressional hearing on Monday, when asked if American football is linked with chronic traumatic encephalopathy. It is the first time a top NFL official has publicly admitted a link between the sport and the degenerative brain disorder.

Oil drilling on hold

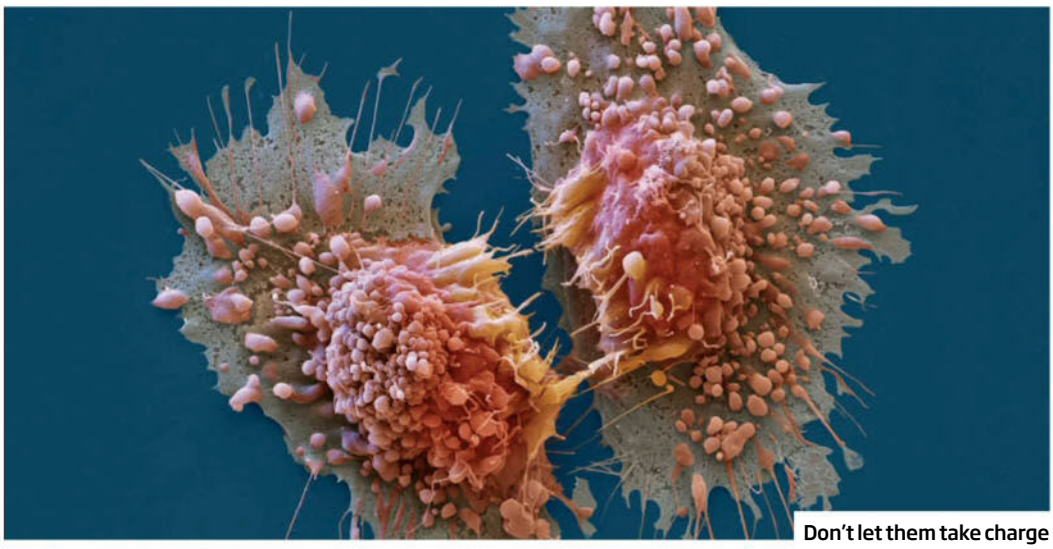
The Obama administration is expected to put off drilling for oil and gas in the Arctic and the southern Atlantic until 2022. The decision on the Atlantic may have been influenced by Pentagon concerns that drilling would affect its ability to carry out training exercises and equipment testing in coastal regions.

Grounded for good

Having returned two weeks ago, after 340 days on the International Space Station, astronaut Scott Kelly is leaving NASA at the end of the month. He will still participate in research related to his stint in space, including genetics studies comparing him with his identical twin, Mark Kelly – also an astronaut.

Zero emissions in law

The UK is gunning for zero. Speaking in Parliament on Monday, energy minister Andrea Leadsom promised to enshrine in law the commitment to zero net emissions made by the government at the Paris climate summit. But the UK has already been criticised for falling behind on its existing commitments.



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Don't let them take charge

Bioelectric cancer hack

Reprogramming tumour cells with lasers could replace toxic drugs

Jessica Hamzelou

OUR bodies are electric. It's not just our brains and hearts – almost every cell has an electrical charge, and hacking it might be a way to treat cancer. Researchers have used light to shift the charge of cancer cells in frogs, making them healthy again.

It's some way off being a human therapy, but this is the first use of a technique called optogenetics to target cancer, opening up the possibility of treatments that don't use toxic drugs. "This is just the beginning," says Michael Levin at Tufts University, Massachusetts. "We hope we have a new strategy for reprogramming cell activity – we're cracking the bioelectric code."

Nerve cells use electricity to transmit signals. They do this by letting ions flow into or out of the cell through channels in their membranes, often triggering similar changes in neighbouring cells. Other cells also communicate in this way, using their ion channels to share information about their function or movement, says Levin.

This communication seems to be important when cells divide to repair damage. But uncontrolled cell division can lead to cancer, and when a cell loses some of its negative charge, it seems to help tumours to spread. These findings have raised a tantalising prospect: could we target these electrical signals to stop cancer?

Treatments that target ion channels are already being tested – one such drug seems to have kept a man's brain tumour in remission for two months. However, the drug had toxic side effects, so he stopped taking it.

Instead of using drugs to target ion channels, Levin's team is using optogenetics. This technique involves injecting a gene into cells that makes a light- sensitive protein. Shining a laser on these newly sensitive cells can then alter their behaviour in different ways, depending on the protein used.

To see if optogenetics can change the flow of ions into a cell to revert it to a non-dividing state, Levin's team have turned to frog embryos, which are particularly easy to work with. They inserted a gene that predisposes animals to cancer, adding a gene for a light-activated ion channel at the same time.

"We hope we have a new strategy for cancer – we're cracking the bioelectric code"

A week later, the tadpoles had hatched and developed tumours. While not exactly the same as human cancers, these tumours had many of the same properties, growing, spreading and forming their own blood supply in a similar way.

When the team pointed a laser at the tadpoles, around a third of the tumours stopped developing. This is an impressive result for a cancer treatment, says William Brackenbury at the University of York, UK, although he says it is hard to know how large the effect would be in humans.

In the tadpoles, cells that had been cancerous looked healthy again, and were absorbed back into other body tissues. "They've reprogrammed the cancer cells, by altering the electrical status of the cell," says Saverio Gentile at Loyola University Chicago. "They are not cancer cells any more."

If the approach works in humans, breast and skin cancers might be targeted first, as they are easy to shine a laser on. Levin hopes his approach will eventually offer an alternative to standard cancer drugs. We might find that drug-free treatments have fewer side effects, he says.

Gentile agrees. Cancer drugs that kill dividing cells don't work perfectly, and the side effects can be worse than the disease itself in some cases, he says. "Levin has shown that you don't need to kill the cells – you can take them back to a normal state." ■

EYES ON THE PRIZE

Optogenetics is the hottest tool in experimental neuroscience, but can it treat human diseases?

The technique inserts genes for light-activated proteins into cells, so lasers can change their behaviour. It could have a range of uses (see main story), but a prime candidate is to restore sight to people who have lost the light-sensitive cells in their eyes.

This has already been done in blind mice, and now researchers are turning to humans. Ed Boyden, who originally helped develop optogenetics, and his colleagues at Eos Neuroscience are one of several groups working on disorders like age-related macular degeneration.

Meanwhile, Paris-based company Gensight plans to test a treatment for a condition called retinitis pigmentosa in humans next year. RetroSense Therapeutics hopes to start testing its version of the treatment in a group of people in Texas as early as next month.

Google victory at Go stokes AI fear in Korea

Mark Zastrow, Seoul, South Korea

AFTER defeat comes resolve. AlphaGo, the artificial intelligence that has mastered one of our oldest and most complex games – Go – is the toast of Silicon Valley. But in South Korea, where Go is considered a form of expression akin to martial arts, the mood is different. Here, the game pulls in television contracts and corporate sponsors. Scholars study it full time in academies. Now, after 2500 years of tradition in the region, South Korea's top player has been bested by a cyborg, its culture shaken by technology.

Watching Google's AlphaGo AI eviscerate Korean grandmaster Lee Sedol put the nation into shock, especially after the national hero confidently predicted that he would sweep AlphaGo aside. The actual result laid bare the power of AI.

"Last night was very gloomy," said Jeong Ahram, lead Go correspondent for the *Joongang Ilbo*, one of South Korea's biggest daily newspapers, speaking the morning after Lee's first loss. "Many people drank alcohol."

Wariness of AI already has deep roots all over the world. Films like *The Terminator* influenced it, and people like Stephen Hawking and Elon Musk have made public warnings of AI's future power. But AlphaGo's schooling of Lee carries extra bite where Go holds a central place in the cultural legacy.

"Koreans are afraid that AI will destroy human history and human culture," said Jeong. "It's an emotional thing."

It is perhaps the perceived beauty of AlphaGo's moves, that it beat Lee not mechanically, but wonderfully, that has ruffled the most feathers. "AlphaGo actually does have an intuition," Google co-founder Sergey Brin told *New Scientist* hours after his firm's series-clinching third victory, which he'd flown in to witness. "It makes beautiful moves. It even creates more beautiful moves than most of us could think of."

This ability to make beauty has left many shaken. "This is a tremendous incident in the history of human evolution – that a machine can surpass the intuition, creativity and communication, which has previously been considered to be the territory of human beings," Jang Dae-Ik, a science philosopher at Seoul National University, told *The Korea Herald*.

"I thought it might be fun to watch, but now it's getting really scary"

"Before, we didn't think that artificial intelligence had creativity," said Jeong. "Now, we know it has creativity – and more brains, and it's smarter."

As Lee's losses stacked up, I kept getting worried messages from my Korean friends. "I thought it might be fun to watch, but now it's getting really scary," one of them said. Another told me: "Thinking that these AIs are only accessible to a few groups and people – it is scary."

Headlines stacked up in the South Korean press too: "The 'Horrifying Evolution' of Artificial Intelligence," and "AlphaGo's Victory... Spreading Artificial Intelligence 'Phobia'."

Some are upbeat that the impact of Lee's loss will spark a revolution in education and learning in South Korea. "We're very weak at AI," says Lee Seok-bong, a journalist for South Korean science website HelloDD.com. "Up to this point, Korean people didn't know much about AI. But because of this match, every Korean knows about it now." ■

Read more about the rise of artificial intelligence on page 20

EPA/YONHAP

Ready, set, Go

MARK ZASTROW

A MACHINE'S HAND

Google DeepMind's Aja Huang has acted as AlphaGo's avatar in the five games against Lee Sedol

What does it feel like to be the physical avatar for an AI?
I feel very serious. I don't want to make mistakes, because it's the team's hard work. Also, I try very hard to respect Lee Sedol. He's a master.

You and Lee bowed towards each other before the first match, even though you're not AlphaGo...
It's a formal game, and we show respect for each other. I bow on behalf of AlphaGo.

Do AlphaGo's moves surprise you?
Oh yeah, of course. What?! Play here? Especially that shoulder hit on move 37 in Game 2. It showed up on the screen, and I was like, woah!

Does the way you place stones vary?
If AlphaGo is confident, I will play confidently. And on some moves that I also think are very good moves, I will play slightly heavier. Like, good move!

How does it seem for Lee?
I think it's a new experience to him. It's different from playing a human. The computer is cold. There is no emotion. So I think it probably makes him not so comfortable.

Do you sympathise with him?
I'm always on AlphaGo's side, but I do have sympathy. I can feel his pressure. He predicted he could crush AlphaGo 5-0, but it's so different from what he expected. But I respect him as a master.

Chernobyl's future hangs in balance

Fred Pearce

IHAR BYSHNIOU/ANZENBERGER/EYEVINE

A WHITE-TAILED eagle soars in the clear winter air. It is hunting for fish in one of the most radioactive bodies of open water on the planet: the 12-kilometre-long cooling pond, whose waters doused the burning Chernobyl nuclear power station after it exploded 30 years ago.

The pond is radioactive – as are the fish. But wildlife is booming in the exclusion zone that stretches for some 30 kilometres from the corroding plant. Grey wolves, lynx, wild boar, rabbits and moose roam the zone, says Denis Vishnevsky, an ecologist at the EcoCentre, which monitors the Ukrainian exclusion zone.

"Some hope to turn the area into a nature reserve, others into Ukraine's radioactive waste dump"

Yet plans to turn the zone into a nature reserve are under threat from the nuclear industry, which wants to dispose of high-level radioactive waste here. The battle may soon be settled as decisions are made ahead of the 30th anniversary of the world's worst nuclear disaster, on 26 April.

On one hand, things are improving. The radioactivity levels are falling. This year marks the half-life of the two most dangerous isotopes released that are still present: caesium-137 and strontium-90. That means just half the amount of these isotopes remains in the region, the rest having decayed. Each emits beta and gamma radiation as it decays, which can penetrate human skin.

Most of the exclusion zone now has radioactivity levels for caesium-137 that are below 500 kilobecquerels per square metre, says Jim Smith of Portsmouth University, UK, who studies the environmental impacts of the disaster. He says this is a safe level of exposure, provided people don't eat mushrooms and berries, which concentrate radioactivity.

Pripyat, the ghost town next to the plant, is still unsafe; but the town of Chernobyl, 10 kilometres away, could be repopulated safely, he says.

Not everyone agrees, as the exclusion zone still contains a large proportion of long-lived isotopes locked up in ecosystems.

Much of the fallout has been contained within the zone's soils, pine forests and wetlands, which have been left alone to allow the isotopes to slowly decay, says Vishnevsky. But if something releases this radioactivity, it could endanger any settled population.

Forest fires are one worry. The risks are rising as unharvested wood builds up. Also, the most radioactive forests contain fewer leaf-litter-eating microbes and insects, meaning that litter is piling up, ready to burn. Last April, an estimated 131 square kilometres of forest burned in the zone. Afterwards, scientists and firefighters demanded a network of smoke monitors across the zone but no funding is available.

Then there are the floods that can wash the contamination from local wetlands into the nearby Pripyat river, which provides some of the drinking water for the Ukrainian capital, Kiev. Big dykes have been dug to prevent this.

Another emerging risk is the spread of radioactive sediment by wind: as the cooling pond next to the power station is drained, the sludge at the bottom is exposed (see "Radioactive pond hung out to dry", below).

Sergey Kireev, director of the EcoCentre and a proponent of the nuclear waste repository idea, raises another concern. The plutonium isotopes have half-lives of thousands of years. And americium-241, a decay product

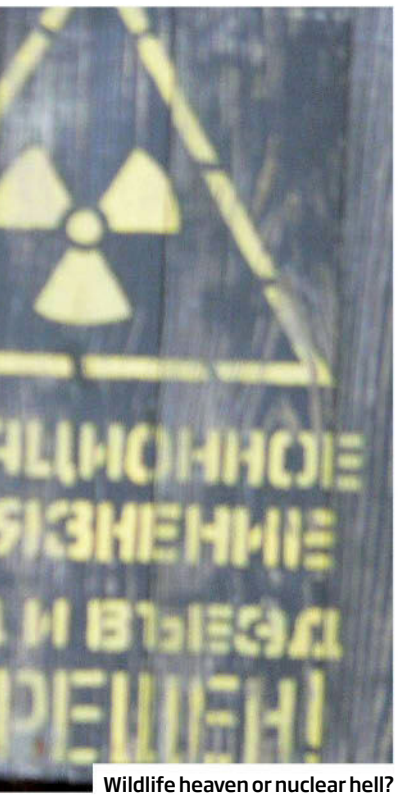
RADIOACTIVE POND HUNG OUT TO DRY

Gennady Laptev, head of the radiometric laboratory of the Ukrainian Hydrometeorology Institute, took me to see the cooling pond built for the Chernobyl power station. In 1986 it received huge amounts of radioactive material from atmospheric fallout and deliberate dumping as workers sought to douse the inferno. Most of the contamination ended up in the pond's sediment, shielded by the water above. But that is set to end.

In 2014, to save money, the government stopped pumping water from the Pripyat river into the pond, which sits some 7 metres above the river's level. "Within four years, 90 per cent of the pond will be gone," says Laptev. The sediment, containing more than 300 terabecquerels of radioactivity, will be exposed to the air. Without measures to map radioactivity hotspots and prevent its spread, much of it could end up dispersed by winds.

"Time is passing and the pond is disappearing forever," says Laptev.

JEAN GAUMY/MAGNUM PHOTOS



Wildlife heaven or nuclear hell?

of plutonium, has one of 432 years. Both emit alpha radiation, which can be stopped by the skin, but causes damage if ingested.

Smith says the risks from these isotopes are low, but Kireev thinks their presence means it would be unsafe for people to return to the area for thousands of years.

Despite such concerns, some people are already back. Around 6000 work in the exclusion zone up to four days a week. Some are erecting a new confinement that will be installed sometime next year on top of the rusting "sarcophagus" that houses the wrecked Chernobyl nuclear reactor. Others, like Kireev, are support staff managing the zone.

Also scattered across the exclusion zone are a hundred or so ageing returnees, who came back to their houses because they didn't like life as evacuees. They have no truck with radiation fears.

Hale and hearty 78-year-old Eugene Fedorovych tells me he and his wife told security staff who tried to stop them illegally catching radioactive fish in Pripyat river to "go away".

Even tourists are allowed to visit Pripyat, the former model Soviet town that now has 20-metre trees bursting through the concrete in the town square.

But officially the zone is still not being repopulated. So why not turn it into a wildlife reserve? To the north, Belarus has turned its part of the zone into the Polesye State Radioecological Reserve.

The idea of doing the same in Ukraine was posed in 2014 by the environment ministry. Ecologists on Kireev's staff would love to create one, and the World Bank's Global Environment Facility has proposed a cross-border reserve. In February, media reports suggested the plan could become official policy in time for the 30th anniversary of the disaster.

But Kireev dismisses the idea. Wildlife is no more welcome than people in the vision for the zone's future he subscribes to. The reason, ultimately, has more to do with politics than radiology.

More than half of Ukraine's electricity is produced by nuclear power plants. The spent fuel needs a home following a recent decision to stop sending it to Russia for treatment. An interim store for spent fuel is already being built in the exclusion zone. The next step is building a permanent geological repository.

"Because the zone is unpopulated, it makes it very attractive," Kireev says, and shows me a map of potential sites.

It would also be cheap. Without people to relocate and compensate, it could be built for $2 billion, he says, against as much as $70 billion outside the zone.

There appears to be a battle going on inside the Kiev government over the future of this poisoned landscape. And local experts think a decision may be only days away. Whatever emerges, it's likely to determine the fortunes of locals, wildlife and the nuclear sector here for the next 30 years. ■

Old-dad evolution is protecting our health

WE'RE running just to stay still. A study of more than a million people going back four centuries shows that we are still evolving – not into superhumans, but to stay as we are.

Almost all children in rich countries now survive to adulthood. That has led some biologists to suggest that evolution has essentially stopped. The thinking is that if children are less likely to die, those with lots of adverse new mutations are more likely to pass these on, so natural selection is no longer stopping these genetic changes from building up in the population.

According to geneticist Michael Lynch of Indiana University in Bloomington, this process could affect our health and intelligence in just a few generations. Some have claimed that our genetic potential for intelligence is already eroding, and that IQ scores should have risen even more than they have over the past century due to better health and education.

But now there's evidence that evolution is still removing our harmful mutations. Ruben Arslan of the University of Göttingen in Germany and his colleagues made this discovery by analysing church records from the 15th and 16th centuries from three areas – in Germany, Sweden and Quebec in Canada – and also in modern Swedish health records.

Studies have shown that for every extra year of their father's life before they were conceived, a child has about two extra mutations. But Arslan's team has found that the mutations of children born to older fathers are less likely to be passed on, because these children grow up to have fewer children themselves. Compared with a sibling born 10 years earlier,

"Additional mutations are preventing the children of older fathers from reproducing as much"

individuals born when the fathers were older had on average 5 per cent fewer children who survived beyond infancy (*bioRxiv*, doi.org/bdd3).

The team thinks this is because the additional mutations are preventing the children of older fathers from reproducing as much as those born to younger dads. In this way, evolution still seems to be weeding out harmful mutations from human populations, stopping them from accumulating over generations.

But Lynch points out that even though there may be some evolution taking place, this selection may be weaker than it used to be. This means that over longer periods of time, mutations could still build up in human populations, albeit more slowly.

Even so, Arslan's work suggests that we can worry less about recent trends towards having children later in life. Although the age at which men first become fathers has crept upwards in the past half-century, the average age of each child's father is still lower now than it was in the 16th century, the study found.

