New Scientist

WEEKLY June 30 – July 6, 2018

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Biological bias

We must make clinical trials fairer for all

TO EVALUATE a new drug, you need a clinical trial that's designed to most clearly reveal its effects. Test it in too variable – or too sick – a group of people, and you are less likely to pick up the powerful effects you hope it is capable of.

That's just statistics. But such efforts to get the clearest signal have led drug developers to skew clinical trials to one particular group: white people. As many as 86 per cent of participants in drug trials are white, according to one 2014 analysis. This is a problem: a person's ethnicity can influence how effective or dangerous a drug is, as can their age, gender or weight. Testing a drug on a group that doesn't represent the wider population means that guidelines on how to use it will then largely apply only to a subset of people.

In the past, many explanations have been put forward for the low numbers of, for example, African Americans in clinical trials. These included lower awareness of trials, low numbers of black biomedical researchers, and a historically justified lack of trust in the US medical establishment.

But it's time to face the fact that the entry requirements are also against them. Just as women have been excluded from research due to fluctuating hormones, minority volunteers can be rejected from trials due to stats that gauge their health. For example, over-reliance on crude markers for kidney or immune health may explain why so few black men are included in prostate cancer trials, despite the disease being more common in this group (see page 15).

This is of particular concern given that minority groups often experience worse health than the population average. So how can we better represent real populations and still detect benefits of new drugs? Bigger trials or extra trials in subgroups may help, although both will cost more money. Whatever we do, what's certain is that we must act. ■

Conceptual difficulties

WHAT hope has consciousness of understanding the world, when it doesn't yet understand itself?

The answer is we don't know – but it's a blast trying to find out. Science is the art of asking hard questions and, whether or not we find answers, finding new perspectives that extend our knowledge.

Often those perspectives are truly mind-blowing, as our special feature "How to think about…" makes plain (see page 28). You might dispute our choice of 13 of the most intriguing ideas from science and technology – indeed, when we undertook a similar exercise in 2014, the list was entirely different (13 December 2014, p 32).

But all exemplify how scientific enquiry defines and shapes our thinking in often unexpected ways. They illustrate the beauty of the subject: how it follows no agenda or preconceptions, but guides us on a stumbling path to greater enlightenment.

Science may often be hard to get our heads around, but to echo the ending of our special feature: it is the worst way of seeking truth, apart from all the others that have been tried from time to time. ■

Time to catch a space rock

The Hayabusa 2 probe will reveal asteroid mysteries, says **Leah Crane**

AFTER a journey of three-and-a-half years, Japan's Hayabusa 2 spacecraft is sidling up to its destination, a small asteroid called Ryugu. Its mission: to bring some space dust back to Earth.

The approach is tricky, says Elizabeth Tasker of the Japan Aerospace Exploration Agency. Ryugu is a relatively small asteroid, less than a kilometre across, so it is hard to pin down its exact location at any one time. "A tiny mistake can mean you miss the target entirely," she says. "The distances are equivalent to trying to hit a 6-centimetre target in Brazil from Japan."

Because of that, Hayabusa 2 is zigzagging towards Ryugu instead of heading straight for it. That allows the probe to repeatedly measure the asteroid's position with respect to background stars.

Assuming everything goes to plan, in August, Hayabusa 2 will descend to just 1 kilometre above Ryugu to measure its gravity.

Ryugu, as pictured from the spacecraft on 24 June

JAXA, ET AL.

The spacecraft will later drop off one big lander and three smaller ones on the surface to study the asteroid's composition, geology and temperature.

Hayabusa 2 will make numerous observations from orbit. And, after deploying the landers, it will itself touch down on Ryugu three times to collect samples in 2018 and 2019.

It will also collect samples by shooting a bullet at the surface

"The distances are equivalent to trying to hit a 6-centimetre target in Brazil from Japan"

and then collecting the dust thrown up afterwards.

To collect deeper samples, the spacecraft will use an even more violent procedure. It is carrying a 2.5-kilogram projectile loaded with high explosives that will blast into Ryugu at 2 kilometres per second. Hayabusa 2 will then collect fresh dust, previously unexposed to space, by descending to the resulting crater.

"Using an impactor and observing the explosion as it strikes the asteroid is going to tell us a lot – way more than we currently know – about the internal structure of these objects," says Daniella DellaGiustina at the University of Arizona. "It's a little bit cowboy, but it's really cool."

The spacecraft will start heading home at the end of 2019. Ryugu's close orbit makes sample return particularly easy: it swings from just within Earth's orbit to just beyond Mars's orbit .

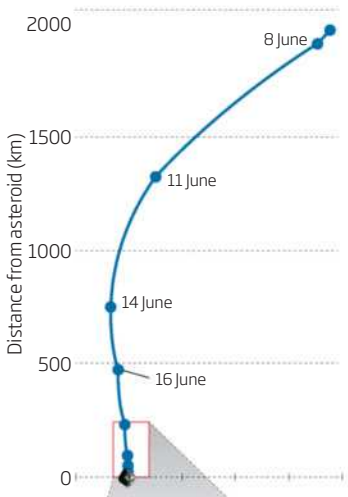
The dust samples will be only the second lot retrieved from an asteroid. But the first Hayabusa mission, which returned in 2010, managed to grab only a few micrograms. NASA also has a sampling mission, OSIRIS-REx, which is due to arrive at asteroid Bennu in August. These efforts are the first baby steps in what could eventually become a full-blown asteroid-mining industry.

Hayabusa 2's first detailed pictures of Ryugu (left) showed an angular rock with a ridge circling its equator – an unusual shape that may make it harder to land. There is a large boulder or cliff about 150 metres across sitting at the top of the image, as well as other apparent clusters of rocks settled on Ryugu's surface. It is riddled with small depressions that might be craters from collisions with other space rocks.