This is because people used to have more children, starting their families earlier, but continuing to reproduce until late in life. In Sweden, between 1737 and 1880, the average age of a baby's father at their time of birth was 35, a couple of years older than dads in Sweden today. Michael Le Page ■

NATALIE SAVEY/MILLENNIUM

How many new mutations?


ROBERT BROOK/SPL/GETTY

More orderly than meets the eye

‘Random’ primes pair up on the sly

Jacob Aron

PRIME numbers are pickier about how they sit than we thought. Mathematicians have been stunned to find that these numbers aren’t quite as haphazard as they seem.

Understanding primes – numbers divisible only by themselves and 1 – is key to deciphering the fundamentals of arithmetic. Mathematicians don’t have a way to predict which numbers are prime, so tend to treat them as if they occur randomly. But now Kannan Soundararajan and Robert Lemke Oliver of Stanford University in California have discovered that isn’t quite right.

“It was very weird,” says Soundararajan. “It’s like some painting you are very familiar with, and then suddenly you realise there is a figure in the painting you’ve never seen before.”

Apart from 2 and 5, all prime numbers end in 1, 3, 7 or 9 (anything ending in 2 or 5 is divisible by that same number) – and each of the four endings is equally likely. But while searching through the primes, Soundararajan and Lemke Oliver noticed that primes ending in 1 are less likely to be followed by another ending in 1 than primes ending in 3, 7 or 9. That shouldn’t happen if primes are truly random – consecutive primes shouldn’t care about their neighbour’s final digit.

The pair found that in the first hundred million primes, a prime ending in 1 is followed by another ending in 1 just 18.5 per cent of the time. If they were random, you’d expect to see two primes ending in 1 next to each other 25 per cent of the time.

“It’s like a familiar painting, and then suddenly you realise there is a figure in it you’ve never seen before”

The patterns get more in line with randomness as you count higher – the pair have checked up to a few trillion – but still persists (arxiv.org/abs/1603.03720).

“I was very surprised,” says James Maynard of the University of Oxford, who on hearing of the work immediately did his own calculations to check the pattern. “I somehow needed to see it for myself to really believe it.”

Thankfully, Soundararajan and Lemke Oliver think they have an explanation. Modern research into primes is underpinned by G. H. Hardy and John Littlewood, two mathematicians who worked together in the early 20th century. They devised a way to estimate how often pairs, triples and larger groupings of primes will appear, known as the *k*-tuple conjecture.

Soundararajan and Lemke Oliver used this to show that the last-digit pattern arises from the groupings given by the conjecture, as they place limits on where the last digit of each prime can fall. What’s more, as the primes stretch towards infinity, they do eventually shake off the pattern and give the random distribution mathematicians have come to expect.

Although the result has no obvious applications to long-standing problems about primes, it has given the field a shake-up.

“It gives us more of an understanding – every little bit helps,” says Andrew Granville of the University of Montreal, Canada. “If what you take for granted is wrong, that makes you rethink some other things.” ■

Mini *T. rex* was a surprisingly smart customer

BRAINS came before brawn for the iconic *Tyrannosaurus rex*. The star of *Jurassic Park* emerged as a huge and cunning predator some 80 million years ago. But how it evolved has long been a mystery, because of a gap in the fossil record that began 100 million years ago.

Now, a skull fragment and other remains show that this dinosaur started out merely the size of a bear, and that it evolved its big brain before its giant 5-tonne stature. The fossils, found in Uzbekistan, date back 90 million years and help us understand how *T. rex* was able to become so big and so dominant, says Stephen Brusatte of the University of Edinburgh, UK.

Brusatte’s team realised the fossils were from a new tyrannosaur species. CT scans showed it had a relatively large brain as well as structures in the inner ear used for balance and for hearing low-frequency sounds. Earlier tyrannosaurs lacked such traits, which could have helped *T. rex* attain its niche as an apex predator (*PNAS*, doi.org/bdd6).

The fossils support earlier proposals that *T. rex* evolved “head first” – brain before bulk. But exactly how it took over as apex predator remains unclear. Brusatte says it may have exploited the disappearance of other large predators, such as allosaurs. Jeff Hecht ■


TODD MARSHALL

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Mystery fairy rings hint at their source

Jane Palmer

DEEP in the Australian outback, grass-ringed circles of bare earth stretch for several hundred square kilometres across the red soil.

This is the first time these "fairy circles" have been spotted outside the Namibian desert, where they have evaded explanation for decades.

The discovery could help resolve the long-standing mystery of how they form. "It shows that the fairy circles of Namibia do not exist on their own," says Stephan Getzin at the Helmholtz Center for Environmental Research in Leipzig, Germany.

Getzin and his team visited the site 15 kilometres south-east of Newman, to measure the circles and analyse conditions on the ground after seeing an aerial shot of them. "From the bird's-eye perspective the pattern becomes clear, and you see the regular features indicative of the fairy circles," Getzin says (see picture).

So what is behind these curious formations? In Namibia, local legends have explained the circles as the footsteps of gods, burn marks from the breath of underground dragons, or even landing spots for UFOs.

The most popular scientific theory is that ants or termites nibble on the roots of grasses, so the plants die back in a circle from the site of an insect nest.

More recently, however, another theory has emerged: the circles arise when the plants compete for water and nutrients, and "organise" themselves to maximise access to scarce resources. This theory suggests such circles should feature in other arid regions of the world.

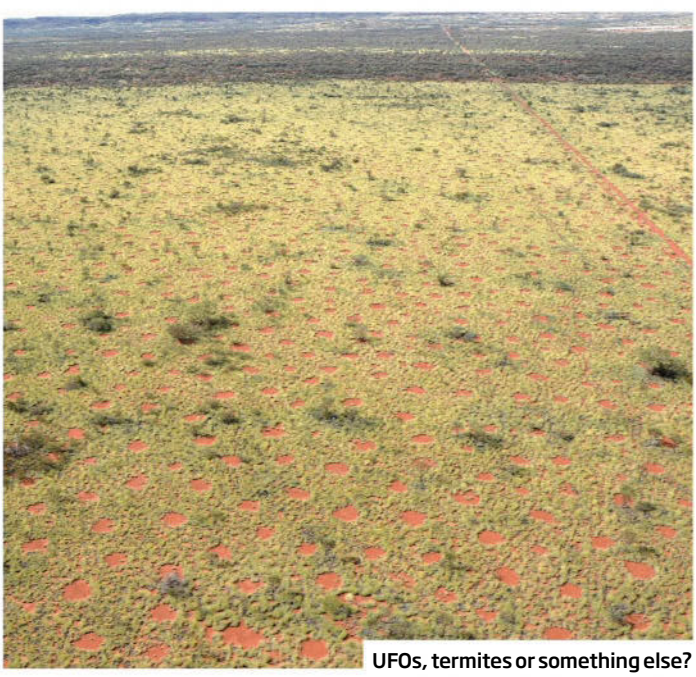
The Australian rings back up this self-organisation hypothesis. Getzin's team found few ant or termite nests within, or near, the circles and no correlation between rings and locations of the nests that did exist.

But they did find that the hard-clay soil crust within the circles was almost impermeable to rainfall – all the water pouring into this area flowed towards the periphery, where the thirsty plants await. "That gave us clear hints that the gaps serve as a source of water for the vegetation," Getzin says.

More water around the circle edges means more biomass and roots, and that leads to the soil becoming looser. Looser soil allows more water to penetrate and feed the vegetation, creating a feedback loop supporting the plants at the edge of the circle (*PNAS*, doi.org/bddw).

The dominant grasses of the *Triodia* genus found close to the fairy circles in Australia also form other typical drought patterns such as stripes, labyrinths or spots with individual plants surrounded by bare earth. This provides strong evidence that the fairy circles also arise due to competition for water, Getzin says, though he doesn't claim to have solved the origin of the circles just yet. "You should never claim to put an end to the mystery," he says. "We've just made one significant step forward in solving the problem."

"It's pretty good evidence for the self-organising theory," says Michael Cramer, a biologist at the University of Cape Town in South Africa. "There's still a long way to go to make it conclusive, but I think the evidence is mounting." ■



KEVIN SANDERS

UFOs, termites or something else?

Taking a detour improves traffic for everyone

TAKE the long way home. It seems that commutes to and from city centres would be better if a few drivers took the scenic route.

Most drivers in urban areas try to find the fastest possible route to their destination. But when everyone does this, congestion increases and everyone suffers. If a handful of people took longer routes, they could cut overall congestion by 30 per cent, says Serdar Çolak of the Massachusetts Institute of Technology in Cambridge.

"When a road is crowded, an additional car makes a very big difference," he says. "If we are able to remove a couple of cars from the morning commute, that's going to save everyone else a lot of time."

Çolak and his colleague Marta González looked at millions of anonymous location-tagged mobile-phone records and matched them to roads in Boston, the San Francisco Bay area, Rio de Janeiro in Brazil, and Lisbon and Porto in Portugal. They noted that when drivers choose the shortest routes for themselves, commute times can lengthen by 60 per cent. Apps that suggest the shortest routes in real time make the problem even worse.

But if a few cars take side roads, congestion reduces, saving each driver up to 3 minutes on average (*Nature Communications*, DOI: 10.1038/ncomms10793). In the future, computers and smart cars could figure out the best way to send everyone, the authors add. Apps that suggest other routes could offer drivers incentives such as a free cup of coffee for sacrificing their time.

"If a handful of people took longer, alternative routes, they could cut overall congestion by 30 per cent"

But not everyone is convinced this is the best solution. "Placing restrictions on roads could have counter-effects that are difficult to forecast," says Marc Barthelemy of the National Center for Scientific Research in Paris, France. "Real success would be that individuals leave their car at home and choose public transportation."

Rebecca Boyle ■

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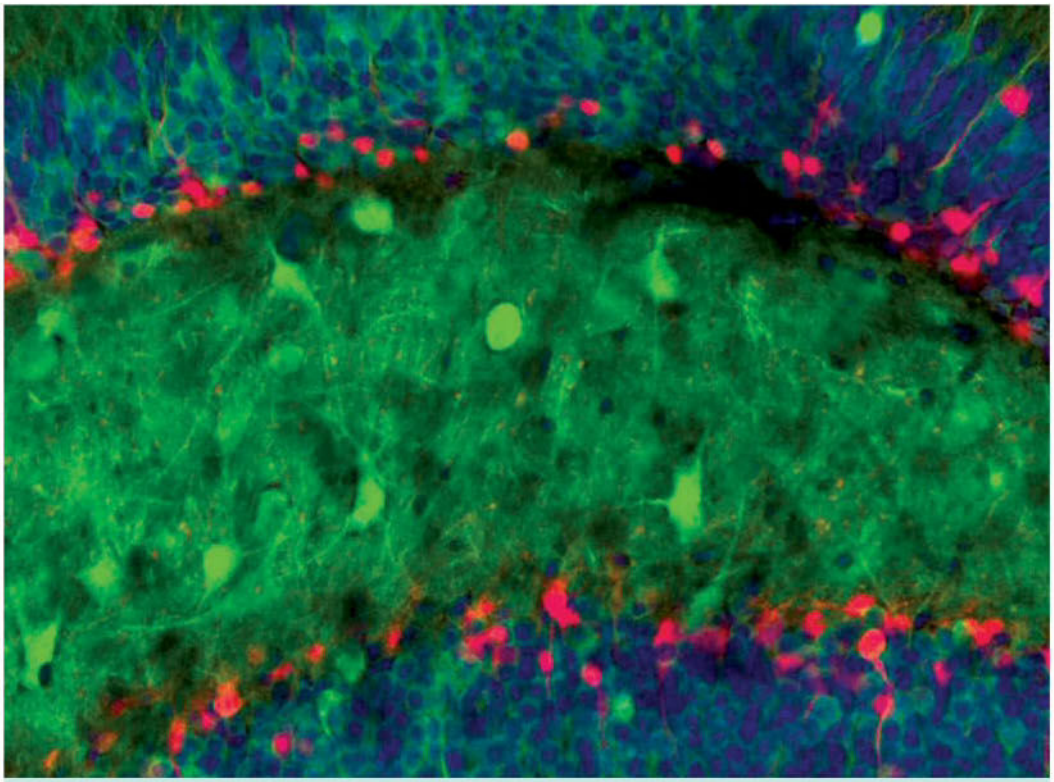

NATHAN DANIELSON

Newborn neurons viewed for the first time in live brains

THERE they are! New neurons vital for memory have been seen in a live brain. The work could aid treatments for anxiety and stress disorders.

Attila Losonczy at Columbia University Medical Center in New York and his team implanted a tiny microscope into the brains of live mice, the brain cells of which had been modified to make newly made neurons glow. The mice then ran on a treadmill as the team tweaked the surrounding sights, smells and sounds.

The researchers paired a small electric shock with some cues, so the mice learned to associate these with an unpleasant experience. They then deactivated the newborn neurons – present in areas of the brain responsible for learning and memory – using optogenetics, which switches off specific cells with light.

After this, the mice were unable to tell the difference between the scary and safe cues, becoming fearful of them all (*Neuron*, doi.org/bc7v). "It suggests that newborn cells do something special that allows animals to tell apart and separate memories," says Losonczy.

An inability to discriminate between similar sensory information triggered by different events, such as the sound of a gunshot and a car backfiring, is often seen in panic and anxiety disorders such as PTSD. This suggests that new neurons, or a lack of them, plays a part in such conditions and could guide novel treatments.

Building quantum circuits is child's play

QUANTUM computers aren't ready for the big time yet, but you could help program their circuits and make them a reality by playing a game.

Simon Devitt of the RIKEN Center for Emergent Matter Science in Saitama, Japan, and his colleagues have turned the problem of programming a quantum computer into a game called meQuanics. The game is based on a technique called topological error correction, which many researchers are using in the quest to create large-scale quantum computers.

The technique works by carving circuits from a 3D grid of quantum bits, or qubits. The larger the circuit, the more qubits you need and the more difficult it is to build. The trick is to make the circuits as small as possible.

A non-quantum computer can be taught to shrink circuits, but requires a helping hand. "We need to give it a huge amount of examples to learn from," says Devitt. Players' solutions to meQuanics puzzles will form this collection of examples.

In the game, circuits appear as 3D puzzles. Players aim to minimise them using a variety of tools to manipulate the circuits without breaking the rules of the underlying theory.

Graphene gets itself in a fold

AN ANCIENT art form just got bang up to date. Graphene – sheets of carbon just one atom thick – has been folded like origami. The technique could be used to build nano-robots and tiny, flexible circuits.

A team led by Itai Cohen of Cornell University in Ithaca, New York, coated a single layer of graphene with a layer of silicon dioxide glass. Where they were bonded to carbon atoms, the glass molecules responded differently depending on temperature, pH and charge, bending some and holding others still. These responses let the team predict how the graphene would expand and contract, and thus fold.

"This really represents the limit," says Cohen. "There's not going to be any way to make the sheet thinner." The team presented the work at the American Physical Society annual meeting in Baltimore, Maryland, this week.

New microbe has a taste for plastics

NATURE has beaten us to it again. A bacterium that breaks down and consumes one of the world's most problematic pollutants has turned up, living off plastic debris.

Kohei Oda of the Kyoto Institute of Technology in Japan and his team found *Ideonella sakaiensis* by analysing microbes on polyethylene terephthalate (PET) samples from the environment. They hope this will lead to new ways to dispose of plastic, using either the bacteria themselves or the two enzymes they produce for the job (*Science*, doi.org/bc8g).

"Large quantities of PET have accumulated in environments across the globe," says Oda. His team is now trying to engineer a bacterial strain that is even better at gobbling it.

DNA find shakes up human origins

A PIT of bones may hold the key to our past. This is the source of the oldest human nuclear DNA to be reconstructed and sequenced, which reveals Neanderthals in the making.

The 430,000-year-old DNA comes from mysterious early human fossils found in Spain's Sima de los Huesos, or "pit of bones". The fossils look similar to the bones of Neanderthals, which evolved some 100,000 years later, but the mitochondrial DNA is more similar to that of Denisovans, who lived in southern Siberia.

Now, a team led by Matthias Meyer at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, has pieced together parts of the hominins' nuclear DNA from a tooth and thigh bone. They found the specimens are more closely related to ancestors of Neanderthals than those of Denisovans (*Nature*, doi.org/bdcn).

Because the specimens look more like one group than the other, this means the two must have split by 430,000 years ago. Given that the lineage leading to modern humans split off even earlier, it also pushes back our origins.

This means we should now refocus on fossils from 400,000 to 800,000 years ago to determine which ones might fit the bill for being that common ancestor, says Chris Stringer at the Natural History Museum in London.

CESAR MANSO/AFP/GETTY

Resistance is futile – MRSA superbug felled by antibiotics

FROM superbug to… just bug. Newly discovered chemical compounds can make MRSA bacteria vulnerable to the antibiotics they normally resist, restoring the old drugs' former powers.

MRSA is a major cause of hospital-acquired infections, and the second biggest cause of death from drug-resistant bacteria in the US. These bugs are resistant to beta-lactams,the most widely used class of antibiotics.

These drugs work by targeting peptidoglycans, essential components of a bacterium's cell wall. But MRSA protects itself against the onslaught using a molecule that can soak up the drug and stop it from working.

Now Christopher Tan and his colleagues at Merck Research Laboratories in New Jersey have identified two compounds that restore the power of beta-lactam antibiotics against MRSA.

Called tarocin A and tarocin B, these compounds target teichoic acid, a different part of a bacterium's cell wall. Neither of these drugs kill bacteria on their own, but when either one is combined with an antibiotic, the two-pronged attack can kill MRSA in both clinical samples and in infected mice (*Science Translational Medicine*, doi.org/bc7t).

"It will take 20 years to come up with a reasonable number of new antibiotics," says David Brown of the charity Antibiotic Research UK. "So we've got to salvage our current antibiotics over the next 20 years or so with resistance breakers, which are really the only chance we've got."

Test can tell you if you need chemo

IT HAS been a long-sought goal: a test that can tell whether someone with cancer needs chemotherapy. Now we may have one for breast cancer.

The test, called Oncotype DX, analyses the activity of 21 tumour genes and gives people a score out of 100 – with high scores indicating a worse prognosis. Researchers used the test on a group of 2600 women whose cancer had spread. One in six had a score below 12 and were given hormone therapy only; normal treatment involves chemo – which has severe side effects that can include life-threatening infections – and a hormone therapy. After five years, just 6 per cent of them had died or had seen their cancer return.

Skipping chemotherapy was the right call, says Oleg Gluz of the Evangelical Hospital Bethesda in Mönchengladbach, Germany, who announced the results at the European Breast Cancer Conference in Amsterdam, the Netherlands, last week. Studies have shown that chemo reduces recurrence by a third – in this case taking the rate down from 6 to 4 per cent. But this reduction would be outweighed by the known harms of chemotherapy, he says.

ALEAH DAVIS, FROM NEW PHYTOLOGIST

Orchid flower impostors fool flies

THEY'RE masters of disguise. The flowers of some *Dracula* orchids have a lower petal that looks and smells like mushrooms that live in their forest habitat in the Ecuadorian Andes.

Scientists had long speculated that this mimicry attracts fungus gnat flies, which lay their eggs on mushrooms and act as pollinators. Now a team led by Tobias Policha at the University of Oregon in Eugene has used 3D-printed replicas of the flowers to investigate. They printed flowers with different scents and colour patterns, and then tested them in the orchid's natural habitat.