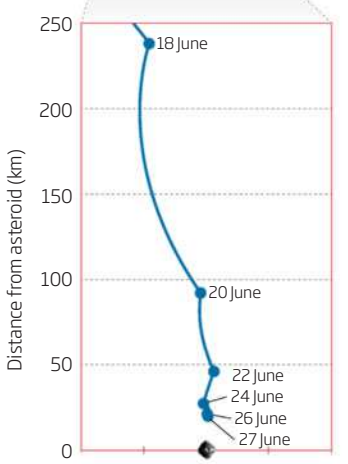
"Comets and asteroids are the dinosaur bones of the solar system. They were here first," says Carey Lisse at Johns Hopkins University in Maryland. Asteroids splintered off larger rocks that were the building blocks of planets in the early solar system. Studying asteroids like Ryugu can tell us what those building blocks were made of, which may help us determine how certain materials – such as water, and the first ingredients for life – came to be on Earth and other planets.

"This means that we are analysing a snapshot of our own past," says Tasker. "If we find water and organics that are similar to those on Earth, it will be evidence that space rocks like Ryugu are how we all began." ■

Hayabusa 2 is at the end of its journey to asteroid Ryugu



The enlarged view below shows the zigzagging path the probe has taken to ensure it reaches its tiny target



AARON CHOWN/PA WIRE

Belugas' Iceland refuge

AN OPEN-WATER sanctuary for two beluga whales is to open in Iceland next year – the first project of its kind.

The Sea Life Trust, a conservation charity, has spent six years hatching a plan to bring the 12-year-old belugas, named "Little White" (pictured) and "Little Grey", from captivity in China to an open-water refuge.

Last year, Klettsvik Bay in Iceland's Westman Islands, the location for the film *Free Willy*, was chosen as the site for a 32,000-square-metre sea pen that will house the whales. Building work has already begun and is expected to finish in March next year.

The Sea Life Trust says it has recently received the crucial authorisation to move the whales from Changfeng Ocean World in Shanghai, where they are still performing for visitors.

To prepare them for the move, the whales are now being introduced to equipment such as stretchers. They are also being trained to hold their breath under water for longer and to swim faster, so that they will cope better with tides and currents at the sanctuary.

The journey by land, air and sea from China to Iceland will take more than 35 hours. That will be a challenge for the whales, says Katrin Lohrengel at Sea Watch Foundation, who is not involved with the project.

"This is quite a long transport the animals will be undergoing. That has a lot of issues and stress related to it," says Lohrengel.

However, given the social nature of whales, having two of them may help the project succeed if the animals arrive safely, she adds.

First cannabis-based drug in US

IT TASTES of strawberry, but Epidiolex is the first drug approved in the US containing an ingredient from marijuana. The US Food and Drug Administration (FDA) approved the drug on 25 June for the treatment of two rare but severe forms of childhood epilepsy: Dravet syndrome and Lennox-Gastaut syndrome.

The active ingredient in the drug is cannabidiol, and it contains only a trace of the psychoactive component of cannabis, tetrahydrocannabinol, or THC. In clinical trials, Epidiolex proved effective at helping people with these conditions control their seizures.

FDA commissioner Scott Gottlieb warned that the organisation would continue to punish illegal marketing of cannabidiol-containing products with unproven medical claims.

The UK government last week announced a review into the possible use of marijuana-based medical products.

For more on the medicinal use of cannabis, see page 8

AI thrashes human gamers, again

AN ARTIFICIAL intelligence has beaten the world's top amateurs at one of the trickiest video games – but it needed thousands of years of practice to do so.

In *Dota 2*, two teams of five attack each other while defending their own base. The game has the largest prize money of any in e-sport.

To teach AI the game, US research lab OpenAI used a technique called reinforcement learning. In essence, the AI is thrown into the game and learns through trial and error, by playing games against itself.

After playing the equivalent of 180 years' worth of games every day for 19 days, the AI was able to beat the top 1 per cent of amateurs at *Dota 2*. Later this year, OpenAI will pit the AI against the world's best players at The International in Seattle – the biggest *Dota 2* event.

AI has mastered games like chess and Go. But *Dota 2* is harder because the AI has to react in real time rather than taking turns, and has to make decisions without knowing everything the opponent is doing.

OPENAI

NASA takes aim at inbound asteroids

NASA is planning to design and test ways to destroy or deflect a hypothetical asteroid on a collision course with Earth. Three techniques could be used, depending on the size of the object and how much warning we have before it hits.

One idea is a gravity tractor, a heavy spacecraft that hovers near the asteroid so that its gravity can pull it off its course.

Another plan is to use a so-called kinetic impactor, deliberately crashing a spacecraft into the asteroid to change its trajectory. NASA will try this with its Double Asteroid Redirection Test mission, scheduled to launch in 2021.

A nuclear device could also be used to either deflect the object or blast it into small fragments that would burn up in Earth's atmosphere.

In a report last week, NASA said it plans to develop mission plans as well as carry out test flights to try out both the gravity tractor and kinetic impactor techniques on harmless near-Earth objects.

BRIEFING

Does cannabis oil really help people?

Alison George

MEDICINAL cannabis is in the headlines after Billy Caldwell, a 12-year-old British boy with severe epilepsy, had his cannabis oil medication confiscated. The UK government has now announced a review into medicinal cannabis. Here's what you need to know.

What is cannabis oil?
Cannabis oil is extracted from the cannabis plant, *Cannabis sativa*. Some varieties of the plant contain high levels of the psychoactive substance tetrahydrocannabinol (THC). The plant's other major chemical component is cannabidiol, which has little or no psychoactive effect.

So can cannabis oil make you high?
It depends on the THC level. Some types of the plant, known as hemp, contain little THC. Extracts from these contain mainly cannabidiol.

Is cannabidiol legal?
It is legal in the UK. Cannabis oils are available in high-street shops, but the THC content must be below 0.2 per cent. The oil used to treat Billy Caldwell, which was obtained in Canada, contained a higher dose. And cannabidiol is illegal in many other countries. In the US, it is a schedule 1 substance, the most stringently controlled, and can be sold only in states where cannabis use is legal.

What is the evidence that cannabis oils can help treat epilepsy?
Recent trials showed that cannabidiol is effective at treating two severe forms of epilepsy: Lennox-Gastaut syndrome and Dravet syndrome. The issue is less clear for commercial cannabis oils, where evidence is mainly anecdotal, and oils can contain differing amounts of THC.

Are there any cannabis-based epilepsy drugs on the market?
Yes. On 25 June, the US Food and Drug Administration approved a drug called Epidiolex for Dravet syndrome and Lennox-Gastaut syndrome (see page 7). The active ingredient is cannabidiol. This is the first time the FDA has approved a drug that contains a purified form of marijuana.