Sure enough, the scented replica flowers attracted three times as many flies as unscented ones. This suggests that scent plays a part in attracting flies looking to lay their eggs on mushrooms (*New Phytologist*, doi.org/bc82).

But the orchids were also playing another, subtler game. Flies were more attracted to flowers with a typical spotted pattern than those that were striped or had no pattern. The reason for this could be that the insects confuse the spots for other flies, and land on the flowers in the hope of finding a mate, says Policha.

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Anything you can do...

Defeating the human Go master is a milestone for machine intelligence. But handling the real world is the bigger challenge, says **Aviva Rutkin**


FABRICE COFFRINI/AFP/GETTY

VICTORY to the machines – again. Google's AlphaGo software has defeated human Go grandmaster Lee Sedol 4-1 in a five-game series. Despite Lee coming back to win the fourth game (see page 21), for many the realisation of what was taking place was stark. "I didn't think AlphaGo would play the game in such a perfect manner," Lee admitted in shock.

The showdown has drawn eyes from around the world – 30 million people watched it in China alone. Like Deep Blue checkmating chess grandmaster Garry Kasparov, or Watson answering questions on *Jeopardy!*, it represents a milestone in our relationship with machines.

"My 5-year-old is more intelligent than AlphaGo. Any child is more able to deal with novel situations"

But it is also a sign of things to come. The machine learning techniques behind AlphaGo are driving breakthroughs in many fields. Neural networks are software models, built from multiple layers of interlinked artificial neurons, that can learn and adapt based on the data they process. They drive everything from facial recognition software on your phone to virtual assistants like Apple's Siri and software that diagnoses disease.

And now software is learning to interact with physical things – one thing we are still better at. While DeepMind has been prepping for the big game, another Google team has been working on a more humble win.

In a video released last week, robotic claws dip and grab at household objects like scissors or sponges. They repeat the task hundreds of thousands of times, teaching themselves rudimentary hand-eye coordination. Through trial and error, the robots gradually get better at grasping until they can reach for an item and pick it up in one fluid motion.

Also last week, Facebook revealed how one of its AIs taught itself about the world by watching videos of wooden block towers falling. The aim was to let it acquire intuition about physical objects in much the way humans infants do, rather than making judgements based on pre-written rules.

Getting machines to handle the real world with the intuition of a child is one of the biggest challenges facing AI researchers. Mastering a complex game is impressive, but it is the AIs playing with kids' toys that we should be watching. Despite its complexity, the challenges in Go are defined by clear rules. The real world rarely affords such luxuries.

"Frankly, my 5-year-old is a lot more intelligent than AlphaGo," says Oren Etzioni, CEO of the Allen Institute for Artificial Intelligence in Seattle, Washington. "Any human child is substantially more sophisticated, more flexible, more able to deal with novel situations, and more able to employ common sense."

Aping humans

Yet the robo-claw experiment shows that the machine learning techniques used to master Go can also teach machines hand-eye coordination. So people are trying to make AIs a little more like us – improving their dexterity through feedback from their successes and mistakes. Over the course of two months, the robo-claw team filmed 14 robotic manipulators as they tried to pick up objects. These 800,000-plus "grasp attempts" were then fed back into a neural network.

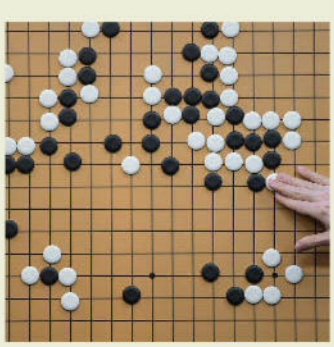
With the updated algorithm now driving the robot's choices, the researchers put their machines to the test. They filled bins with random objects, including some that would be difficult to pick up for the two-fingered grippers – Post-it notes, heavy staplers, and things that were soft or small.

Overall, the robots failed to grasp something less than 20 per cent of the time. And they developed what the team described as "unconventional and nonobvious grasping strategies" – learning how to size objects up and treat them accordingly. For example, a robot would generally grab a hard object by putting a finger on either side of it. But with soft objects such as paper tissues, it would put one finger on the side and another in the middle.

The Facebook team took a similar approach. They trained algorithms on 180,000 computer simulations of coloured blocks stacked in random configurations, as well as videos of real wooden block towers, filmed as they fell or stayed in place. In the end, the best neural networks accurately predicted the fall of the simulated blocks 89 per cent of the time. The AI fared less well with real blocks, with the best system only getting it right 69 per cent of the time.

WHAT IS GO?

The game of Go involves two players placing black and white counters to conquer territory. It is played on a 19 by 19 board, which allows for 10^{171} possible layouts, versus roughly 10^{50} possible configurations on a standard 8 by 8 chessboard. To give you a sense of scale, it's estimated there are 10^{80} atoms in the universe. "Go is probably the most complex game ever devised by man," says DeepMind founder Demis Hassabis.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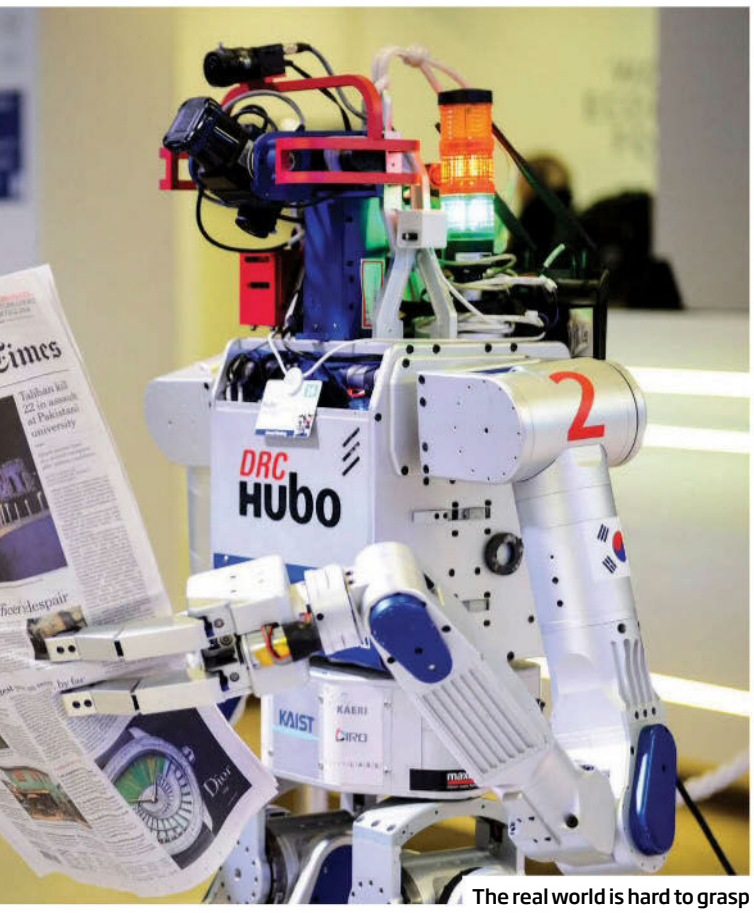

The real world is hard to grasp

That was better than human guesses on what would happen to virtual blocks, and the same as humans for predicting the fall of real blocks.

Studies like these start to move away from supervised learning, a standard approach to training machines that involves slipping them the right answers. Instead, learning becomes the algorithm's responsibility. It takes a guess, finds out if it succeeded, then tries again. AlphaGo also trained in part through such a trial-and-error approach, helping it to make moves that perplexed Lee.

"Currently, we need to take the computer by the hand when we teach it and give it a lot of examples," says Yoshua Bengio of the University of Montreal in Canada. "But we know that humans are able to learn from massive amounts of data, for which no one tells them what the right thing should be."

Another skill that AIs will have to master to rival a child is doing not just one task well, but many tasks. Such intelligence is likely to be decades away, says Etzioni. "The AI field has been taking on narrow tasks, very limited things, whether that's speech recognition or Go or whatever," he says, "but human fluidity, the ability to go from one task to another, is still nowhere to be found."

Ultimately, the greatest benefits may come from working alongside AIs. After losing to AlphaGo in October, European Go champion Fan Hui has been its training partner. He helped the AI improve to the point that it could beat Lee easily. But the experience has made Fan a better player too. In October, he was ranked in the 500s. Having played against the AI for several months, he is now ranked about 300 in the world. ■

Machine outsmarts man in battle of the decade

An AI has beaten a human at our most complex game. **Mark Zastrow** reports from Seoul, South Korea

LAST week, millions of people watched a man play a computer in one of humanity's oldest boardgames – Go. An artificial intelligence trained by DeepMind – a start-up firm in London owned by Google – played five games against Lee Sedol, one of the game's leading players. The AlphaGo AI was ahead from the opening game.

"It's so shocking. I expected AlphaGo to win one game, but I didn't expect it to be the first one," said Myung-wan Kim, a 9-dan professional Go player living in Los Angeles, after the first game.

Lee felt the same: "I am in shock, I admit that. I didn't think AlphaGo would play the game in such a perfect manner."

It got worse for Lee, the South Korean hero, as he lost the second and third games. AlphaGo flashed its calculating nature towards the end of the game two, when it seemed to make a mistake that allowed Lee to capture several stones. Lee blinked in disbelief, but it was false hope. AlphaGo didn't care about the margin of victory – it makes whichever move will maximise its chances of winning.

But Lee turned the tables in the middle of game four on Sunday, with an astonishing wedge play. Gu Li, one of Lee's rivals, called it the "hand of god". The press room started buzzing as AlphaGo went into death throes, playing increasingly bizarre moves. Lee sat bolt upright, focused. Aja Huang, the AlphaGo programmer who acts as the AI's human avatar and places its stones on the board, seemed resigned. Then a message appeared on Huang's monitor: "The result 'whiteresign' was added to the game information. AlphaGo resigns."

> "If Lee cracked a smile in his moment of victory, I didn't see it. His focus was on the board"

Lee versus DeepMind is a milestone for a new kind of artificial intelligence, one that learns how to play rather than being programmed with rules. The reaction to that new power is playing out in South Korea right now (see page 9). After the third match, in which AlphaGo clinched the series 3-0, Lee apologised "for not being able to satisfy a lot of people's expectations". More than one reporter was holding back tears. Lee stressed it was not humanity's defeat, but his.

One of Lee's fellow pros, Lee Hyun-wook, paid tribute to his courage. "He is fighting such a lonely fight, and a hard fight against this invisible opponent."

Game four was an emotional 180. Yet if Lee cracked a smile in his moment of victory, I didn't see it. His focus was on the board, on the game he'd just won.

In Go, it's customary to go over the match with your opponent to share your thought processes. But across from Lee, there was only Huang, looking around, unable to explain AlphaGo's blunders. As he left his chair, Lee gave him barely a nod. In victory, just as in defeat, Lee Sedol was utterly alone. ■

SEO MYUNG-GON/YONHAP/REUTERS

Time for a smile, afterwards

Making senses

We're learning how to augment the brain. **Andy Coghlan** plugs in

BRAINS get data about the world through senses – sight, hearing, taste, smell and touch. In a lab in North Carolina, a group of rats is getting an extra one. Thanks to brain implants, they have learned to sense and react to infrared light. This demonstrates the brain's ability to process unfamiliar data – an early step towards augmenting the human brain.

Miguel Nicolelis of Duke University School of Medicine is leading the experiment. His team implanted four clusters of electrodes in the rats' barrel cortex – the part of the brain that handles whisker sensation. Each cluster is connected to an infrared sensor that outputs an electrical signal.

To train and test the rats' new sense, feeding stations with infrared lights were put at the corners of their cage. The rats got a reward for pressing a button when the station emitted an infrared signal.

In an older, single-sensor version of the experiment, it took the rats one month to adapt. With four sensors, it took them just three days. This speed-up could be because of the increased amount of data reaching the rats' brains (*Journal of Neuroscience*, doi.org/bdb6).

"This is a truly remarkable demonstration of the plasticity of the mammalian brain," says Christopher James of the University of Warwick, UK.

Also, the rats' new sense doesn't appear to diminish their original senses. "The results show that nature has apparently designed the adult mammalian brain with the possibility of upgrades, and Nicolelis's team is leading the way showing how to do it," says Andrea Stocco of the University of Washington in Seattle.

Nicolelis says unpublished data from a follow-up experiment shows that rats learn even faster when the sensors feed directly into their visual cortex, taking just 6 or 7 hours. Nicolelis thinks the quicker learning comes from using a part of the brain that already interprets light. He is planning a subsequent experiment in which the rats only get a reward if they "see" both parts of the spectrum – visual and infrared – at once.

If it can be done with infrared, why not with ultraviolet light, microwaves, or other inputs? "It would be a fusion, total vision," says Nicolelis.

"It seems that nature designed the adult mammalian brain with the possibility of upgrades"

"Now there's no doubt that it's easy for the mammalian brain, even in adulthood, to adaptively use a novel, never-experienced sense, such as infrared, GPS or magnetism," says Yuji Ikegaya of the University of Tokyo in Japan.

Nicolelis's brain interfaces will probably find their first application in medicine. Filippa Lentzos of King's College London points out that cochlear implants are already widely used. "We do a lot of this already, so whether completely new senses would be acceptable is a very interesting debate."

The idea is part of a trend that erodes the boundary between our brain and the outside world. Some people already have sensors and chips implanted in their flesh, and although implanting in the brain is dangerous, the benefits may outweigh the risks someday.

"Is it safe, and are these capabilities we necessarily want to develop?" asks Lentoz. She sounds a note of caution: "Could it be abused by the military, to enhance battlefield performance or degrade enemy performance?" ■

CONEYL JAY/GETTY

Powers of perception

ONE PER CENT

Pigeons on patrol

Pigeons are everywhere in London, so why not use them to our advantage? Air pollution monitoring app Plume teamed up with Twitter on Monday to release 10 pigeons over central London. Each bird will wear a little sensor backpack that sniffs the air as it flies. The backpacks will be tweeting out air pollution readings over the next three days, via twitter handle @PigeonAir.

"I didn't need extra motivation, but it certainly provided that"

After being "swatted" by an online abuser, resulting in armed police swarming her home looking for a non-existent gunman, US congresswoman **Katherine Clark** pushes ahead with plans to introduce tougher penalities for cybercrime against women.

Clever stuff

It's the ultimate Transformer. Flick a switch and your house folds itself into a backpack, or its walls open into a doorway. That's the vision behind a programmable, shape-shifting material being developed by Johannes Overvelde at Harvard University and colleagues. The tech allows objects to be made in one shape – and then morphed into others at will.

DIGITALSLBI

THE WONDERS OF SPACE

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NewScientist

Midnight excess

CAUGHT on the prowl, one of Scotland's most voracious predators is in search of a midnight snack. But this time, no blood will be spilt. This European pine marten (*Martes martes*) is on its way to snaffle a peanut treat from a dispenser set up at the end of the log.

"The martens tend to raid the feeder boxes set up mainly for squirrels," says photographer Terry Whittaker, who used a camera trap to get the image. Whittaker says that the pine marten took its own photo when its head broke a laser beam and activated the camera. "I leave it on all day and night," he says.

Eerily illuminated by the night-time light pollution from the city of Inverness, this shot was taken on Black Isle, a forested peninsula bounded by water on three sides.

Whittaker says the pine martens seldom kill red squirrels, primarily because they are too agile to be caught. But if the non-native grey squirrels that have invaded much of the UK ever make it to Black Isle, they had better watch out. In neighbouring Ireland, the population of the less nimble greys crashed when pine martens became more abundant, while the reds were unaffected. Andy Coghlan

Photographer
Terry Whittaker
Naturepl.com

Bail out the world?

Pumping ocean water onto Antarctica to stem sea level rise sounds crazy, but thinking the unthinkable has merits, says **Jeff Goodell**

TO STOP rising seas from flooding coastlines, inundating cities and creating millions of refugees, scientists have looked into a novel solution: pump the troublesome extra seawater onto the Antarctic ice sheet, turning it into a salty mountain of snow and ice.

Of course, acting as if Earth's oceans are a flooding bathtub and bailing water onto Antarctica like it's a big bucket is an extreme idea. But given the collective failure to tackle global carbon emissions – the sensible way to slow the rising seas – we are now in an era when such ideas need airing.

Sea level rise is driven by unforgiving physics: as Earth's temperature rises, seawater expands and ice melts into the ocean. Each 1 °C of temperature rise bakes in an extra 2 metres of sea level over the next 2000 years. Warming so far means we're committed to at least this rise.

This being the case, Potsdam Institute for Climate Impact Research in Germany examined the Antarctic ice dump idea (*Earth System Dynamics*, doi.org/bc7n). It acknowledges major resources are going into protecting the likes of New York and London. But though walls and dykes can do a lot, as the study points out, you can't wall off entire ecosystems. And they can't help cities such as Miami, which is built on porous limestone, while poorer nations can't afford big projects. The simplest response is to retreat and watch the old world go under.

Bailing out the oceans to avoid this may sound crazy, but it's no crazier than some other geoengineering ideas, such as injecting particles into the stratosphere to reflect sunlight and lower temperatures. And it's not unthinkable. Sucking out 3 millimetres per year of water –

Don't gag science

Muzzling research will hit progress on solving society's biggest challenges, says **Neil Adger**

A NEW anti-lobbying clause in the UK is causing a chill in science circles. It appears to have the potential to muzzle research funded by government grants.

The clause was initially aimed at charities to stop them from using grants to pay for lobbying activities. But its apparent wider scope could mean it will not be permissible for hard evidence to be used to "influence legislative or regulatory action".

That would be a disaster. Politicians make tricky decisions. Evidence is required in every aspect of their work, and is critical for progress on society's big challenges. Charles Clark, a former home secretary, has identified a list of policy areas that are never solved: nuclear waste, drug regulation and climate change are put in a "too difficult box".

With climate risks, for example, more evidence, not less, is needed. Storm Desmond played havoc in northern England last December. In its aftermath, the government set up a review, calling for evidence on the adequacy of climate and river modelling, the design of critical infrastructure, and emergency forecasting and planning. I submitted work to it based on studies of people hit by the 2013 floods in Somerset and on lessons from bad floods in 2009. It was all paid for by public funds.

"The worry for researchers is that the anti-lobbying clause is dangerously ambiguous"

That consultation deliberately excluded opinion, anecdote or pleading from special interest groups. If it excluded publicly funded research findings, what would be left? Perhaps nothing. Or perhaps only privately funded research findings from insurance or engineering companies. Either way, the job of making the UK more resilient would be harder.

It is important to remember that the public pays for a lot of research and deserves for it to be

about the current rate of sea level rise – would require 90 pumps the size of the biggest ones now protecting New Orleans. Because the Antarctic ice sheet is slowly sliding into the sea, the water would have to be sent 700 kilometres inland to avoid speeding up coastal ice loss. Once there, after 100 years of pumping, it would raise the elevation of the ice sheet by about 25 metres.

The pumps would require 1275 gigawatts which, thanks to the steady winds in Antarctica, could be provided by 850,000 1.5-megawatt wind turbines.

Granted, this would transform the last pristine continent into an industrial zone. And the study foresees pumping for 100 years, so the project as imagined could only buy a century of grace before seas start to rise again.