The drug contains no THC. "There is currently very little scientific evidence to support cannabis oil containing both THC and cannabidiol as a treatment for epilepsy," said the charity Epilepsy Action, in a statement.

Are cannabis-based medications available for other conditions?
They are. A synthetic version of THC called nabilone has been used since the 1980s to treat nausea after chemotherapy. A drug called Sativex is also approved in some countries, but not the US, to treat pain and spasms in multiple sclerosis. It contains high levels of THC as well as cannabidiol and so would be unsuitable for treating children with epilepsy.

What is the aim of the UK government's review?
First, it will look at the evidence for the therapeutic value of cannabis-based products. Depending on what that discovers, the Advisory Council on the Misuse of Drugs can recommend a change to the legal medical status of cannabis and its active ingredients. ■

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Billy Caldwell and his mother, Charlotte

Mystery gibbon found in ancient royal tomb

AROUND 2200 years ago, the grandmother of the first emperor of China was laid to rest. But Lady Xia was not alone in death. Buried alongside her was a previously-unknown species of gibbon, and the ape was probably her pet.

Lady Xia's tomb in modern-day Shaanxi, the second largest known in China, was excavated in 2004. Inside, the partial facial bone and lower mandible of an ape was found. Now, analysis of the bones has revealed it to be an entirely new species.

The ape was identified by Sam Turvey at the Institute of Zoology in London and his team, who named it *Junzi imperialis*.

The facial bone (pictured) has upper teeth including two large canines, the nose cavity and part of the eye socket and forehead. The mandible also includes teeth.

Enough detail remained for distinctive features in the cranial bone and teeth to be compared with corresponding ones from data sets of hundreds of gibbons from present-day species. The comparisons revealed *Junzi* was also a new genus, separate from the four known surviving ones (*Science*, doi.org/crd8).

Turvey's team thinks the gibbon evolved locally, as the tomb also held remains of other animals native to the Shaanxi region of central China, including a leopard and a black bear.

No gibbons have been seen in the area for hundreds of years. "This is a warning, another piece of evidence we've caused the loss of species well before the last 200 years," says Susan Cheyne at the University of Kent, UK.

All 20 of the world's remaining gibbon species are endangered. They include China's Hainan gibbon, of which only 26 remain. Andy Coghlan ■

SAMUEL TURVEY/ZSL

The newly discovered ape is another species we seem to have wiped out

Surname sexism boosts men's careers

DARWIN. Einstein. Marie Curie. When we talk about professionals, we tend to refer to men by their surnames, but not women, according to new findings. And it matters: calling someone by their surname also boosts people's perceptions of them.

Psychologists Stav Atir and Melissa Ferguson at Cornell University in New York began by analysing almost 5000 online student reviews of professors, as well as transcripts of more than 300 US political radio show segments.

They also gave 184 volunteers identical bullet points about the work of fictional chemist Dolores Berson or Douglas Berson, and asked them to rewrite the information in full sentences.

The pair found that on average both men and women referred to men by their surname twice as often as they did with women (*PNAS*, doi.org/crgh).

This surname bias might have important consequences. In follow-up experiments, Atir and Ferguson found that scientists referred to by surname rather than full name were judged to be more famous and eminent.

We know from past research that fame can lead to more fame. This is known as the Matthew effect, and was reflected in a final experiment. Participants were asked to decide whether scientists, referred to by full name or surname, should be granted a $500,000 National Science Foundation award. Participants were 14 per cent more likely to award it to scientists referred to by surname.

Counter-intuitively, Atir thinks that we may refer to women by their full name to help them get recognition. Many professionals are often assumed to be male, she says. So using women's full names may be a way to highlight their contribution – even if this motive can backfire.

The surname bias joins a list of biases that research shows can add up to large gender differences in the workplace. Alison George ■

FRANZ ABERHAM/GETTY

The unique ecosystem of the Barents Sea is in serious danger

The Arctic sea that is on the brink of disappearing

AN ENTIRE Arctic ecosystem suddenly started shrinking within the last 10 years and could be gone within another decade. This would be the largest, fastest impact of climate change seen yet.

"It could happen within the next few years, or within 10 or 20 years," says Sigrid Lind of the Institute of Marine Research in Tromsø, Norway. The region in question is the Barents Sea, a stretch of ocean covering 1.6 million square kilometres between the Arctic Ocean and the north coasts of Norway and Russia.

The Barents Sea has always had two distinct zones: a warmer one to the south, and a colder one to the north. The northern zone is fed seasonally with sea ice from thicker ice cover in the Arctic Ocean and has a unique Arctic-like ecosystem, supporting polar bears, seals and ice plankton. This zone seems to be collapsing.

Lind and her colleagues compiled data collected from the Barents Sea by Norwegian and Russian research vessels over the past 50 years, to see how its make-up has changed.

The cold northern zone exists because the sea there is divided into three unusually distinct horizontal layers. The surface layer supports sea ice in the winter. Below that is a middle "Arctic layer", where fresh water from melting ice settles. At the bottom is the "Atlantic" layer, a tongue of warm water from the Atlantic.

"With ongoing global and Arctic warming, it's hard to see how such a shift will be reversed any time soon"

This stratification depends on differences in density between the three layers. Because the meltwater is relatively salt-free and cold, it is less dense and so "floats" above the warmer, saltier Atlantic water.

This layering is sustained by melting sea ice, which provides a plentiful supply of fresh water into the Arctic layer each year. But this crucial input has suddenly fallen away.

From 1970 to 1999, the influx of fresh water to the Barents Sea was constant. But annual input began falling from 2010 onwards. In 2015 and 2016 it was 40 per cent below the 1970 to 1999 average.

Seasonal sea ice cover fell by a similar amount between 2010 and 2016, compared with 1970 to 1999. In effect, the cold Arctic parts of the Barents Sea are being replaced by warmer Atlantic waters. Ultimately the top two layers will be replaced, a process Lind calls Atlanticisation.

The underlying cause is the rapid warming of the Arctic due to our greenhouse gas emissions. The warmer temperatures are melting sea ice across the Arctic, before it reaches the Barents Sea. In 2017, global sea ice shrank to its smallest extent on record.