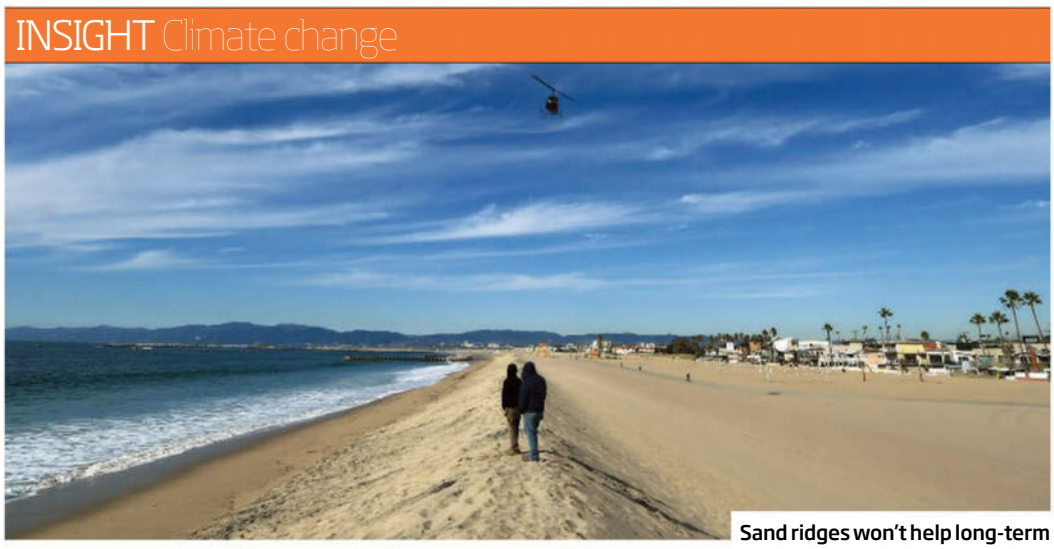
Such geoengineering is unlikely to ever happen. But there's virtue in exploring provocative ideas like this, because it reminds us of what we're up against. Earth is warming, and the seas are rising – fast. Millions of lives are at stake and the shape of the world is being transformed. The question is, what do we do about it? ■

Jeff Goodell is a fellow at independent think tank New America and is writing a book about sea level rise

used in the best way. And the government has long called for engagement and a real-world impact for research.

The worry for scientists working in controversial areas is that the anti-lobbying clause is dangerously ambiguous. Politicians make difficult decisions, usually on the basis of imperfect information. They should not further restrict themselves or hide behind anti-lobbying regulations to avoid unwelcome truths. ■

Neil Adger is a professor of human geography at the University of Exeter, UK



MARK RALSTON/AFP/GETTY

Sand ridges won't help long-term

The scary trend masked by El Niño

Michael Le Page

CLIMATE records are being smashed, and not in a good way. In July last year I wrote about how 2015 was set to become the first year with an average global surface temperature more than 1 °C higher than before the rise of modern industry.

It was, and 2016 is likely to be another record-breaker as surface temperatures are now shooting up at rates never before recorded (see page 6).

That's not all that is soaring. Last week came the news that atmospheric carbon dioxide levels are rising at the fastest rates ever recorded – and bear in mind that our records go back 800,000 years, thanks to ice cores.

These are alarming figures, but they are short-term spikes linked to the ongoing El Niño. It's the long-term trends we need to stay focused on, and they are far more frightening.

Let's start with temperature. In the long run, the planet is getting warmer. But the current spike we are seeing is not to do with Earth suddenly retaining more heat. Instead, the oceans – which soak up more than 90 per cent of the extra heat created by global warming – have been absorbing slightly less than usual, thanks to El Niño. The rapid rise in surface temperatures is the result.

If El Niño is followed by a La Niña later this year, the oceans will soak up more heat than usual and surface temperatures will fall (even though the planet as a whole is still warming). So while 2016 is likely to be the warmest year on record, at about 1.1 °C above pre-industrial levels, 2017 and 2018 will probably be cooler.

"If CO_2 levels continue to rise, claims of progress in limiting warming must be taken with a pinch of salt"

Ultimately, though, how fast the world warms depends on the level of CO_2 in the atmosphere. The record rise of over 3 parts per million seen in 2015 is partly due to El Niño-linked drought conditions triggering more wildfires. But it is also part of a long-term trend: the amount of CO_2 added to the atmosphere each year is growing, from an average of under 1 ppm per year in the 1960s to over 2 ppm a year in the past decade.

This means that in the not-too-distant future, surface temperatures will rise consistently above the record-breaking spike we are now seeing. What's more, CO_2 is being released into the atmosphere at faster and faster rates, Ralph Keeling of the Scripps Institution of Oceanography in La Jolla, California, told me last week.

That may come as a surprise if you have been reading about the rise of renewables and the death of coal, and reports of how global emissions actually fell in 2014 and 2015.

But these reports only looked at emissions from energy generation and industry. They don't include emissions from changes in land use, such as deforestation and the loss of peat. If those are included, it is likely that our emissions are still increasing, one of the authors of those studies, Corinne Le Quéré of the University of East Anglia, UK, told me last year. In addition, those studies rely largely on countries' own emissions estimates. And it's not just China's figures that are questionable. The European Union, for example, does not count emissions from wood-pellet burning.

Atmospheric CO_2 is the single most important measure of global warming, because it determines how much hotter the planet will become. As long as it continues to climb ever faster, claims that we are making progress in limiting future warming should be taken with a big pinch of salt. ■

The undocumented killing fields

The US is using the desert as a trap for clandestine migrants crossing from Mexico, says **Jason De León**

How did you get interested in researching migration at the Mexico-US border?
After years of working on archaeological excavations in Mexico, I got to know a lot of working-class Mexicans who were hired to dig ditches. Many had lived in the US, or had tried to migrate. So I started looking at immigration. Migrants leave a lot of stuff in the desert, and so archaeology ended up being one of the many ways that I could approach this phenomenon. But I've had to become an expert in a bunch of approaches, such as forensic science and anthropology.

You have said that the US government uses the Arizona desert as a killing machine. In what way?
By increasing border patrols in populated areas and funnelling migrants into remote areas, they have created a system where the environment does all of the beating back of migrants for them. No public record explicitly states that the goal is to kill border crossers, but the consequence has been to increase fatalities. Every year the bodies of around 300 people are found. There are probably many more whose bodies are either too ravaged to be identified, or who just disappear.

Is this set-up deterring migrants?
That depends who you ask. In 2000, over 700,000 migrants were apprehended in southern Arizona. Today it's down to 330,000 for the entire southern border region. Barack Obama has claimed that increased border security has been deterring illegal migration, but the economic crisis that began in 2008 and the xenophobia that came afterwards have been huge deterrents. Obama was never going to come out and say "our economy being in the toilet is a good way to stop migration", but it was.

Migration from Mexico has also slowed because it has seen more economic prosperity, but you're now seeing more people coming from Central America – particularly Honduras. You also see more US outsourcing of border enforcement to the Mexican government.

Are there parallels between what is happening on the southern border of the US and the refugee crisis in southern Europe?
Too many parallels. The most striking for me is the way in which the Mediterranean echoes the Sonoran desert. You've got people dying en masse, bodies disappearing, and nobody wanting to reclaim them. But refugees fleeing to Europe probably have more in common with Central American migrants to the US than with Mexicans. Migrants from North Africa and the Middle East are crossing multiple borders and facing more intense levels of violence. Central American migrants are suffering extreme brutality at the hands of transnational gangs and immigration officials, and that's just to get as far as the Mexico-US border. Then they have to get across the desert.

What is the Sonoran desert like?
The sun can be blinding, you can experience temperatures as high as 120 °F [49 °C] in the summer and freeze to death in winter, and it is super-rugged and mountainous. It seems like every living thing that has evolved in that environment is there to bite you, scratch you or injure you. Then you have hundreds of square miles where there is nobody around. Even with a compass, it is very hard to navigate and you can get yourself into difficulty.

Why aren't migrants better prepared?
They know the desert is dangerous; that you can be robbed by bandits – or worse. But everybody also hopes for the best. You don't expect that you will be the person who dies. In any case, you can never be fully prepared. You might have good hiking boots, but still hurt your ankle or get bitten by a rattlesnake. You might have a pre-existing medical condition that you didn't know about, and the desert exacerbates it and kills you.

Most migrants don't have big backpacks; they might be carrying a gallon of water and they're in sneakers. Nobody carries a compass

PROFILE
Jason De León is an assistant professor of anthropology at the University of Michigan in Ann Arbor and director of the Undocumented Migrant Project. He is the author of *The Land of Open Graves: Living and dying on the migrant trail* (University of California Press, 2015)

MICHAEL WELLS

or a map because if you get caught with these items you are more likely to be charged as a people smuggler.

It used to be a couple of days' walking and maybe if you were carrying 3 gallons [11 litres] of water, you might be able to hold out until you found a drinking trough for cattle. But as the number of US border checkpoints has increased, folks might now walk for six or seven days. You just can't carry enough water.

You've been using dead pigs dressed as migrants to recreate what happens to those who die in the desert. What did you find out?
We were shocked by the speed at which vultures skeletonised the remains, destroying personal effects and context, and spreading the bones far and wide. Also, migrants have told me that if someone dies in the group, their first instinct is often to cover them up with rocks to protect the body and hope that someone can recover it later. But rocks conduct heat so you end up cooking the

Shining a light on the desperate measures migrants will take

bodies, which attracts scavengers much quicker. If you're trying to conserve a body in the Sonoran desert, probably the worst thing you can do is to cover it with rocks.

What sort of possessions have you recovered from the desert, and what do they tell us?
It can be very personal things such as religious items or photos of children, through to worn-out sneakers, bandages or consumables. Most of it is for survival – either physical or emotional – but you also find some weird stuff, such as hair curlers or cocktail dresses.

As you get further away from the border fence on the US side, at the end of the journey when they're about to get picked up by smugglers, the migrants are told to change their clothes and clean up so it doesn't look like they've just walked for five days. At these sites, called migrant stations, there are football-pitch-sized areas piled with objects. Over 5 million people are estimated to have come through southern Arizona alone since 2000. That number is hard to wrap your head around, but seeing thousands of backpacks and water bottles dumped at migrant stations gives you a sense of the scale of movement.

What do you think is the most common misconception about Mexican migrants?
We overgeneralise about the demographic. Many people have this idea of the noble economic migrant crossing the border to help her family back home. There are lots of those, but there are also many crossing the border who came to the US when they were babies,

> **"If someone dies, the worst thing you can do is cover their body with rocks"**

and were then deported because they were undocumented. I've worked with migrants who don't speak Spanish and they have to cross the desert just to reconnect with the only life they have ever known. There are also a lot of kids crossing the border to reunite with parents who entered the US 10 or 15 years earlier as economic migrants.

What do you make of Donald Trump's hostile comments regarding Mexican migrants?
We're in an election cycle, so I expect some of that: the American public has long history of blaming immigrants for societal ills. It's politically much easier to say nasty things about migrants than it is to have a nuanced conversation.

Do you hope that the US government will alter its policies to improve safety for migrants?
It will take comprehensive reform. Stopgap measures such as periodically granting amnesty to undocumented migrants in the US don't help the folks who are dying in the desert. Nor do such measures address the root causes of this out-migration, such as the impact of US trade relationships on the Mexican economy, or the role that American drug consumers play in fuelling Mexico's narco-wars, from which many migrants are fleeing.

I hope that with the increase in voting power of Latinos in the US, there will be greater opportunity to address these big immigration issues. ■

Interview by Linda Geddes

DESPERATELY SEEKING...

Gravitational waves are finally in the bag, after a century of searching. But that's just one item ticked off a long list. From spawning eels to a black hole's event horizon, here are 11 more things that must be out there somewhere – if only we could find them

1 | BLACK HOLES

2 | INITIAL DARWINIAN ANCESTOR

3 | THE OORT CLOUD

4 | SEAT OF CONSCIOUSNESS

5 | GLUEBALLS

6 | MAGNETORECEPTORS

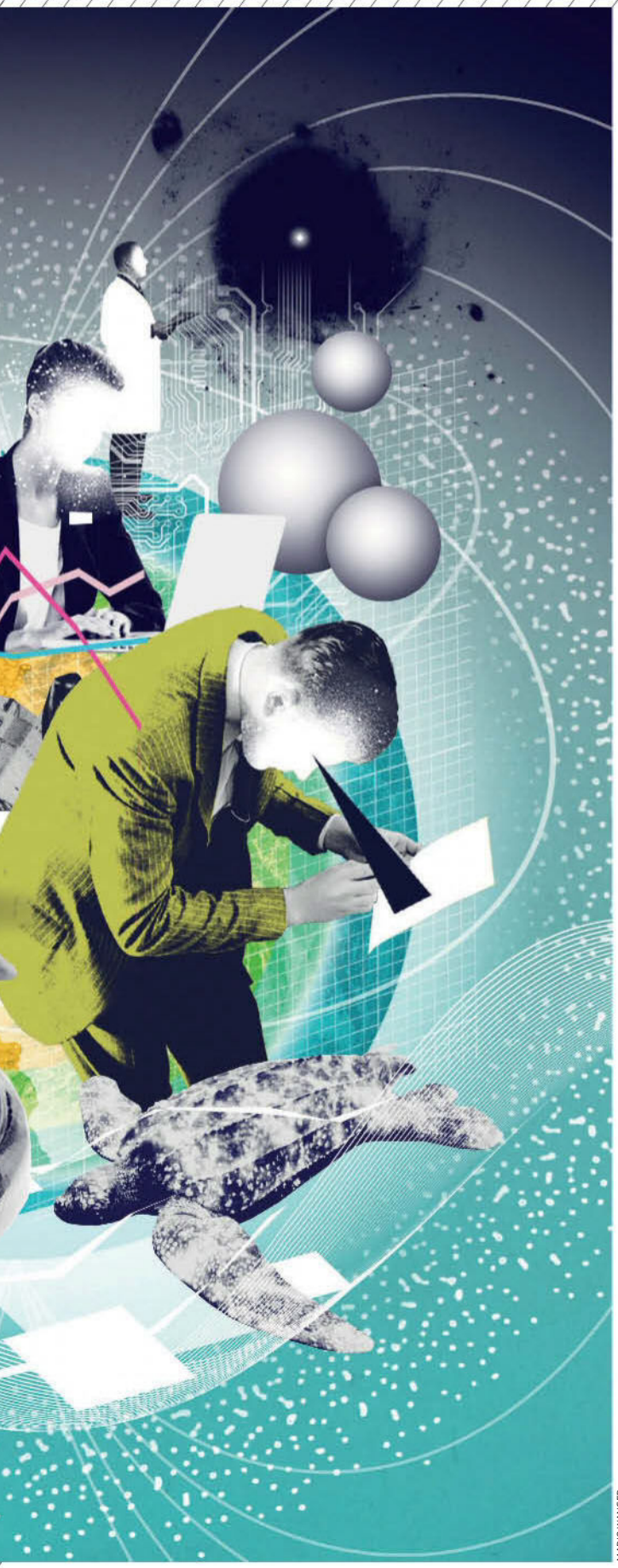
7 | PRIMORDIAL GRAVITATIONAL WAVES

8 | WHALE 52

9 | SPAWNING EELS

10 | THE CHIMP-HUMAN MISSING LINK

11 | INFINITY



MARIO WAGNER

DESPERATELY SEEKING...

1 BLACK HOLES

AT THE heart of the Milky Way lurks an object so extreme it defies description. For good reason – no one can see it.

We're pretty sure something monstrous is there by the way nearby stars crazily whirl around as if orbiting an object 4 million times the mass of our sun. For most physicists, that screams "black hole". "We have a spectacularly good case for this, considering that we can't see it directly," says Daniel Marrone of the University of Arizona.

Black holes are objects so dense and so massive that nothing – not even the light by which we might see them – can escape their gravity. Last month's detection of a gravitational wave apparently rippling out from the merger of two relatively small black holes is the latest circumstantial evidence that they are more than a theoretical pipe-dream. "The LIGO signal looks like a very important test – maybe our best so far – that black holes, or something very similar to them, exist in nature," says Steve Giddings of the University of California, Santa Barbara.

That is a problem. Black holes throw up glaring paradoxes between general relativity and quantum theory, the two bedrocks on which our understanding of physical reality perches. Models indicate that black holes must slowly evaporate to nothing over time, bleeding out an emission known as Hawking radiation. But what happens to the matter and light they swallow, and particularly any information encoded in it? "There doesn't seem to be a fully consistent story of how they can do that without modifying some of our most basic physical principles," says Giddings.

Marrone is involved in a project that aims to help clear things up. The Event Horizon Telescope is a global network of telescopes gearing up for full service in 2017. Its aim is to provide a shadowy image of the supposed black hole at the Milky Way's heart by looking for the glow given out by hot electrons spiralling in its intense magnetic fields. If what it sees is consistent with a black hole, features such as the light distortion will give us clues to the black hole's internal workings – and whether we really are staring at the dark destroyers of theory. **Richard Webb**

DESPERATELY SEEKING...

2 INITIAL DARWINIAN ANCESTOR

IN THE beginning was Ida, the initial Darwinian ancestor – the first material on Earth to transform from inert to, well, ert. Ida begat Luca, the last universal common ancestor, a molecule that stored information as genetic code, and gave rise to all life on Earth.

Ida and Luca live on within us. Our cells all use the same genetic code embodied in DNA, suggesting Luca was itself made of DNA. Except it isn't that simple. All life uses proteins to make DNA and execute its code – but proteins themselves are made from DNA templates. Which came first?

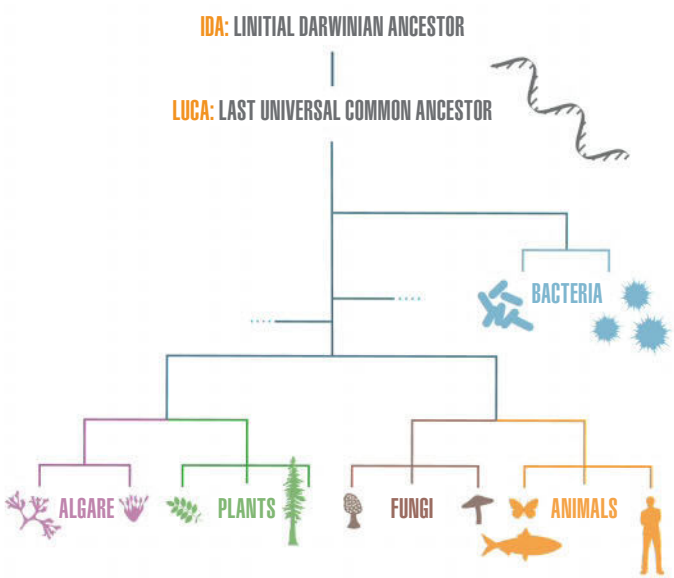
Probably neither. RNA is a close relative of DNA found in all living cells that also carries genetic code and, crucially, can catalyse chemical reactions on its own. The RNA world hypothesis says Luca was born out of an RNA soup that eventually gave rise to DNA and the first cells.

But where did RNA come from? In the 1950s, US chemists Stanley Miller and Harold Urey famously zapped a mixture of gases and water with electricity and ended up with a handful of biotic molecules. Nowadays, though, more nuanced ideas are in vogue. Nick Lane of University College London, for example, thinks that warm vents on the ocean floor provided a soup of methane, minerals and water from which RNA could form. Michael Yarus of the University of Colorado in Boulder, meanwhile, favours a slushy pond whose continual freezing and thawing pushed chemicals together in just the right way.

Intriguingly, more recent experiments trying to coax RNA into existence have shown that when the chemistry is just right, many of life's building blocks seem to form almost spontaneously – increasing the likelihood it happened elsewhere, too. **Catherine Brahic**

THE FIRST ANCESTOR

4 billion years ago, IDA became the first thing to make the transition into life. We don't know what it was made of but scientists are piecing together the story



DESPERATELY SEEKING...

3 THE OORT CLOUD

YOU'LL find it in every astronomy textbook: the spherical cloud of a trillion lumps of rock and ice, most a few kilometres across, that forms the solar system's outermost boundary. The Oort cloud's distant edge could lie some 100,000 times further out from the sun than Earth, more than a third of the way to its nearest stellar neighbour, Proxima Centauri.

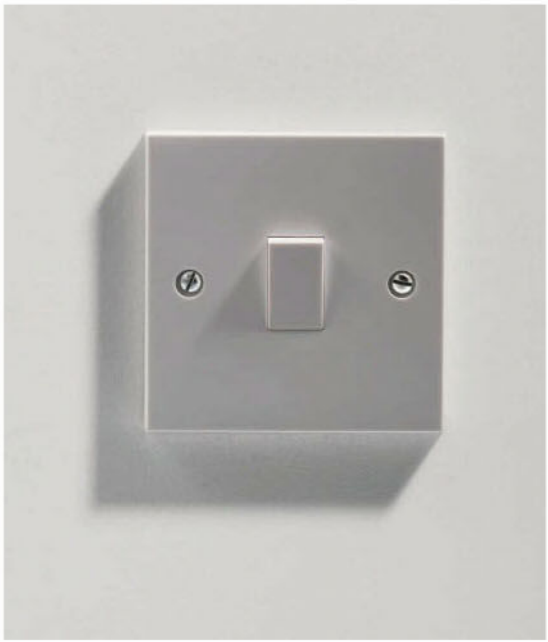
Yet the textbook Oort cloud denizen is far too small for us to observe, and exists in almost total darkness. "From that distance, the sun appears so small that you could completely block it out with the head of a pin," says Brown. The only, rather circumstantial, evidence we have for its existence is the occasional passage of a "long period" comet – presumed to be an Oort cloud object knocked in our direction by the gravitational perturbations of other stars.

Oort cloud objects are thought to be stuff left over from when the planets formed, and their distribution and sizes could help us understand that process. One idea for spotting them involves a technique that exoplanet hunters use: looking for a dip in light as an orbiting planet "transits" across a star's face. In 2009, Eran Ofek of Caltech and Ehud Nakar of Tel-Aviv University in Israel showed that the then newly launched Kepler space telescope could theoretically detect Oort cloud objects a few tens of kilometres across, were they to cross the face of a star.

In practice, a single fleeting dip in starlight could be a detector glitch – and besides, Kepler is pointing above the plane of the solar system, away from the densest concentration of objects. But a constant influx of new comets such as comet ISON, which broke up in December 2013 as it came too close to the sun, is good enough for most astronomers. "We can be quite confident the Oort cloud exists even though we have never actually imaged an object," says Scott Sheppard of the Carnegie Institution for Science in Washington DC. **Stuart Clark**

DESPERATELY SEEKING...

4 SEAT OF CONSCIOUSNESS



TIM MACPHERSON/GETTY

CONSCIOUSNESS feels like an on-off phenomenon: either you're experiencing the world or you're not. But finding the switch that allows our brains to move between these states is tricky. "Consciousness is not something we see, it's something through which we see, which makes it challenging to study," says George Mashour, director of the Center for Consciousness Science at the University of Michigan in Ann Arbor.

One common definition of consciousness is "the thing that abandons us when we fall into a dreamless sleep, and returns when we wake up". But say I anaesthetise you: you may hear my voice, but not respond to it; you may be dreaming and not hear my voice; or you may hear or experience nothing at all. What patterns of brain activity correlate with these levels of conscious experience?

We do know there are certain brain regions that, if damaged or stimulated, cause loss of consciousness. The claustrum – a thin, sheet-like structure buried deep inside the brain – is one of them. But many leading theories that aim to describe consciousness veer away from a single anatomical site being its seat.

Global workspace theory hinges on the idea that information coming in from the outside world competes for attention. We only become conscious of something – a ringing telephone, say – if it outcompetes all else to be broadcast across the brain.

Then there's information integration theory, which suggests that consciousness is the result of data being combined to be more than the sum of its parts. "Unconsciousness doesn't necessarily need to be mediated by brain regions being shut down or extinguished, but rather by a communication breakdown," says Mashour.

A recent study that scanned people's brain activity as they were slowly anaesthetised seems to back up that picture. It might also explain how a drug like ketamine knocks people out: this potent tranquilliser ramps up activity in many of the brain areas that promote wakefulness, but depresses communication between different regions.

Linda Geddes

DESPERATELY SEEKING...

5 GLUEBALLS

IF YOU want a working lightsaber, try one made of glueballs – particles consisting entirely of force. There's just one problem. Although theorists are adamant glueballs must exist, experimentalists are equally adamant we're unlikely ever to prove it. "You can't do an experiment and know they exist," says Frank Close of the University of Oxford.

Glueballs are bundles of gluons, the particles that transmit the strong nuclear force between quarks, sticking them together into things like protons and neutrons within the atomic nucleus. Gluons have an odd quirk: they themselves carry strong-force charge, meaning they can also stick to each other.

Simulations of a world chock-full with gluons suggest that an energy of around 1500 megaelectronvolts (MeV), or about one-and-a-half times the energy contained in a proton, should be enough to stick a load of them together into a glueball. In 1995, Close and fellow theorist Claude Amsler of the University of Zurich in Switzerland showed that two particle "resonances" with energies of 1370 and 1500 MeV, which had just been discovered at CERN, might fit that bill. They have since been joined by a third candidate at 1710 MeV.

But the strong force is notoriously hard to do calculations with, and for simplicity's sake glueball simulations tend to assume a world with a whole load of gluons and not much else. "That is not what the real universe is like," says Close. "If things can mix together, they will."

So in the real universe, by the time you measure a glueball state, quarks will have also begun to stick to it like burrs on a sock, making it impossible to prove it ever was a pure glueball. The explanation for the three suggestive resonances is most probably a substantial pot of glue contaminated by varying amounts of different quarks, says Close – and we'll probably have to content ourselves with that ambiguity for now. "If nature was kind, something might stick out," he says. "But I'm not optimistic." You might be better off banking on a conventional light-based lightsaber.

Richard Webb

DESPERATELY SEEKING...

6 MAGNETORECEPTORS

AS THE hatchlings emerged from their eggs on a Florida beach, Ken Lohmann lay in wait. He scooped up 32 of the tiny turtles and whisked them off to a dark room and a water tank surrounded by electromagnetic coils. One by one, he fitted his captives with Lycra harnesses – then flipped on the magnets.

Lohmann's seminal 1991 experiment confirmed what many suspected: turtles can sense magnetic fields, switching their swimming direction in response to it. How else, other than by sensing Earth's field, would they be able to navigate in the open ocean? Species as varied as mice, lobsters and fruit flies seem to have similar abilities – yet no one can find the magnetoreceptor, the biological machinery that allows them to do it.

On the brain side, we do have clues. In 2009, neuroscientists David Dickman and Le-Qing Wu imaged pigeons' brains while varying the angle of a magnetic field. They observed 53 pairs of neurons changing their firing as the angle changed. But where were they getting the signals from? "There is no obvious organ, like an ear or a nose," says Peter Hore of the University of Oxford.

One suspect is cryptochrome, a protein found in the eyes of many animals including birds and trout. It is known to produce chemical fragments called radicals in a way that depends on magnetic fields, and fruit flies engineered to lack the gene for cryptochrome no longer respond to magnets.

But that can't be the full story. For a start, our eyes have cryptochrome too, and we can't sense magnetism. And we don't know how the radicals make a signal the brain can interpret.

Last year, Xie Can of Peking University found a magnetically sensitive protein that can control muscle and nerve cells. Could this be a new candidate? "I doubt it is completely wrong," says Hore, who says he saw the protein particles in the lab spinning around as a magnet was waved nearby. But this is one area where we're all still a little lost.

Joshua Howgego

DESPERATELY SEEKING...

7 PRIMORDIAL GRAVITATIONAL WAVES

WHEN the champagne has been on ice for nigh on a century, the corks pop all the louder. So it was last month, when physicists at the Advanced LIGO experiment announced the detection of a gravitational wave passing through Earth. That was indeed a triumph – but what about the ones that got away?

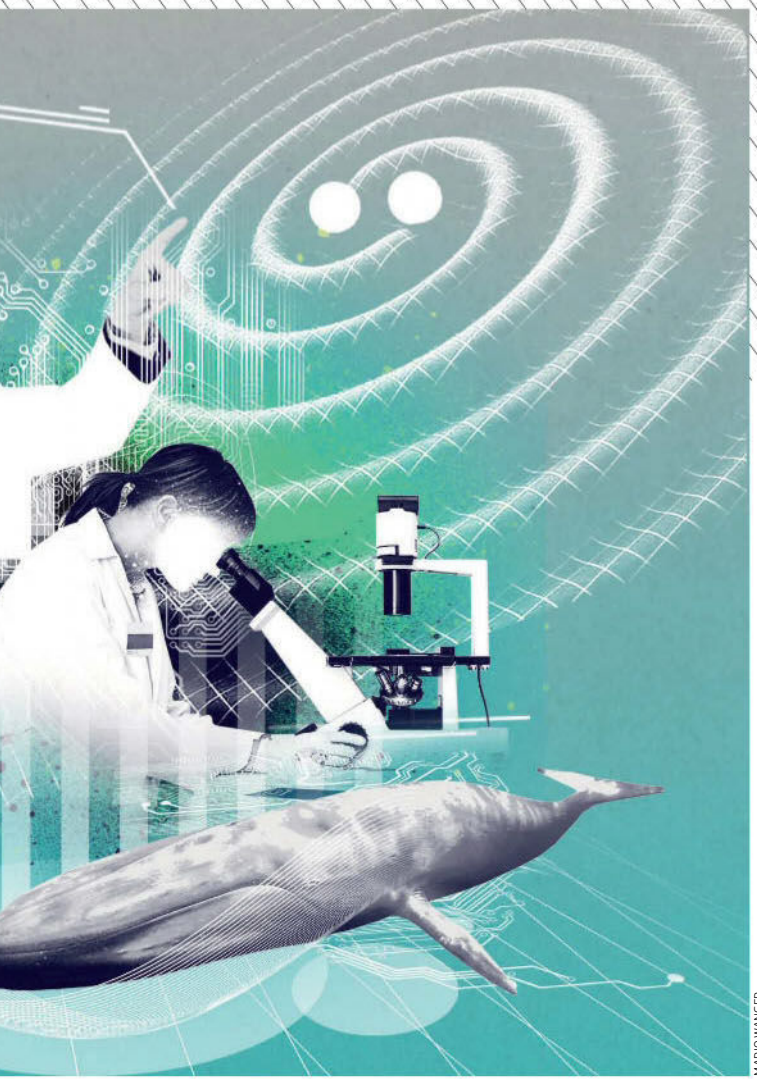
Gravitational waves are ripples in the fabric of the universe created when massive bodies move and accelerate in each other's gravitational fields. Advanced LIGO's catch apparently emanated from two black holes, each around 30 times the mass of our sun, falling into each other's arms 1.3 billion light years away.

But mergers of bigger black holes, such as the supermassive ones thought to form the centres of mature galaxies (see page 33), will emit gravitational waves with much longer wavelengths. "LIGO will not be sensitive to them," says astronomer Avi Loeb of Harvard University. "We need different observatories."

A planned space-based detector known as eLISA should be sensitive to these waves, and a test probe for this project, LISA Pathfinder, blasted off last December. But even eLISA won't detect the most eagerly sought-after gravitational waves of all. Our most cogent, but untested, model of the universe's birth in the big bang suggests space-time underwent a period of breakneck expansion known as inflation, sending out extremely low frequency gravitational waves with wavelengths perhaps as big as the visible universe.

No detector yet conceived is large enough to sense these "primordial" gravitational waves (see diagram, right), so evidence is likely to be indirect. Back in March 2014, researchers at the BICEP2 experiment at the South Pole thought they had found it in patterns of light polarisation in the cosmic microwave background, the relic radiation of the big bang. That proved to be a false alarm – but last month's detection provides a fresh spur to think how we might detect these echoes of creation, says Loeb. "It opens a new window into the universe."

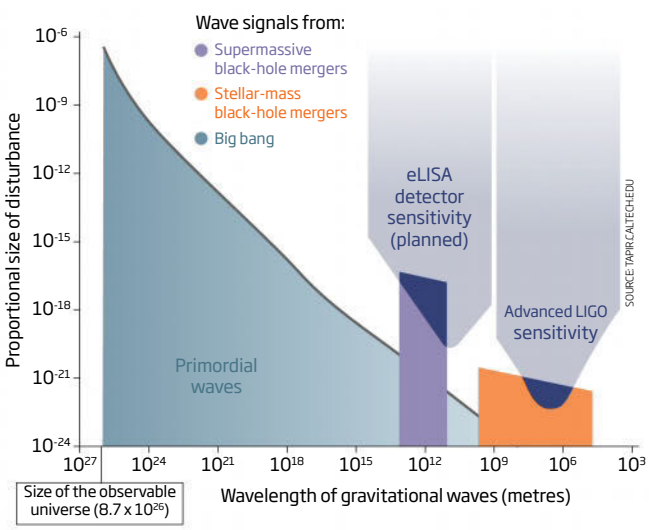
Richard Webb



MARIO WANGER

WAVE GOODBYE

The Advanced LIGO and eLISA detectors have the sensitivity to spot gravitational wave signals from black holes combining – but "primordial" waves created in the big bang have far bigger wavelengths



8 DESPERATELY SEEKING . . . WHALE 52

IT HAS become famous as the loneliest whale in the world. It swims through the Pacific calling out for others, but never gets an answer. Whale 52 is the only one of its kind, with a unique song all of its own – or at least, that's the story.

In fact, he – male whales do the singing, so it almost certainly is a he – may not be alone. "There is probably more than one," says John Hildebrand of the Scripps Whale Acoustic Lab in San Diego, California, whose team has recorded the distinctive call on widely separated hydrophones within a few hours.

When Whale 52's unusual call was first heard by biologist Bill Watkins in 1989, he sang at 52 kilohertz, but that has gradually deepened to 47 kHz. His seasonal movements resemble those of blue whales, and Watkins proposed he is a hybrid between a blue and a fin whale. Hildebrand thinks he is the offspring of a blue whale mother and fin whale father. Fin whales are drummers, singing in short pulses, he says, while blue whales are opera singers, holding the note. Whale 52's song is a bit of a mix. "Culturally it's like a blue whale's," Hildebrand says.

Last year, the preliminary expedition of a Kickstarter-funded project to film Whale 52 drew a blank. The acoustic lab's network of hydrophones is not connected to shore, and by the time the recordings have been retrieved and analysed, the animals they detect are long gone. A live monitoring network in the Santa Barbara channel off California proposed to help stop blue whales being killed by ships would greatly increase the chances of finding the mysterious animal – or animals.

If there is only one, is it fair to describe him as lonely? Pop star Taylor Swift raised this question in a 2014 interview. "Everybody feels so sorry for this whale – but what if this whale is having a great time?" she asked.

Male whales are thought to sing mainly to attract mates, but mating is not about companionship for whales. That said, Whale 52 could well be frustrated by his lack of success. Perhaps he is actually the horniest whale in the world.

Michael Le Page

9 DESPERATELY SEEKING... SPAWNING EELS

ARISTOTLE thought they came from earthworms. Others thought they spontaneously generated. To this day, no one really knows where eels are made.

Yet there are eels – lots of them.

This is the story as currently told: American and European eels swim thousands of kilometres to spawn in the Sargasso Sea, a vast, self-contained gyre of water in the western Atlantic near Bermuda noted for warm, salty water. The newly spawned elvers then wiggle and swim their way back.

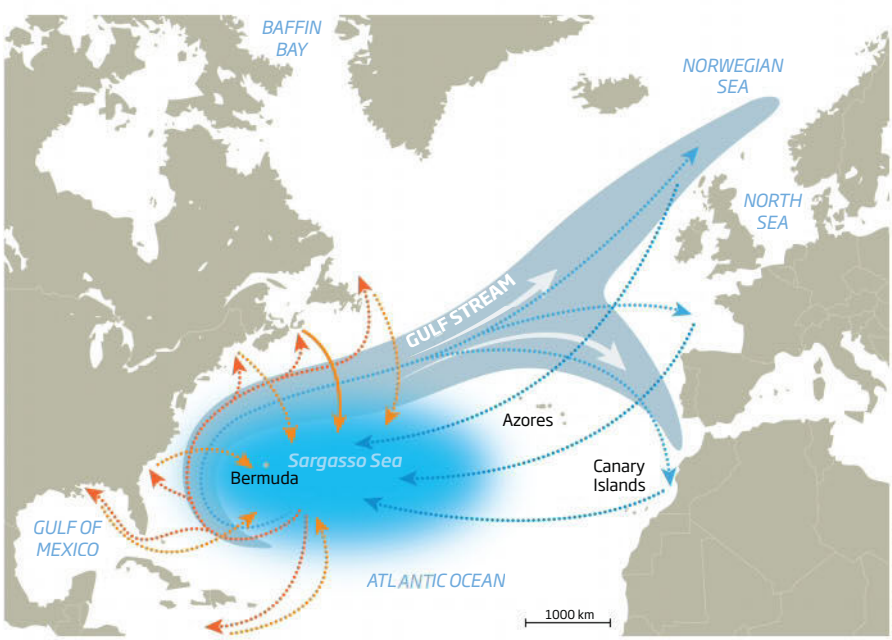
But this extraordinary mission is a matter entirely of inference, first drawn by Danish researcher Johannes Schmidt after a series of expeditions to the Sargasso a century ago. No adult eels have ever been caught spawning there. Until recently, no adult eel had even been seen en route. "Their migration remains a complete mystery," says Melanie Beguer-Pon of Laval University in Quebec. Yet there must be something to the Sargasso tale, says Håkan Wickström of the Institute of Freshwater Research in Drottningholm, Sweden. "They must spawn there because the tiniest eel larvae are found there," he says.

This is a matter of more than academic curiosity. European and American eels have been in precipitous decline in recent decades, and are now listed as endangered. Pollution, dams that block rivers, fishing and ocean warming have all been blamed – although that doesn't explain large numbers of eels returning to European rivers since 2009.