The speed of the change is startling. Until a decade ago, according to Lind's data, the Barents Sea was stable (*Nature Climate Change*, doi.org/crfh).

"This striking study could be the first example of a tipping point in the climate system being passed on a regional scale," says Tim Lenton at the University of Exeter, UK. "It provides persuasive evidence that we're seeing an abrupt shift in the state of the Barents Sea. With ongoing global and Arctic warming, it's hard to see how such a shift will be reversed any time soon."

The loss of the sea ice in the Barents Sea is bad news for species that rely on it, such as polar bears, some seals and ice algae. And the warmer waters are already attracting cod species from the southern zone of the Barents Sea, which could outcompete native predators like harp seals, minke whales and Arctic cod. "This could have unexpected knock-on effects in the ecosystem, and cause loss of biodiversity," says Bjarte Bogstad of the Institute of Marine Research in Bergen, Norway. **Andy Coghlan** ■

Ultra-fast space blast is an enigma

Leah Crane

SOMETHING in the sky is exploding incredibly quickly, and astronomers are scrambling to figure out what it is. On 17 June, the twin ATLAS telescopes in Hawaii spotted a bright flash that was not there when they had looked about two days earlier.

Most supernovae take a few weeks or even longer to reach their full brightness, but this explosion took days. "It really just appeared out of nowhere," says Kate Maguire at Queen's University Belfast, UK, who is part of the ATLAS team. Its peak luminosity was incredibly high, 10 to 100 times brighter than most ordinary supernovae.

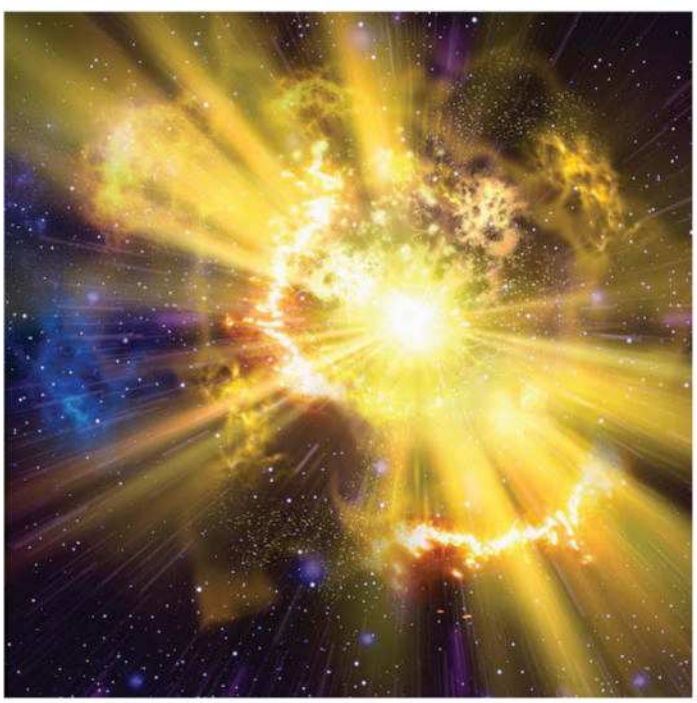
Other objects have been discovered that brighten as fast, says Maguire, but it is unusual for something to turn so bright so quickly. "There hasn't really been another object like this."

The sightings were reported on a website called the Astronomer's Telegram, where astronomers post new observations of short-lived cosmic phenomena. There it was catalogued as AT2018cow, or "the Cow" for short. The name was pure coincidence: events on the Astronomer's Telegram are given three-letter labels based on when they were added.

Initially, it seemed as if the explosion must be in our own galaxy to appear so luminous. But shortly after the initial sightings, a group of Chinese astronomers found signatures in its light that indicated it was probably in another galaxy, almost 200 million light years away.

In the following few days, assorted teams used at least 18 more telescopes to look at the Cow, making more detailed observations at a variety of wavelengths of light. "I think it's the largest number of reports for any single object ever on the Astronomer's Telegram," says Robert Rutledge at McGill University in Canada, the site's editor-in-chief.

We have no pictures of the real thing, so enjoy this one instead



OLIVER BURSTON/ALAMY

Some have interpreted those observations as suggesting that the Cow is some sort of explosion of high-energy particles, moving at close to the speed of light. Its temperature is in excess of 8900°C, and it is expanding outwards at 20,000 kilometres per second.

"We're not sure yet what it is, but the normal powering mechanism for a supernova is radioactive decay of nickel, and this event is too bright and too fast for that," says Maguire.

Some follow-up observations indicate that it might be a variety of supernova called type Ic, says Rutledge, but "more spectroscopy will be necessary before we put a lid on it".

The Cow is relatively nearby compared with other fast explosions we have spotted, so is easy to study in detail. Rutledge says we may know what is really going on within the next few days. It is so close that even gravitational wave and neutrino detectors could plausibly have spotted it.

"We're going to have a lot more observations very soon," he says. "Whether or not it is really going to be unusual in some way remains to be seen." ■

Just four tweets can unmask an online troll

TROLLS might not be as anonymous as they think. Just four geotagged posts are enough to identify which of a phone company's 10 million customers made them.

In order to effectively route calls to a phone, telecoms firms need to know which cellular towers are nearby. This also means they can build up a crude map of each customer's movements.

Apostolos Pyrgelis at University College London and his colleagues examined these mobile "fingerprints" to see whether they could be matched with social media posts.

The researchers modelled how many "leaks" – tweets or Facebook posts that give away where a person was at a particular time, for example – would be necessary to match a unique mobile fingerprint.