In the latest attempt to crack the spawning mystery, scientists on both sides of the Atlantic began to equip mature "silver" eels with tiny microwave trackers that pop off and float to the surface after six months, transmitting their data to passing satellites. Initially there was not a peep – until in 2014, one Nova Scotian eel was pinpointed 2400 kilometres away at the northern limit of the Sargasso (see map, right). As evidence goes, it's not much. No European eels tagged in Sweden have successfully sent back any data from beyond the Azores, less than halfway to the Sargasso. And until scientists track even one eel to the moment of spawning, any claim to understand these slippery customers will remain a fisherman's tale. **Fred Pearce**

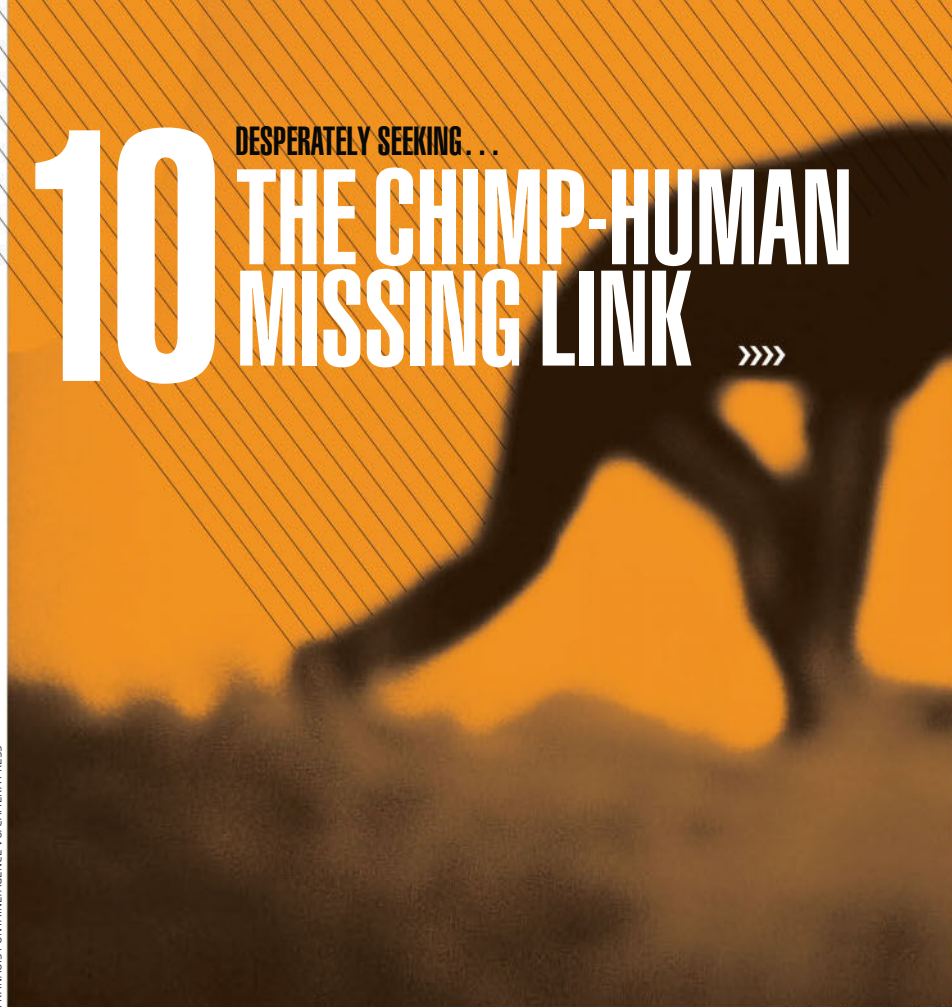
MYSTERY MIGRATION

It is presumed that adult American and European eels migrate to the Sargasso Sea in the north Atlantic to breed, then their growing spawn use the Gulf Stream to float and swim back (dotted lines). However, only one American individual has been tracked going in remotely the right direction (solid line)



SOURCE: SAMSA, VERISPAN

10 DESPERATELY SEEKING... THE CHIMP-HUMAN MISSING LINK



FRANÇOIS FONTAINE/AGENCE VU/CAMERA PRESS

DESPERATELY SEEKING . . .

11 INFINITY

RAYMOND DEPARDON/MAGNUM PHOTOS

ASTONISHING fossils are found every year, but we still haven't dug up the original "missing link". Where is this last common ancestor of humans and chimps? "I would love to know," says Sergio Almécija of the George Washington University in Washington DC. "That question is keeping me awake at night."

We have a pretty good idea when and where this creature was dragging its knuckles, or swinging through the trees: in Africa, around 7 million years ago. But fossil evidence will be very, very hard to find. After decades of searching we have a reasonably rich collection of fossils of our hominin ancestors stretching back 4 million years, but barely a couple of shoe boxes full from earlier lineages.

There are many reasons for this, says Nathan Young at the University of California, San Francisco. "Hominins are comparatively more abundant both because they began living in regions that are more likely to fossilise, like lake shores and caves, and there are a lot more people actively searching for them."

It would help if we knew precisely what we are looking for. Comparing early hominin fossils, ape fossils and large numbers of living primates, Almécija thinks our forebear had hands and thigh bones that were more human-like than chimp-like. It probably still walked on all fours, he says, but not in the way that chimps do. Young and his colleagues have used a broadly similar approach to conclude the animal's shoulders were chimp-like – suggesting it swung through the trees like chimps do today.

One hope is that comparing the genomes of living apes might provide evidence everyone can agree on. But this assumes there even was a single ancestor. Genetic studies so far hint that some of our chromosomes diverged from the chimp versions much earlier than others, possibly indicating that primate-like populations separated for a time, came back together and hybridised, and then split permanently – all of this over the course of millions of years. Try picking a single ancestor out of that tangled mess. Colin Barras

WITH infinity, we made a monster. Our minds demand that it should exist – only to rapidly melt at the consequences of a concept that is, by definition, too big for our brains.

The pleasure and the pain start when we write out the whole numbers: 1,2,3,4... There is no obvious end point to this sequence – so we call it infinite. But then take the real numbers: the whole numbers plus all the rational and irrational numbers in between (1.5, π, the square root of 2 and so on). There are also infinitely many of these – except you can show that this infinity is a bigger number. "In fact there is an infinite set of infinities and however far you go, you can always get to a bigger one," says mathematician Ian Stewart of the University of Warwick, UK.

Very little of mathematics works smoothly without manipulating the infinite and its obverse, the infinitesimal. Defining a perfect circle requires the infinite digits of π; calculating smooth motions requires chopping time into infinitesimally small chunks (see diagram, below).

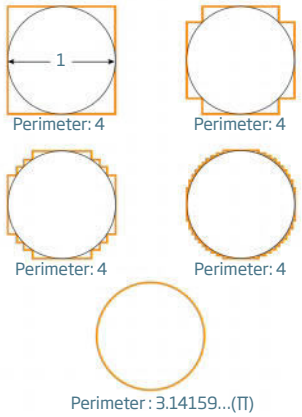
But is any of this actually real? Take those whole numbers: you could never actually write all of them out. "You'd snuff it before you did," says Stewart. Even if someone else took over, a finite universe would eventually run out of information to encode them with.

Such practical considerations mean physicists generally see infinity as something to be avoided – although that's often easier said than done. The big bang theory, for instance, suggests the universe began as a "singularity" of infinite density and temperature, but the mathematical description breaks down when you pack too much gravity in too small a space. Replacements such as string theory that aim to get us closer often conjure up an infinitude of universes, making it impossible to work out why ours looks as it does.

A small minority of physicists and mathematicians eschews infinity completely, claiming it has no place in a finite universe. That is a step too far for most people, says Stewart, but it's probably a concept we don't want to stare at too hard. "Infinity is incredibly useful, but only if you can make sure it doesn't blow up in your face," he says. **Richard Webb**

INFINITE RECTANGLES

When approximating a circle with a combination of rectangles, the total perimeter of the rectangles is always four times the circle's diameter – unless you use infinitely many



Written in blood

We might spot cancer earlier if we can learn to read the clues it leaves in the bloodstream, finds **Linda Geddes**

CASEY LIM* was 11 weeks pregnant when she gave a blood sample to test for Down's syndrome. It revealed multiple abnormalities in fragments of DNA circulating in her blood. Further analysis showed that the mutant DNA wasn't from the fetus but from Lim's own white blood cells. A form of blood cancer called follicular lymphoma, which she had battled two-and-a-half years earlier, had stealthily returned.

Lim was one of the lucky ones. All too often, cancers are caught only after they have spread and mutated into subtly different forms. This ability to evolve and resist our best treatments is what makes cancer such a formidable foe. One way to root out its weaknesses is to repeatedly remove chunks of tumour for analysis, but that is invasive and often risky.

So how do we keep an eye on a cancer's ominous transformations, figure out the best way to treat it and check that it is not stealthily growing back? The answer could be written in blood. A test based on tiny bits of DNA released into the circulation by cancer cells might even give doctors a way to catch the disease earlier.

"The best time to treat cancers is when there are very few cancer cells, when there are fewer chances for them to develop resistance," says Bert Vogelstein, director of the Ludwig Center for Cancer Genetics and Therapeutics at Johns Hopkins University in Baltimore, Maryland.

Vogelstein's lab is one of several dedicated to developing a blood test to spot cancer early and follow its every move. It's a laudable ambition. To make these "liquid biopsies" reliable enough to be useful, however, they will have to figure out how to track down and decode the faint, potentially misleading traces tumours leave in the blood.

All cells, including cancer cells, release DNA into the blood when they die. Researchers have known for some time that it is possible to detect this free-floating DNA in the circulation, and that people with cancer have more of it than healthy people. In the earliest stages of the disease, the number of fragments deriving from cancer cells – known as circulating tumour DNA, or ctDNA – is vanishingly small. But as the tumour grows, so does the quantity of DNA fragments.

In the late 1990s, Dennis Lo, now at the Chinese University of Hong Kong, was struck by the opportunities this offered. His main interest was in developing non-invasive ways to detect fetal abnormalities. Eventually, he came up with a way to detect fetal DNA in the blood plasma of the mother, and within 10 years he'd devised a blood test for Down's syndrome. He also set his sights on cancer.

Tumour DNA is rarer than fetal DNA, but as sequencing technology has improved, so has our ability to catch it and read what it can tell us about the cancer. The simplest strategy is to search for genetic mutations you already know about from a biopsy of the tumour.

In 2007, Vogelstein's group used this approach to monitor tumours in 18 people with bowel cancer. Their technique took advantage of the fact that bits of single-stranded DNA stick to other bits with the corresponding sequence of nucleotides. Once they had generated multiple copies of all the DNA fragments in the blood samples, using a process called PCR, they added tiny magnetic beads covered with many copies of a sequence mirroring the target mutation. Any bits of mutant DNA that fastened to these beads were then pulled out and counted, giving an estimate of its concentration in the blood.

After these patients had their tumours removed surgically, a blood test was still able to detect ctDNA in most of them, even though quantities had fallen dramatically – and all of those people eventually saw their cancer return. In the handful of patients with no detectable tumour DNA in their blood, the cancer has not come back. This suggests that the quantity of ctDNA in blood reflects tumour size, and that liquid biopsies could be a useful monitoring tool.

Since then, Vogelstein has shown that almost every type of cancer sheds fragments of DNA into the blood. In 2014, his group announced the detection of ctDNA in the blood of more than 75 per cent of a group of 640 people with a range of cancers, such as advanced pancreatic, ovarian, colorectal and breast cancer. Brain, renal and prostate cancer seemed to shed fewer DNA fragments – although they could still be detected in half of those whose disease was at an advanced stage (*Science Translational Medicine*, vol 6, p 224).

Shards of DNA can also be used to predict whether those with cancer will respond to drugs. Last year, for instance, the European Medicines Agency approved a blood test that indicates whether people with non-small-cell lung cancer will respond to gefitinib, a drug which works against cells carrying a particular mutation. This is a big deal because taking a lung biopsy is difficult, meaning doctors often don't get enough tissue to understand the tumour. "That's a perfect situation for a liquid biopsy," says Vogelstein.

You also want to look at how the cancer ›

In England, 46 per cent of cancers are diagnosed at an advanced stage

Cancer Research UK, 2014

SCIENCE PHOTO LIBRARY

*not her real name

WHEN IS A CANCER NOT A CANCER?

The sooner you catch cancer, the easier it is to treat. But early screening methods have fallen from favour in recent years because they can identify healthy people as potentially having cancer. This is not only distressing, but can result in unnecessary medical procedures that carry their own risks.

Take PSA screening. It looks at raised levels in the blood of a protein called prostate-specific antigen, which can indicate prostate cancer. But men with high PSA counts don't always have the disease and men with low counts sometimes do. That's because PSA is produced by all cells in the prostate, not just cancerous ones. PSA levels tend to be raised in prostate cancer because the tumour has generated more cells, but can also be raised if you have an infection.

Blood tests for the genetic signatures of cancer, now being developed, sidestep such problems because the mutations associated with cancer are unique to the disease. And tests that look for circulating tumour DNA (see main story) will not flag up benign tumours as they don't shed this type of DNA.

That's not to say screening for cancer using DNA or other debris from tumour cells won't create problems of their own. Say you detect cancer DNA in the bloodstream when the tumour is too small to be seen with the best imaging techniques: you may not be able to identify its location, or determine whether it will prove life-threatening.

You could test again in six months to see if the quantity of signature DNA has increased, indicating a growing tumour. But in the meantime, the initial detection will almost certainly spook the person being screened and may lead to unnecessary treatments. "Our society is not very comfortable with knowledge that there's a very high likelihood of cancer somewhere in the body," says Bert Vogelstein at Johns Hopkins University in Baltimore.

For cancer blood tests to be accepted, then, we might have to change our outlook. Doctors will certainly have to think carefully about how to use such a test. "We're now entering a world where you can start getting information from blood that you could never get before," says Daniel Haber, director of the Massachusetts General Hospital Cancer Center in Boston. "We're going to face exactly the same questions [as we did with PSA testing]: who do you test, what does a positive test mean, how do you interpret it?"

evolves to evade treatment. One of cancer's grim ironies is that the better the drug you throw at it, the more you prime it to resist. "Some of the targeted drugs against cancer are so dramatically effective that they select for major changes in the cancer biology," says Daniel Haber, director of the Massachusetts General Hospital Cancer Center in Boston. "This is a great rationale for monitoring cancers through the blood continuously."

Vanishingly rare

At the Institute for Cancer Research in London, Delila Tandefelt and her colleagues have done just this, taking monthly blood samples from men with advanced prostate cancer. Their aim was to look for changes in a known genetic sequence that predict how likely it is that the patient will respond to the drug abiraterone. Sure enough, the researchers spotted the emergence of resistance to the drug four months earlier than with standard clinical assessments, such as CT scans. "Instead of giving them abiraterone, which they probably won't benefit from, we can give them an alternative treatment," says Tandefelt.

Impressive as these early applications of liquid biopsies are, they are merely the low-hanging fruit. "A major interest all along has been to develop a diagnostic test that could be applied to asymptomatic people," says Vogelstein. Considering that even in wealthy countries nearly half of cancers are diagnosed at a late stage, a blood test that could detect the disease early could save millions of lives.

In 2014, just 12.8 per cent of the US National Cancer Institute's research budget was spent on detection and diagnosis

NCI, 2014

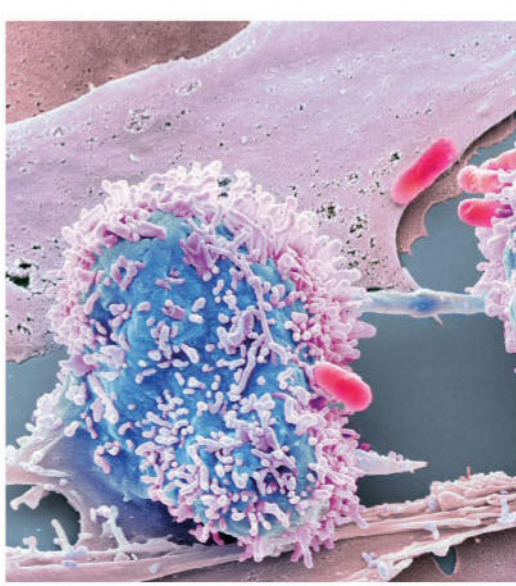
The devil is in deciding what to look for. If you already have a sample of the cancer tissue, it's relatively easy to probe the blood for its signature mutations. If not, you need to look for all kinds of mutations. What's more, ctDNA is exceedingly rare in the early stages of cancer. "The problem with blood is there's a lot of stuff in it, and the material from cancer is relatively small," says Haber.

Another approach is to sequence all of the circulating DNA in the blood and then look for differences in the ratios of fragments from various regions of chromosomes, the thread-like structures in cells that contain most of your DNA. This might flag up whether some areas have become duplicated, deleted or rearranged – all classic hallmarks of cancer.

In 2012, Vogelstein's group sequenced DNA from the blood of 10 people with late-stage breast or colorectal cancer and 10 healthy people, searching for these structural alterations. They detected abnormalities in all of the cancer patients, but none of the healthy people. However, it is not certain that the technique would work in cancer's early stages, when there are fewer bits of rogue DNA to analyse. Nor do we know if it would detect every significant alteration, or distinguish between pernicious and harmless changes.

The caveats don't end there. Even a test that is sensitive and broad enough to detect very early cancers runs the risk of generating false positives (see "When is a cancer not a cancer?", left) unless you can confirm the result with some sort of imaging technique.

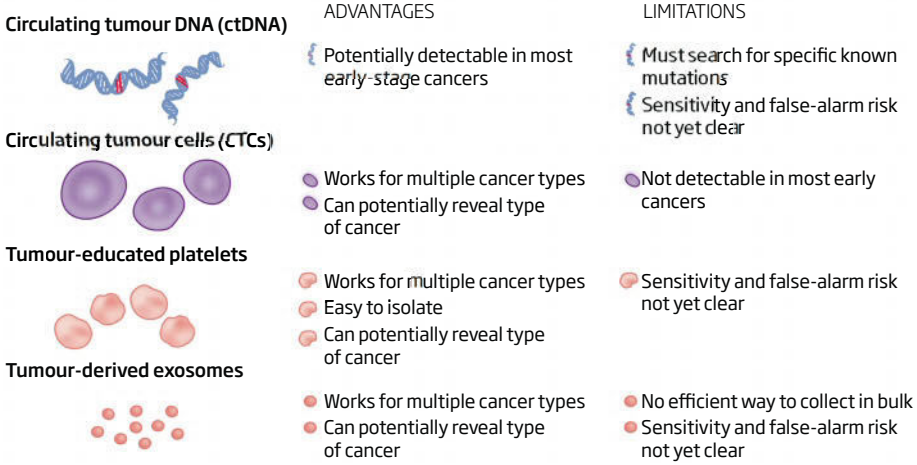
And assuming you can detect the genetic signature of a cancer, how would you know



STEVE GSCHMEISSNER/SPL/GETTY

Liquid assets

Tumours shed bits of themselves into the blood. These could form the basis of a test to detect cancer early

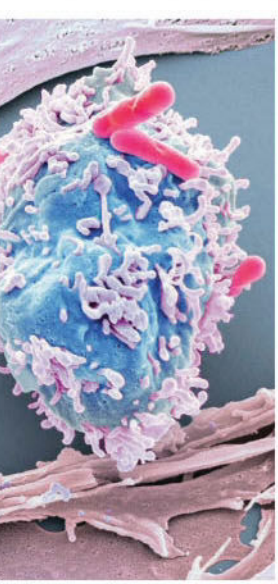


In the US, only 15 per cent of lung cancers are caught before the disease has spread elsewhere

American Cancer Society, 2014

which part of the body is affected? Some mutations provide a clue: a mutant *KRAS* gene, for instance, is usually associated with lung, colon or pancreatic cancer. Other mutations, such as in the *p53* gene, could be associated with just about any form of the disease.

The good news is that ctDNA isn't the only tumour-derived material in the blood. There are also circulating tumour cells. They are harder to spot than ctDNA as there is typically just one CTC for every billion blood cells, and they may not get into the bloodstream until later in the cancer's development. It is possible to catch them, though, either by separating them by size from smaller white blood cells or fishing them out using magnetically tagged antibodies that latch onto specific cell-surface markers. And CTCs can reveal far more than ctDNA.



Tumours release all kinds of signals into the bloodstream

With CTCs you can scrutinise not only the tumour's DNA but also its RNA – the chemical go-between that helps translate genetic code into proteins. This extra information ups the chances of pinpointing the site of the cancer and offer clues about the genetic reshuffling that might be driving it, such as translocations – where a chunk of DNA has jumped to a different location in the chromosome, potentially altering the expression of genes nearby. Such insights could be vital in diagnosing prostate cancer, for example, which is more often characterised by translocations than a particular mutation.