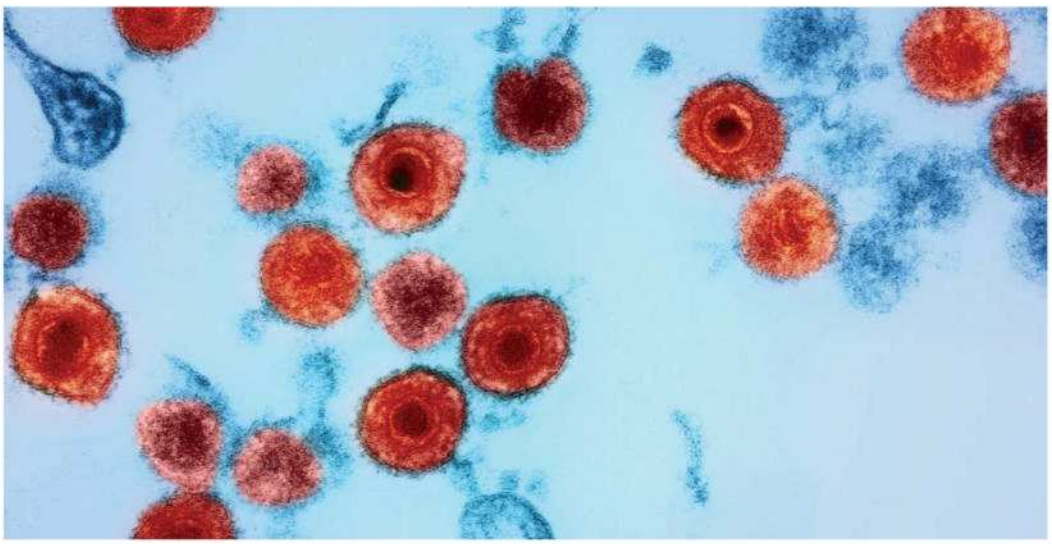
They found that a single geotagged post was enough to exclude 99.999 per cent of the phone company's database. But with 10 million records in total, this still left 100 people in the frame. Four location leaks was enough to uniquely identify the originator in 95 per cent of cases (arxiv.org/abs/1806.02701).

Team member Nicolas Kourtellis at Telefónica Research in Barcelona, Spain, says this technique can be used for positive purposes, such as fighting terrorism or identifying trolls. "The police could say to a telco, 'I have this set of geolocated posts, and I want you to tell me with some probability who this person is from your database.'"

"A single geolocated post was enough to exclude 99.999 per cent of phone company customers"

But there is also a risk to users if telecom databases are accessed illegitimately. Hackers or authoritarian governments could use the data to unmask anonymous critics, or learn where they live and work.

People leak identifying data regularly, says Sarah Jamie Lewis at the Open Privacy Research Society in Vancouver. "We need to build better tools that are aware of and can identify these kinds of location leaks." Frank Swain ■



SCIENCE PHOTO LIBRARY

Herpes infection link to Alzheimer's

Sam Wong

THE most in-depth analysis ever done of human brain tissue related to Alzheimer's disease has found evidence for the disputed theory that viruses play a role in the condition. If true, it could allow some Alzheimer's cases to be treated with antivirals.

Alzheimer's is the most common cause of dementia, but remains poorly understood. Despite past studies suggesting that viruses, particularly herpes simplex virus 1, are a risk factor, many researchers are sceptical.

In the latest study, Joel Dudley at the Icahn School of Medicine at Mount Sinai, New York, and his colleagues analysed molecular data – including DNA, RNA and proteins – from 622 donated brains affected by Alzheimer's disease and 322 without the condition. They also examined clinical data.

They found that many of the genes implicated in Alzheimer's were those involved in the body's defence against viruses. So they went back to the raw genetic data and found that genes from two viruses, human herpes virus 6 and 7 (HHV6 and HHV7), were significantly more abundant in the brains of people who had Alzheimer's.

That doesn't tell us whether the viruses are a result of Alzheimer's or if they contribute to it. So the team went further, using the data to build a model of how viral genes and human genes interact.

"It might be that Alzheimer's risk genes and viruses work together to cause symptoms"

That revealed that many human genes previously implicated in Alzheimer's are switched on or off in response to the presence of viral genes (*Neuron*, doi.org/gdpczx).

"While this does not prove a causal role, it draws the attention of the field towards the possibility that an infection could contribute to the disease process," says Bart De Strooper at University College London, who was not involved in the research.

The human herpes virus might contribute to dementia

HHV6 and HHV7 are common. In most people they are dormant and don't cause disease. But in some people they become active and infect neurons in the brain.

It may be that Alzheimer's risk genes and viruses collectively lead to the symptoms of the disease, says co-author Sam Gandy.

The results also fit with the idea that there is a connection between Alzheimer's and the innate immune system, a primitive defence against infections.

Some researchers believe that plaques of beta-amyloid protein – a hallmark of Alzheimer's – are produced to kill microbes in the brain, but cause problems when not cleared away fast enough.

If viral infection does play a part in Alzheimer's, it is not clear how many cases it contributes to.

Dudley's team hopes to develop tests that identify carriers of HHV6 and HHV7 who have Alzheimer's, then see if treating them with antiviral drugs can change the disease's course.

Recently, other studies have shown that people with herpes infections have a higher risk of senile dementia. Crucially, in patients treated with antiviral medications, the risk of dementia was reduced by a factor of 10. ■

A lagoon teeming with robotic wildlife

A SQUAD of robots will invade a lagoon near Venice, Italy, next month.

As well as three aPads (one pictured below), floating devices powered by solar cells, there will be 12 aMussels. These sensors will drop from the surface to the lagoon bed, measuring oxygen levels, salinity and the number of microscopic organisms.

When an aMussel detects something interesting, or its battery runs low, it will bob to the surface and summon an aPad. After docking, the aMussel recharges and transfers its data to the aPad, which sends it on to a base. Radio doesn't work underwater, so this exchange allows the aMussels to communicate what they have found. The aPad can then take the aMussel to a new location if needed.

The plan is to share knowledge. For example, an aPad might work out how to use currents to stick to a straight line when moving, and pass this information to the aMussels, forming a sort of collective memory. Over time, different clusters should build up "cultures" based on local conditions.