Another option is to focus on platelets, the sticky discs in blood which promote wound healing by forming clots. As they circulate, platelets accumulate fragments of RNA from the tissues they come into contact with, including cancer cells. By sequencing this RNA, you can learn about tumours in their earliest incarnations, long before CTCs can be detected. Indeed, Thomas Wurdinger at the VU University Medical Center in Amsterdam, and his colleagues recently used platelet RNA to distinguish cancer patients from healthy people with 96 per cent accuracy. They were also able identify the location of the primary tumour in 71 per cent of cases.

Then there are exosomes, tiny secreted packages containing DNA, RNA and proteins. Last year, researchers at the University of Texas MD Cancer Center in Houston were able to differentiate people with pancreatic cancer from healthy people by searching the blood for exosomes carrying a particular protein.

So ctDNA is not the only game in town. It remains a strong contender, though, and methods for reading abnormal DNA fragments are improving all the time. Lo's group, for instance, has developed a novel technique that looks at methylation – where chemical tags known as methyl groups stick to DNA, often altering gene expression. This allows them to trace ctDNA back to its tissue of origin by comparing its methylation pattern against a database of tissue types.

Casey Lim's cancer was spotted because she gave a blood sample to Lo, who was testing this new approach. It traced the abnormal DNA to her immune cells. "Chemotherapy had to be commenced immediately," says Lo. "Given the early stage of pregnancy, the patient opted for a termination, received the chemotherapy and is currently well."

Lo and his colleagues also recently discovered that DNA fragments from tumours tend to be significantly shorter or longer, on average, than those from healthy cells. They showed that the mere presence of these short or long fragments is enough to distinguish people with liver cancer from healthy people, even at a very early stage of the disease.

As the sensitivity of such tests improves, they could start to make a real difference. Vogelstein points out that on average it takes 20 to 30 years for a cancer to progress from initial mutations to a full-blown metastatic disease. That is a big window in which to intervene, one that we are failing to exploit.

"In the US this year there will be about 55,000 people who die from colorectal cancer, and every one of them will only have died because their cancers were not detected in the first 27 years or so," says Vogelstein. So even if they can't reliably detect cancer in its earliest stages, blood-based biopsies could still give us a valuable head start. ■

Linda Geddes is a *New Scientist* consultant based in Bristol, UK. Links to studies and statistics appear in the online version of this article at bit.ly/NSbloodtest

Sounds like a theory

Smart analogies are no use when it comes to tough physics, finds **Michael Brooks**

The Jazz of Physics: The secret link between music and the structure of the universe by Stephon Alexander, Basic Books, $27.50; *Bananaworld: Quantum mechanics for primates* by Jeffrey Bub, Oxford University Press, £25; *Why String Theory?* by Joseph Conlon, CRC Press, £19.99

IF ONLY intuition could get us where we want to go. In the late 1960s, John Coltrane drew a mandala that connected five musical notes in patterns, including a five-pointed star. Inspired by Einstein's work to unify physics in a single theory, the jazz musician's diagram was an attempt to understand the connections between musical scales. Its form is so beautiful that it is tempting to wonder if there is a link between music and physics stretching all the way to a theory of everything.

That is unlikely, however. In his marvellous *The Jazz of Physics,* physicist and musician Stephon Alexander explains that analogies can seed new insights, but are no substitute for deep understanding of the thing itself. An intuitive analogy between music and physics is "part of the journey", Alexander says, but during this long journey, the scenery will change. Not having an adequate analogy – and needing the clarity of rigorous calculations – is also part of the journey.

Ultimately, a physicist's universe is mathematical: you can't get at it through intuition alone. Mathematics, Alexander notes, "is like a new sense, beyond our physical senses, that enables us to comprehend things that we cannot understand solely through our… perceptions or intuitions".

It is a theme repeated in the extraordinary *Bananaworld*, in which Jeffrey Bub employs an innovative way of explaining the intricacies of quantum physics. He takes the state of a banana (peeled or unpeeled) and its flavour (ordinary or intense) as a more intuitive analogy for the state and quantum properties of particles. But Bub, too, is forced to lament intuition's shortcomings: wave descriptions in quantum theory are "intuitively appealing", but that appeal is "misleading".

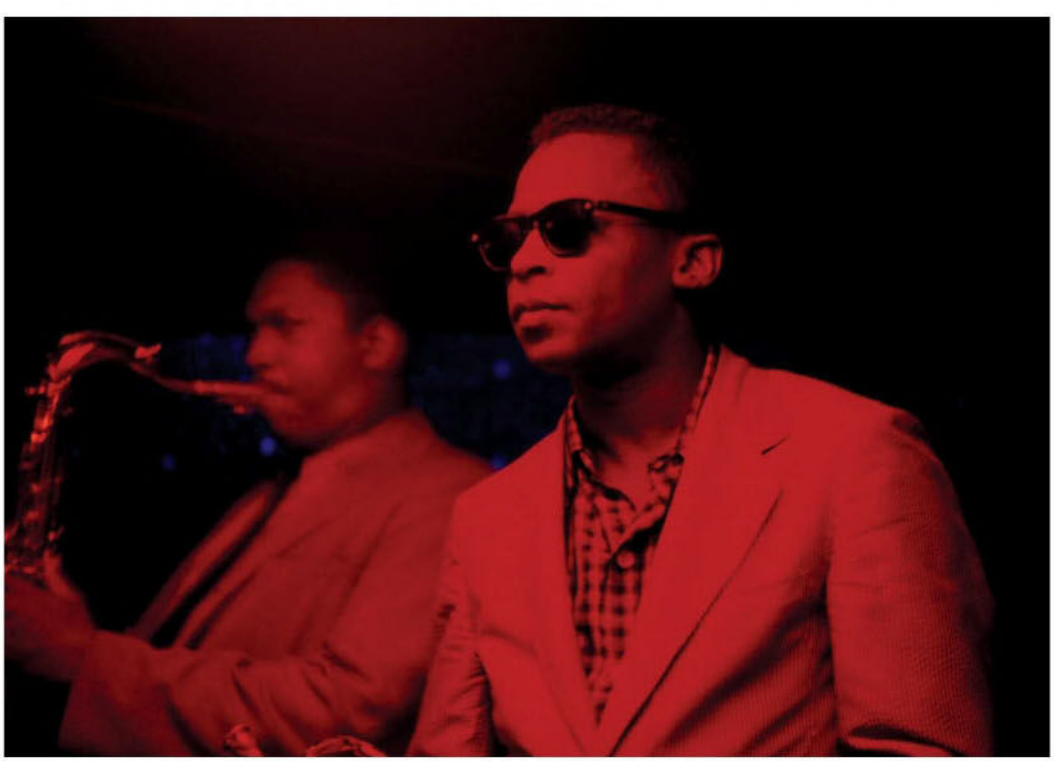
At school, we learn of electrons orbiting atoms, following Niels Bohr's model, and we talk about fitting a certain number of whole waves into that orbital path, which gives us quantum structure. This is, however, an entirely erroneous way to think. The wave associated with a quantum system "evolves in an abstract, multidimensional representation space, not real physical space", Bub points out. As Schrödinger said, using a wave to talk of quantum reality is "merely an adequate mathematical description of what happens".

Despair, non-experts: it will always come back to the maths. "Mathematics is the light that illuminates physics, and mathematics-free physics has marked similarities to alcohol-free wine," says Joseph Conlon in *Why String Theory?* This is why he says that his book, written for a lay audience, inevitably contains "only a shadow of the argument I would like to make".

"Physicists must show they can recalibrate their ideas, or non-experts may spend taxes on other things"

Conlon delivers his argument, diluted as it is, with panache and humour. Chapter seven is only nine words long: "There is no direct experimental evidence for string theory." And a section called "The world is described by quantum mechanics" is followed by a section called "The world really, honestly, truly is described by quantum mechanics."

Conlon recognises why string theory is so controversial: many smart people are justifiably frustrated by the dislocation from testable reality, he says. His



MARVIN KONER/CORBIS

Einstein's work held some mojo for John Coltrane (left)

response is that, for all their good faith, most sceptics simply can't appreciate what maths brings to the table. "The greater the ability to calculate in theoretical physics, the clearer the appeal of string theory becomes," he says. "Nature really is written in the language of mathematics, and many results that flow easily using it are hard to justify in any other way."

The lack of experimentation can cause string theory to be derided as "merely philosophy". But we should be cautious about the subtext of such an accusation. Bub is a philosopher of physics, and the subject has never been more in need of input such as his: thoughtful, humble, informative. This is why, for me, *Bananaworld* should be mandatory reading for anyone studying or working in quantum or theoretical physics.

We live in dangerous times for theoretical physics. Experiments cannot distinguish between interpretations of quantum theory, verify which of the "final" theories is correct, or check the assumptions used to create cosmology's narrative of our universe's history.

Self-regulation and self-awareness are now vital. Perhaps theoretical physicists would benefit from philosophy retreats, where they could recalibrate their thinking and shed the pride and prejudice acquired in partisan departments. It is important that they show they can, otherwise the intuition of non-experts may lead them to spend taxes on things that feel more comfortable.

Even more important is that philosophy (and history) can fuel new ideas. Viewing theoretical physics and mathematics through other lenses may help us make headway. How else to grasp how primitive our understanding of reality really is? These books make it clear: for all our mathematical dexterity, in physics nobody knows anything. Yet. ■

Michael Brooks is a consultant for *New Scientist*

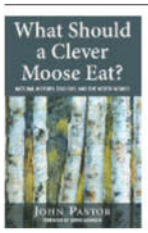
JIM BRANDENBURG/MINDEN PICTURES

After the harsh winter, hardy moose make the most of the warm weather

Into the woods

A beguiling tale of fieldwork shows its importance, says **Adrian Barnett**

What Should a Clever Moose Eat? Natural history, ecology, and the North Woods by John Pastor, Island Press, $30



WAFFLE-nosed and spindly legged, often weighing well over 400 kilograms and munching its way through more than 30 kg of food every day, the moose is a splendid beast. It is also an excellent animal for John Pastor to focus on in his evocative, multilayered and fascinating book, *What Should a Clever Moose Eat?*

Pastor is a long-time explorer of North America's great northern forests in both the physical sense and the academic. Here, he shows the area's complexities and the ecological interplays between multiple species. He also shows how these are moulded by geological history and factors such as the fluctuations in population size of lynx and hares, and the frequency of forest fires.

Pastor progressively pieces together the region's delicate ecological jigsaw puzzle. We come to understand the connections between past glacial events and current soil varieties, how these determine forest types, and what the size, shape and distribution of the resulting patchwork of vegetation do to the abundance and spread of animal life.

The cascade of consequences is laid out in clear, logical and beautifully informative prose. Beavers turn out to be hugely important: they are veritable ecological engineers, with their dams, water meadows and selective logging having modified much of the low-lying land from the northernmost US to Canada's Arctic treeline.

Then there are the delicate interactions between warblers and armyworm caterpillars, including what happens when the system breaks down through habitat destruction from logging and the overuse of insecticides.

So, what does a smart moose eat when it is -40 °C in midwinter Minnesota and the snow is belly-high, at 1.5 metres? Mostly, it is astonishingly choosy and selects the most nutritious twigs. But sometimes the creature just toughs it out and waits for spring, while eating food so toxic its kidneys bleed and produce urine that makes red spots in the snow.

Within all this, Pastor explains, natural history – so often derided as scientifically quaint and mere informational stamp collecting – is paramount. Whether he is recounting the relationship between fungi, vole faeces and fir-tree regeneration, or the complexities of fire dynamics, it is, Pastor says, natural observation, those backstories and the painstaking work of recording that are the keys to the storehouse of ecological knowledge. Only then, with all that old-fashioned, systematic graft safely in the bag, can modern technology do its thing.

Clearly as dedicated a teacher as he is a researcher, University of Minnesota professor Pastor is continually pointing out that one or another facet "is a golden opportunity for a graduate student project".

Just like the forest he studies, Pastor himself is surprisingly diverse – not only is he a fervent believer in the value of natural history, a fine species ecologist and an accomplished mathematical modeller, but also a wildlife artist of note. His 15 black and white drawings of everything from ice walls and pollen grains to beaver ponds and fir cones are elegant and evocative, and complement the text perfectly.

The result is not only an elegant and multi-tiered examination of the complexity and interplays of a region's current, past and future ecology, but one of the few science books I can recall in which the author not only drew all the illustrations, but also painted its beautiful, intriguing cover. ■

Adrian Barnett is a rainforest ecologist at Brazil's National Institute of Amazonian Research in Manaus

KAREN KRAMER, THE EYE THAT ARTICULATES BELONGS ON LAND

Fishing, post-tsunami: a desolate scene captured by Karen Kramer

Storms and teacups

In an increasingly tricky world, art can help us home in on the threats that are truly worth fearing, finds **Simon Ings**

Borrowed Time, Jerwood Space, London, to 24 April, then at CCA, Glasgow, UK, 28 May to 10 July

THE current crop of young artists showing in London look pretty incorruptible. Handed £20,000 each to make films about economic unease and ecological anxiety, Alice May Williams (fresh-ish out of Goldsmiths, University of London) and Karen Kramer (who cut her artistic teeth at the Parsons School of Design, New York City) have made video installations that deliver on this minatory brief. And they have done so with the sort of bloodless precision that leaves a visitor to Borrowed Time unsure whether to admire their high seriousness or worry at their apparent lack of character.

Be patient: both pieces reward closer attention. There are, ultimately, two very strong, staggeringly incompatible visions at work here.

Through its fictional narrator-protagonist, Kramer's *The Eye That Articulates Belongs on Land* gives viewers the opportunity to wander the deserted, out-of-bounds byways neighbouring Japan's Fukushima nuclear power plant while growing increasingly upset.

Actor Togo Igawa's choked voice-over suggests a wronged salaryman driving back and forth over his pet shih-tzu. Pictures of urban dereliction lovingly reference the 2011 release of radioactive material from the plant (worldwide casualties to date: nil) while providing not much more than a passing reference to the tsunami (Tohoku district casualties: just shy of 16,000) that triggered the plant's meltdowns.

The power plant offered us "a false promise of dominion" apparently – a formulation I'm sure to recall next time I turn on a kettle for a cuppa – before Nature Wrought Her Terrible Judgement.

Actually, Kramer might not be going this far – it's hard to tell. But she is dangerously close, achieving with the line "They let loose a reaction here that belongs on the surface of the sun!" an impressive hat-trick: at once morally irrelevant, intellectually vacuous and factually incorrect. The piece then degenerates into a paranoid animation involving shards of uranium glass and a mummified fox.

"Disasters are like the rain and eclipses: inevitable. The whole reason we have societies is to cope"

Meanwhile, in *Dream City – More, Better, Sooner*, Alice May Williams invites us to stare at her toes, and, beyond, at the towers of the long-since decommissioned Battersea power station, a crumbling Art Deco masterpiece. This gem is currently aswarm with builders, surveyors, architects and their ilk as that swampy, vital, smelly, industrious corner of London gets a landscaped corporate makeover after 30 years of dithering.

Williams is taking deep, centring breaths, following the advice of a meditation teacher. She is learning to let go of past errors and future plans, and to embrace the now. In other words, Williams's well-being involves letting go of the very forces, prejudices and habits that make her city tick. Can you imagine the mess we would be in if our utilities "embraced the now"? The disjunct between personal time and civic time is built steadily, with humour and poetry and a tremendous sense of mounting threat. "SHOP STAY EAT LIVE WORK and PLAY", a hoarding screams. A promise or a threat?

"Sometimes we are right inside the drawings," Williams sighs, interleaving the view from her window with corporate videos, blueprints and historical footage to capture the inevitable bind of city living. That bind has us living inside other people's visions, hardly able to distinguish between big-business blather and the untethered voices of our own suicidal ideations.

Both films play to our fears, but only Williams understands what's worth fearing. Disasters are not and never were the point. They are like rain and eclipses: inevitable. The reason we have complex societies is to handle disasters. A famine here, a flood there, a cave-in at the mine. The rest is window dressing, and none of it comes out the way it is meant to.

All over London, the kettles are boiling merrily as the old power station is turned into a retail-residential park "with community built in". We can embrace the now all we want, but the city has no such luxury. That is what makes it such a terrifying friend. ■

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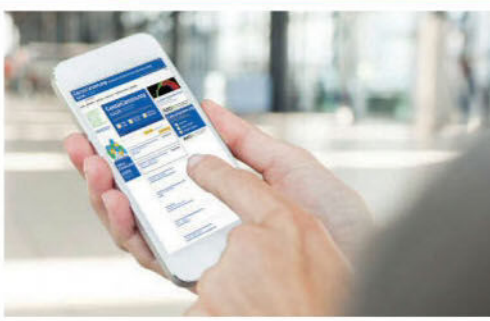

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Faculty Position
in Structural Biology and Drug Discovery

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

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

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

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

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

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

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

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SAN ANTONIO

Assistant Professor/Research Faculty in Bioinformatics

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

SUMMARY

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

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

RESPONSIBILITIES

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

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

EDUCATIONAL EXPERIENCE

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

KNOWLEDGE, SKILLS, AND ABILITIES

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

WORKING CONDITIONS

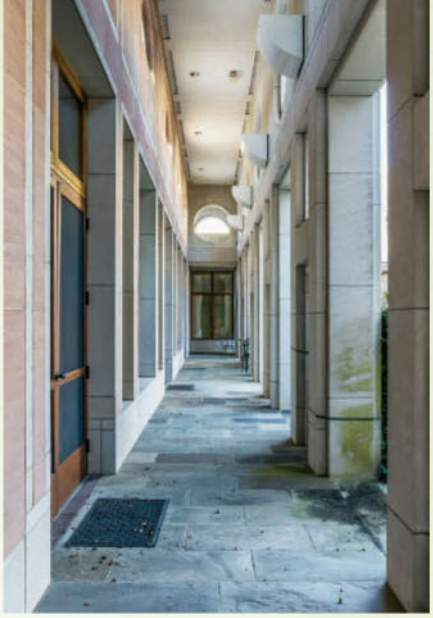
Work is performed in an office environment. The position requires occasional travel to attend professional and grant meetings, as well as meetings for the University of Texas System.

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

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

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

For complete program information, including deadlines, please visit www.bwfund.org



Grant Programs

BIOMEDICAL SCIENCES

Career Awards for Medical Scientists: Five-year awards for physician scientists provide $700,000 to bridge advanced postdoctoral/fellowship training and the early years of faculty service. This award addresses the on-going problem of increasing the number of physician scientists and will help facilitate the transition to a career in research.

Collaborative Research Travel Grants: Provide up to $15,000 in support for interdisciplinary biomedical researchers from degree-granting institutions to travel to a laboratory to acquire a new research technique or to facilitate collaboration.

DIVERSITY IN SCIENCE

Postdoctoral Enrichment Program: Provides $50,000 over three years to support the development of underrepresented minority postdoctoral fellows in biomedical research.

INFECTIOUS DISEASES

Investigators in the Pathogenesis of Infectious Disease: Five-year awards provide $500,000 for opportunities for accomplished investigators at the assistant professor level to study infectious disease pathogenesis, with a focus on the intersection of human and microbial biology. The program is intended to shed light on the overarching issues of how human hosts handle infectious challenge.

INTERFACES IN SCIENCE

Career Awards at the Scientific Interface: Five-year awards provide $500,000 to bridge advanced postdoctoral training and the early years of faculty service. These awards are intended to foster the early career development of researchers with backgrounds in the physical/mathematical/computational/engineering sciences whose work addresses biological questions. BWF has moved to a self-nomination format for this award.