Thomas Schmickl, who leads the project at the University of Graz in Austria, aims to develop robot societies in which information is shared and persists after individual robots are replaced. The robots are designed to be mass produced, with the goal of creating much bigger swarms in future. David Hambling ■

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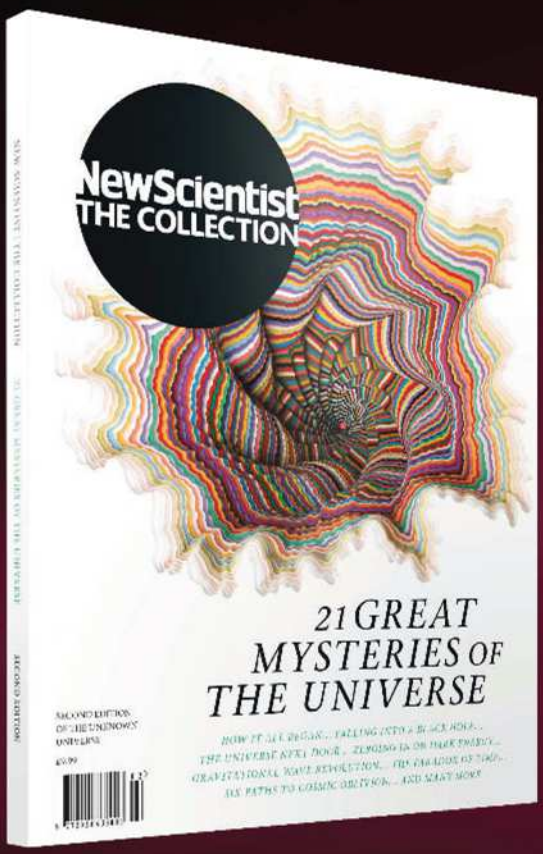

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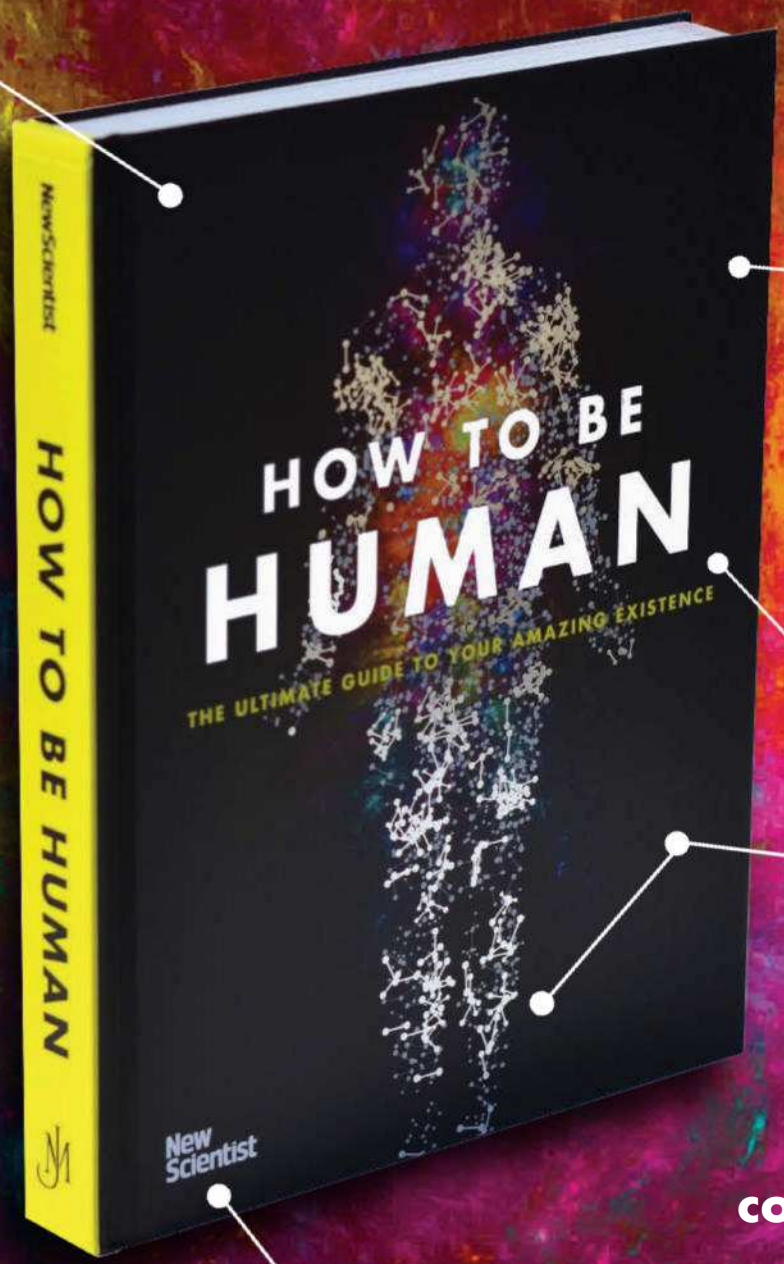

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Black men left out of cancer trials

Ian Graber-Stiehl

PROSTATE cancer is 60 per cent more common in African Americans than in Caucasians, and black Americans are twice as likely to die from the disease when they get it. Yet black men are less likely to be included in clinical trials of cancer drugs – and accidental biases seem partly to blame. As a result, we don't know how new drugs affect these men.

Speaking at a meeting of the American Society for Clinical Oncology in Chicago this month, Susan Halabi of Duke University in North Carolina says her team found that black men make up only 12 per cent of the participants in phase 3 clinical trials – the type that is most crucial for drug approval. They make up around 15 per cent of men in the US.

Social and cultural factors have long been blamed for the low participation rate, but researchers are beginning to understand that the way prostate cancer trials are run may be biologically biased.

Before a trial starts, researchers decide on exclusion criteria. These are usually health issues that could skew findings on any ill effects a novel drug may have. By testing a treatment in the fittest possible individuals who have a particular condition, the trial has the best chance of detecting any positive effects.

Earlier this year, Marie Vastola at the Dana-Farber Cancer Institute in Massachusetts and her colleagues found that two common exclusion criteria are biased against black men. One is the amount of serum creatinine in the blood – a measure of kidney health. Black men can naturally have higher levels of this, making them more likely to be excluded.

The second is absolute neutrophil count – a measure of a type of white blood cell.

"The health of black men, for instance cholesterol, can bar them from equal access to clinical trials"

This is used as a proxy for immune health. But black men tend to have counts that are lower than average, due to a condition called Benign Ethnic Neutropenia (BEN).

Vastola and her team found that nearly half of all prostate cancer trials use at least one of these criteria. A quarter of trials use serum creatinine, and more than a quarter of these don't adjust their metrics to account for these differences in black people.