POPULATION AND LABORATORY BASED SCIENCES

Institutional Program Unifying Population and Laboratory Based Sciences: Five-year awards provide $2.5 million to unite population-level and laboratory-based biological sciences. The award supports the training of researchers working between existing research concentrations in population approaches to health and in basic biological sciences. The goal is to establish interdisciplinary training programs by partnering researchers working in disparate environments and intellectual frameworks.

REGULATORY SCIENCE

Innovation in Regulatory Science Awards: Provides up to $500,000 over five years to academic investigators who are addressing research questions that will lead to innovation in regulatory science, with ultimate translation of those results into improving the regulatory process. These awards are intended to provide support for academic researchers developing new methodologies or innovative approaches in regulatory science that will ultimately inform the regulatory decisions the Food and Drug Administration (FDA) and others make.

REPRODUCTIVE SCIENCE

Preterm Birth Initiative: Provides $600,000 over a four-year period to bring together a diverse interdisciplinary group with the more traditional areas of parturition research to address the scientific issues related to preterm birth.

SCIENCE EDUCATION

Career Awards for Science and Mathematics Teachers: Five-year awards provide $175,000 to eligible science or mathematics teachers in the North Carolina public primary and secondary schools. The purpose of this award is to recognize teachers who have demonstrated solid knowledge of science or mathematics content and have outstanding performance records in educating children. The award is a partnership between the North Carolina State Board of Education and BWF.

Student Science Enrichment Program: Three-year awards provide up to $180,000 to North Carolina nonprofit organizations, including public/private schools, universities, colleges, and museums. This program supports creative inquiry-based science enrichment activities that occur outside the typical school day for K-12 students. The program's goals are to nurture students' enthusiasm about science, expose them to the excitement of scientific discovery, and interest them in pursuing careers in research or a variety of other careers in science.

Promoting Innovation in Science and Mathematics: Awards provide teachers with funding for materials, equipment, and training to conduct hands-on, inquiry-based science and mathematics projects in North Carolina public schools.

The Burroughs Wellcome Fund is a private foundation located in Research Triangle Park, North Carolina. Find out more at **bwfund.org**

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EDITOR'S PICK

We can do trials of a ketogenic diet

From David Torgerson, York Trials Unit

Hal Hodson suggests that it might not be possible to conduct a randomised clinical trial of the ketogenic diet, which involves cutting back on carbohydrates and increasing fat intake, for the treatment of brain cancer (27 February, p 10). While people would of course know what diet they were on, so the trial could not be "blind", randomised trials of diets have been done, such as those of the Mediterranean diet.

Instead of giving a sample of people such a diet and monitoring them for two years, as suggested by an oncologist interviewed for the article, I think it would be better to place half of a sample of, say, 50 people at random on the diet, and half not.

This would allow a clear comparison of recurrence rates in the two groups. If instead we follow the design outlined in the article, it would not be possible to determine whether any reduction in recurrence of cancer was due to patient selection or the effects of the diet itself.

Until a randomised trial has been done, many clinicians, quite rightly, would not recommend such a diet. A small, rigorous trial should be done to demonstrate whether this diet has merit.

York, UK

To read more letters, visit newscientist.com/letters

The evidence for a maternity review

From Soo Downe, Susan Bewley, Sheena Byrom and 186 others

Clare Wilson's online opinion piece, published on 25 February, argued that the recent NHS England Maternity Review will lead to harm to mothers and babies (newscientist.com/article/2078853). We were surprised that no reference was made to the scientific evidence underpinning the review. A Cochrane Collaboration review of 15 randomised controlled trials on the benefits of continuity of midwifery-led care found that it reduces rates of both preterm birth and overall fetal and neonatal death, and improves maternal outcomes.

High-quality studies comparing outcomes for healthy women and babies found that planned out-of-hospital births resulted in no increase in perinatal mortality, nor severe morbidity, and in reduced maternal morbidity.

The most recent National Institute for Health and Care Excellence (NICE) guidance recommends that healthy women are given evidence-based information and supported in their choice of birth place.

Our reading of the Maternity Review recommendations is that they are designed to deliver respectful, kind, safe, evidence-based maternity care, centred on the values and needs of women and their families and intended to improve their wellbeing and that of their babies.

Preston, Lancashire & London, UK

■ See newscientist.com/article/2080286 for references and all signatories.

From Bill Kirkup

Wilson's piece is misleading in several respects. Much of this springs from the perceived link between the investigation into failings in maternity services at Morecambe Bay NHS Trust (which I chaired) and the National Maternity Review (of which I was a member). The national review may have had its origin in the response to events at Morecambe Bay, but it was much more wide-ranging.

The national review does not "extol the virtues of births at home or at midwifery-led units separate from hospitals". Enabling more women to exercise an informed choice may well mean fewer births in obstetric units, because more women would like this than manage it currently, and – as the review rightly puts it – there is no evidence that outcomes differ by place of birth in second or subsequent pregnancies.

When assisted birth is required, there is sometimes a choice between caesarean section, forceps and vacuum extraction. There is a legitimate and continuing debate about which to use when, but this has nothing to do with either place of birth or midwife-led care.

Observations such as "spitting on the graves of those who died" are offensive to everyone who contributed to the review.

Gateshead, Tyne and Wear, UK

Humans also paint landscape of fear

From Andrew Ainger

Sam Wong writes that predators "don't control populations of their prey just by killing them. They also paint… a landscape of fear" (27 February, p 9). Does this apply to dominating managers too? In an industrial landscape of this kind, will fear drive the innovative managers into hiding for fear of being eaten alive?

Harpenden, Hertfordshire, UK

From Nelson Dale

After the study finding that the sound of dogs barking reduced raccoon feeding time through fear, it seems that the real question is not about the absence of large predators, but what is the effect of essentially every animal on the planet being mortally scared of humans?

Bedford, Massachusetts, US

When following orders is adaptive

From Chris Daniel

The Milgram experiment in which participants willingly deliver (fake) electric shocks to actors because they are "only obeying orders" could be tapping into normal learned behaviour (27 February, p 14). Humans are socially primed from childhood to respond to commands.

If, as you report, astronauts react more quickly to voice alerts than to other audible sounds (p 19), it may simply be part of the same pattern of behaviour. Airline cockpits are already equipped with voice alerts where urgent action is needed, such as terrain avoidance ("pull up, pull up!"). "Only obeying orders" in these circumstances could save lives.

Glan Conwy, Conwy, UK

Feedback on *The Ecologist* and Zika

From Oliver Tickell, The Ecologist

Feedback is admirable for its exposure of fruitloopery but a recent item taking aim at *The Ecologist* and me as purveyors of "conspiracy theories" over Brazil's microcephaly cases misses the mark (27 February).

Feedback attacked the idea of a link between the insecticide pyriproxyfen, used to kill mosquitoes in water tanks, and the birth defects: "There is no evidence to suggest it causes birth defects – and plenty to demonstrate that it doesn't, having been thoroughly tested

"The problem is those in engineering who aren't used to the presence of a female thinker in their team"

Zara Teaffee Talat reflects that her problem wasn't encouragement to go into engineering (newscientist.com/gallery/unsung-heroines)

in animals" (27 February).

The same was once said of the drug thalidomide, and we know how that ended. Exposure of humans to pyriproxyfen in drinking water without the strict clinical surveillance programmes advised in the wake of thalidomide is a public health scandal that leaves the possibility of a link open.

You can read my full response to this, and to Feedback's comments on my piece about Zika virus and genetically modified mosquitoes (20 February), on theecologist.org.
Oxford, UK

Driverless cars roll on and on

From Patricia Shannon
Anna Nowogrodzki discusses the time it takes for self-driving cars to start up when traffic lights turn green (23 January, p 21). Much of the reason for traffic congestion is that the faster cars are moving, the more distance there needs to be between them for safety. This holds true whether or not the cars have a driver. Even though a self-driving car could react faster if the car in front of it slows or stops, it would still take time for it to slow or stop itself.
Norcross, Georgia, US

From Ted Webber
This phenomenon is the reason why, contrary to the expectations of many non-engineers, a lower speed limit allows a greater throughput of vehicles per hour. Cars can travel with less space between them at the lesser speed. The safe space increases as the square of the speed.
Buderim, Queensland, Australia

From Alec Logan
Some years ago research was carried out in Switzerland on maximising the number of cars passing through traffic lights each cycle. The optimum was found to involve a two-car space between all cars and the whole line moving off simultaneously.

In practice this is never going to happen, but we can each stop further back, so we can see where the rear wheels of the vehicle in front touch the ground, and move off as soon as the vehicle in front does.
Eastbourne, East Sussex, UK

Who will accept ownerless cars?

From David Pipe
Emily Wolfe suggests that driverless cars could provide environmental benefits by encouraging a shift to ownerless cars (Letters, 5 March). Suburban streets are currently lined with cars that are driverless for days on end. Why should the desire to own cars used only once or twice a week change, because the latest cars are robotic?
London, UK

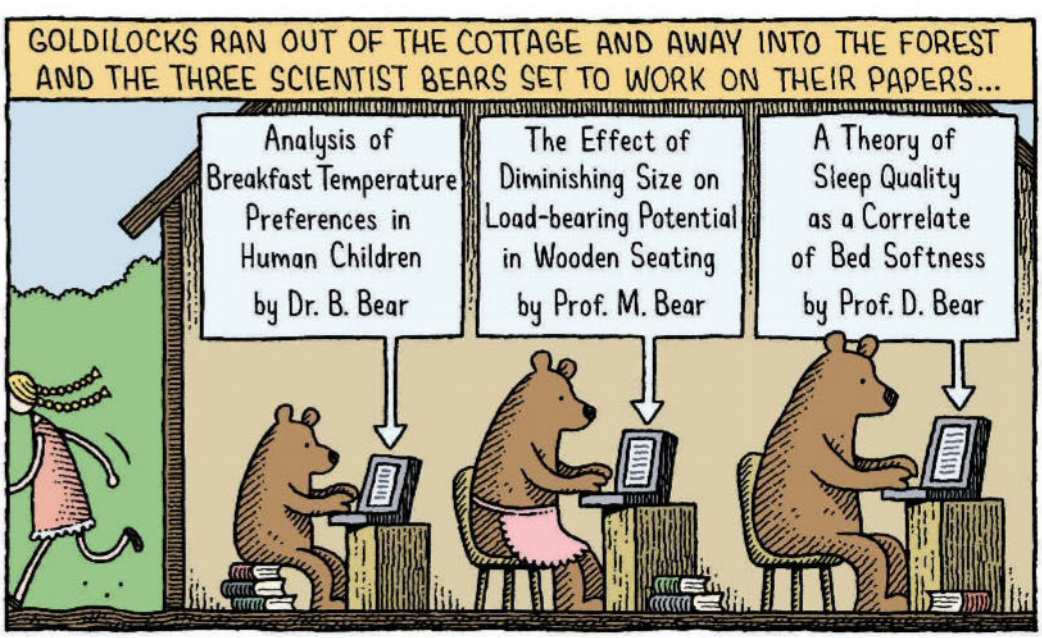
From Ian Downie
Another major reason to encourage driverless cars is to make it possible to charge for road travel by distance, varying with the time of day and how busy the road is. The UK government has long wanted to do this. The monitoring technology is easy, but at present it would be too expensive to catch cheats. A self-driving car can't lie about where it is and is going.
Southampton, Hampshire, UK

From Andrew Sanderson
Hal Hodson's discussion of self-driving cars (16 January, p 20) made me think about the problems to be encountered by these vehicles. Simple decisions, such as keeping an appropriate distance from other vehicles, are easy to solve. But what about issues like which car reverses when two meet on a single-track road? If both are driverless, they can communicate. But if one has a human driver who never gives way, what happens?
Spennymoor, County Durham, UK

To see the colour of the hat, look

From Ernest Ager
One hundred people standing in line, each wearing either a red or blue hat, can only see those in front. Devise a strategy to maximise the chance of guessing one's own hat colour (27 February, p 25). Simple: move your head close to the person in front and look for the reflected colour change on his/her clothing.
Exmouth, Devon, UK

TOM GAULD



For the record

■ **The histogram showing how UK companies recruit showed too long a bar for "trade publications" (27 February, p 50).**

Letters should be sent to:
Letters to the Editor, New Scientist,
110 High Holborn, London WC1V 6EU
Email: letters@newscientist.com


News
After handshakes, we sniff people's scent on our hand
After handshakes, we sniff our hand
YouTube
This suggests that handshakes might transmit chemical signals
You won't believe you do it, but you do. After shaking hands with someone, you'll lift your hands to your face and take a deep sniff. This newly discovered behaviour – revealed by covert filming – suggests that much like other mammals, humans use bodily smells to convey information.
We know that women's tears transmit chemosensory signals - their scent lowers
Free sample issues

PAUL MCDEVITT

FEEDBACK's fruitloopery detector previously warmed up in the presence of Blue Bottle Love's solar-powered healing water (30 January). Now we find it positively sizzling upon the discovery of Blue Moon Dream Water.

London's *Evening Standard* newspaper reports that the turquoise tipple is in vogue with the city's health trendsetters, and notes that its alkaline properties are purportedly the key to looking like a supermodel.

At the time of writing, Feedback hasn't been able to get its hands on any of this blue elixir. We wonder if a glass of Toilet Duck is an acceptable substitute.

UNUSUAL units from around the world are still wandering into Feedback's inbox.

Anthony Daniel sends us a clipping from a guidebook he used on a recent trip to the volcanic region of Lanzarote, which reveals that "The camel can carry at least 600 books, and some can carry as many as a thousand."

Anthony says: "At least if you find your camel can only manage 600 books, you will have plenty of reading matter to pass the time while waiting for a second camel."

READERS continue to be vexed by quantum superposition manifesting itself at the macro scale.

Chris Knight reports: "When putting a fitted sheet on my mattress, the sheet begins in a state of being long enough to fit the mattress in any direction.

"It is only after I get two corners in place that it collapses into having a long and a short side – invariably, the short side is the one I am trying to fit over the length of the mattress, requiring me to start over."

Chris also reports another confounding factor, in which the square duvet cover fits "well enough" in either orientation. "Only when observed by my wife, however, does it collapse into a correct or incorrect alignment," he sighs.

MEANWHILE, Chas Bazeley writes that "it is well known amongst those with an interest in do-it-yourself that any tool placed on a workbench will instantly flip out of existence, only to reappear 10 minutes later in the same spot once they are looking for something else".

THOSE looking to cut down on their calories might like to try loading up on a few bags of Domino Sugar. Sue Jarvis directs us to the company's website, which boasts that its sweet stuff is "certified carbon free".

While it's possible this is simply a reference to a carbon-emissions certification system, Feedback thinks you may need an airtight shopping bag rather than a basket for this carbon-free carbohydrate, and advises you to steer clear of naked flames.

YET more rules for life: Peter Steggle tells us that our battles with macro-scale quantum effects are a manifestation of the mysterious 50-50-90 rule. He explains: "Any time you have a 50-50 chance of getting something right, there's a 90 per cent probability you'll get it wrong."

Peter also provides evidence from his day-to-day life. "As an electrician, when we connect up a three-phase motor, it has a 50-50 chance that it will rotate in the right direction. But they always seem to go the wrong way."

SPEAKING of electrics, Mick Johnson sparks our curiosity with a strange clause he discovered in some anonymous guidance notes for the latest edition of the UK's wiring regulations, which claims that they "purely outline a standard by which all electrical installations, using normal electricity as opposed to Nuclear and other types of electricity, are installed…"

Mick is left wondering how he can tell the difference between normal, nuclear and other types of electricity at the point at which it boils his kettle – and whether a special type of plug is needed.

IN RESPONSE to the UK government reducing its recommended alcohol limit (newscientist.com/article/dn28742), Richard Sleeman tells us he has "enrolled on a wine-tasting course to ensure that the meagre quantity which is allowed to pass my lips is of the highest quality".

During a class, Richard was shown a bottled labelled "750ML". "Throughout my career as a chemist, the abbreviation for millilitre has changed several times: cc, cm^3, ml, and seems to have settled on mL," he says. "But I've never come across ML, which must surely be megalitre."

Feedback can only begin to imagine what a 750-megalitre bottle might look like – let alone which biblical king the bottle should be named after.

AN IMPORTANT announcement from our colleagues on the news desk: there are at least 2.8 billion years left before the universe tears itself apart (5 March, p 18). "Thank goodness," says Neil Winegarden, "I still need to paint the kitchen." But surely not everyone will be so fortunate. Feedback is certain readers can suggest some things that still won't be done by the year 2800002016.

READER Max Galloway informs us: "When I first bought condoms, I bought a *New Scientist* magazine with them to not look weird". We're happy to be of assistance to Max, although it makes us wonder what other unusual uses readers have found for this publication.

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.

Peter Davies on quantum footwear: "I thought socks existed in a state of superposition, since they are simultaneously both right- and left-footed until you put them on"

Mississippi melter

Can anyone explain what this odd thing is (see photo, above)? It was found on a sandy beach along the Mississippi river in Minneapolis in early September. It was solid and it had the consistency of a jellyfish, but appears to have formed along a strand of reed (seen running through the middle) or some other plant-based material.

That is a photo of *Pectinatella magnifica*, a member of the Bryozoa – a group commonly known as "moss animals". The gelatinous mass is in fact a colony of dozens of animals, or zoids. A popular name is jelly ball.

Most colonies are elongated and they adopt the best shape for clinging to the object to which they adhere. Free-floating colonies tend to be spherical. They are found in stagnant or slow-moving water, so this one in the Mississippi must have floated in from a tributary or a riverside pond. I once encountered a round one as big as a soccer ball. They sometimes sprawl out over a metre or so, resembling a giant amoeba.

Donald A. Windsor
Norwich, New York, US

Beach bun

I found this object on a beach in northern Tasmania (see photo, above right). It weighs 60 grams, is very hard to the touch and it stinks. Somebody suggested to me, because of the evil smell, that it might be ambergris. Is it ambergris? And if not, what could it be?

This looks – and apparently smells – like the secretion of a sperm whale that has yet to turn into ambergris, which begins life in the animal's digestive tract. It is soft and white when fresh, sometimes with black streaks running through it. Floating on the surface of the sea in lumps of up to 50 kilograms, it smells a bit like human waste.

After a few months or years, it eventually turns into ambergris – grey lumps with a much sweeter aroma. Before ambroxan was developed as a synthetic alternative, ambergris was used to make perfumes and still is in some expensive examples.

Mike Follows
Sutton Coldfield, West Midlands, UK

This week's questions

LUNAR ATTRACTION

If a sea-level canal was dug from east to west across Asia, would the moon have a tidal effect on the water level, with a daily tidal bore in phase with it?

Lyndall Smith
Ferny Hills, Queensland, Australia

LAST SHOW ON EARTH

When the sun has used up both its hydrogen and helium and it begins to expand, what would be seen from Earth? Assuming that anyone could survive the event, what would they see when Earth was swallowed up by the sun's expanding outer atmosphere?

Andrew Crysell
Peterborough, Cambridgeshire, UK

COLOURED DOTS

I've noticed that when an object is seen from a distance in daylight, the colours appear changed. For example, when I observed my wife walk round a lake in Switzerland, her pink top looked white and her blue trousers pink from 600 metres or more away. Do surfaces need to be sufficiently large in our field of view for us to perceive their colours correctly?

Neil Croll, Derby, UK

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