PAOLO PELLEGRIN / MAGNUM PHOTOS

Another study came to a similar conclusion about neutrophil counts eight years ago, stating that automatically excluding people because of BEN is not medically justified and can reduce minority participation in trials. Vastola's findings suggest that not much has changed since then.

The problem goes further. Halabi's team has found that the health of black men can also bar them from equal access to clinical trials. High blood pressure, blood sugar and cholesterol are all traits that are more common in black men. Clinical trials will often use these to refine their participants to healthier people. But if these parameters were loosened, more people might die during trials.

Drug trials need a mix of people or the results can't be generalised

"It's a fine line," says Sumanta Kumar Pal, an oncologist at the City of Hope Medical Center in California. "We don't want to make eligibility so relaxed that we put patients in danger."

Until prostate cancer drugs are tested in groups that represent the general population, the findings cannot be generalised beyond the predominantly white men participating in trials. ■

Weird rock towers were built by bacteria

ROCK "chimneys" that tower 3 to 4 metres above a lake in California may have been built by microorganisms.

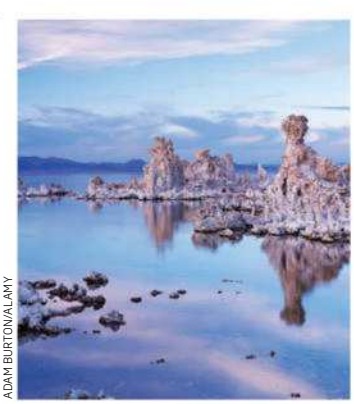
For many years, scientists studying the towers in Mono Lake have debated whether they formed by a chemical process or whether single-celled microorganisms played a role.

Alexander Brasier at the University of Aberdeen, UK, and his colleagues visited the lake to examine the towers. They saw that each was built of numerous pipes made of a mineral called calcite.

The team found fossilised bacteria in the pipes (*Geobiology*, doi.org/cq9z). Such bacteria often live in dense colonies, which are called biofilms and look like mats of slime. The slime forms because the cells secrete a mix of goopy chemicals. This helps explain how they could drive the formation of chimneys.

The process starts when water bubbles up through vents in the lake bed. Colonies of bacteria grow around this water, enclosing it in a tube, and the organic matter they produce sticks to calcium, binding it together. When the bacteria die and the slime breaks down, the calcium crystallises into calcite around the dead cells. Over time, the tube-shaped mats of bacteria would give rise to tubes of calcite, which would grow taller and taller.

If the Mono Lake towers formed this way, it suggests they are a marker of life. For instance, if similar towers could be found on Mars, it would imply that life once existed there, even if it has long since died out. Michael Marshall ■



ADAM BURTON/ALAMY

The strange landscape of Mono Lake in California

Moth uses magnetic field to navigate

AN AUSTRALIAN moth uses Earth's magnetic field to find its way across the continent. While other insects have been shown to navigate using this field, the moth is the first to have been discovered doing so over long distances and at night.

Like the famous monarch butterflies in the Americas, Bogong moths (*Agrotis infusa*) make an epic migration. In spring, about 2 billion leave their breeding grounds on the dry, flat plains of south-east Australia and fly more than 1000 kilometres to a set of 50 caves high in the Australian Alps. In autumn, they return to the plains, where they reproduce and die.

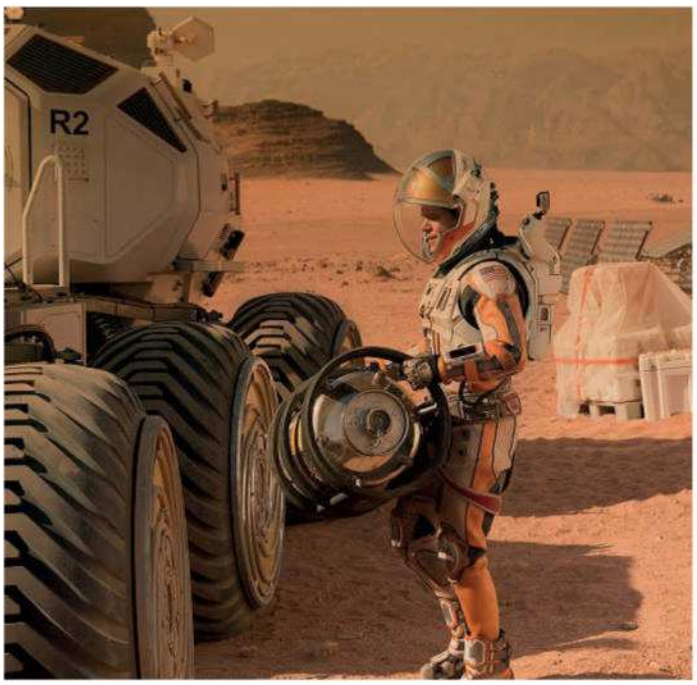
Eric Warrant at the University of Lund, Sweden, and his colleagues studied how the moths find their way. They trapped moths and placed them one at a time in a flight simulator where they could watch them closely. The simulator was blank inside except for two simple visual landmarks. It was fitted with magnetic coils so the team could manipulate the magnetic field within.

The researchers had assumed that the moths used celestial cues to navigate, such as the stars and moon. They found that if the visual and magnetic cues both directed the moths to fly in a particular direction, they did so. But if the cues were contradictory, the moths became disoriented (*Current Biology*, doi.org/gdpdmb).

"When we disrupted the relationship between the magnetic and visual cue, they totally lost it, and it was as if the visual landmark had disappeared," says Warrant. "They flew hard, but in the wrong direction."

Warrant thinks the magnetic field is the most reliable guide for the moths, because it doesn't change, but that they check visual landmarks as well.

It's not yet clear how the moths do it. Warrant suspects the magnetic sensor is an eye protein called cryptochrome 4, which is sensitive to magnetic fields. Michael Marshall ■



20TH CENTURY FOX

Surviving on Mars is no walk in the park – just ask Matt Damon

Bacteria could help build Mars habitats

Michael Le Page

PACKING bacteria could be the best way for humans to survive on Mars. Colonists could use "living" self-healing materials to build habitats, make them airtight with rubber grown by *E. coli* cells and power them with batteries made of bacteria.

Lynn Rothschild at the NASA Ames Research Center in California thinks synthetic biology is the key to making a home on other planets. It could allow materials and even machinery to be grown locally rather than have to be brought all the way from Earth.

Her group at NASA has been exploring the feasibility of this approach with the Stanford-Brown iGEM team. This group of undergraduates is taking part in the international Genetically Engineered Machine competition.

Rubber is one key material Mars colonists will require to create habitats and spacesuits. On Earth, it is either extracted from rubber trees or made from fossil fuels. On Mars, it could be produced by genetically modified *E. coli*.

Several iGEM teams have managed to get *E. coli* to make rubber by adding genes from the rubber tree. But this rubber can only be extracted by breaking open the cells, which requires chemicals that Mars colonists wouldn't have. To get around this, Rothschild's group has engineered *E. coli* to make rubber on the outside of their cells, so there is no need to break them open (*bioRxiv*, doi.org/crd6).

"Rubber for habitats and spacesuits could be made on Mars by genetically modified *E. coli*"

The group has also created self-healing plastics by encapsulating a glue-making bacterium called *Bacillus subtilis* within them. These bacteria form spores that can survive long periods with no food. NASA has shown the bacteria can survive in this state for at least six years in space.

While the plastic is intact, the bacteria should remain dormant. But if cracks expose the spores to light or oxygen, they should awaken, begin feeding on nutrients included in the plastic and start making glue. Once the cracks are sealed, they should become dormant again.

"This technology is promising," says material scientist Gregory Odegard at Michigan Technological University. Current self-healing materials have capsules of liquid glue that break and fill cracks if the material is damaged, he says, but this works only once at any one place in the material.

The bacteria could heal repeated cracking events, says Odegard. "For deep-space exploration, spare parts will not be available, and repeat healing cycles may be necessary."

The team is also trying to create batteries made from colonies of *E. coli* that all pump ions in one direction and therefore generate an electric potential. The idea is to find a replacement for the lithium ion batteries used to store solar energy on the International Space Station. These batteries are heavy, potentially dangerous and would be difficult to manufacture on other planets.

Rothschild thinks future colonists of other planets will use modified organisms to produce everything from food to fuel, alongside clothes and building materials. They could even tweak the organisms they take with them as necessary. For instance, if someone fell ill and needed a drug that wasn't available, people on Earth could transmit the DNA recipe needed to create an organism that could make it. ■

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Meet Kraken, the ancient galactic monster in our midst

AFTER the Milky Way began to form, it merged with about 15 other galaxies to create what we see today. A study of star clusters has identified three of them: two that are still being absorbed, and a bigger one that hadn't been known before – now nicknamed Kraken.

Globular clusters are dense groups of old stars found in most massive galaxies. The evolution of these clusters depends on their original environment. Clusters formed in different galaxies have a different ratio of heavier to lighter elements, known as metallicity. By measuring a cluster's age and metallicity, it is possible to estimate the mass of the galaxy where it originally formed.

Diederik Kruijssen at Heidelberg University, Germany, and his colleagues homed in on 35 globular clusters in the Milky Way that are less metal-rich, indicating that they originally formed in lower-mass galaxies. They divided these clusters into three "branches", representing three galaxies the Milky Way has devoured.

One branch has a much lower metallicity than the others, probably corresponding with the Sagittarius dwarf galaxy, which the Milky Way is still absorbing. The second is associated with a galaxy called Canis Major. The third is from the new discovery, Kraken. It was probably about one-tenth the mass of the our galaxy and was the most massive galaxy the Milky Way ever swallowed (arxiv.org/abs/1806.05680).

Cocaine in water makes eels hyperactive

EELS exposed to traces of cocaine in water become hyperactive and experience muscle damage. They may struggle to complete their long migration as a result.

The finding adds to evidence that drugs in fresh water can harm wildlife, even at low levels.

Anna Capaldo at the University of Naples Federico II in Italy and her colleagues studied European eels (*Anguilla anguilla*). They had previously found that cocaine accumulates in the eels' flesh and affects their skin and hormones.

The team kept 150 eels in tanks for 50 days. Some of the tanks contained a low level of cocaine, just 20 nanograms per litre, akin to that found in some rivers. The rest held tap water.

Those exposed to cocaine were hyperactive, swimming faster than the control eels. The researchers found that exposed eels' skeletal muscle, which powers swimming, was swollen and some muscle fibres were broken. This damage was still there if the eels had been allowed to recover in cocaine-free water for three or 10 days (*Science of the Total Environment*, doi.org/cq68).

Since cocaine accumulates in the eels' flesh, people who eat them will be consuming low levels of the drug – although probably not enough to have any effect.

Gut bacteria may wire young brains

A LACK of "good bacteria" in childhood could change the way the brain develops – if they affect people the same as they do mice.

Changes in gut bacteria have been implicated in several types of mental illness, but it is unclear whether these changes are cause or effect. Now a lack of certain gut bacteria has been found to cause faulty patterns of connections between brain cells in rodents. The microbes are a group called *Bifidobacteria*, among the most common in babies and children.

James Versalovic at Baylor College of Medicine in Texas bred mice with no gut bacteria, then put *Bifidobacteria* into one group. By adulthood, the brains of mice lacking gut bacteria had an unusually large number of connections. The findings were reported at the American Society for Microbiology Microbe conference in Atlanta, Georgia, earlier this month.

Red meat raises endometriosis risk

WOMEN who eat less red meat have a lower risk of endometriosis.

The condition occurs when tissue from the uterus spreads to places like the ovaries. It affects one in 10 women of reproductive age and can result in infertility. Its cause is unclear, but may relate to excess levels of the hormone oestrogen. Red meat is thought to affect oestrogen levels.

Holly Harris at the Fred Hutchinson Cancer Research Centre in Seattle and her team tracked 80,000 women for 22 years. They found two servings of red meat a day raised the risk of having endometriosis by 56 per cent compared with those eating no more than one serving a week (*American Journal of Obstetrics and Gynecology*, doi.org/crbc).

Birdy song was a hit 1500 years ago

YOUNG swamp sparrows learn the notes of birdsong and copy them, passing the refrains down the generations. Some tunes may go back more than 1000 years, a simulation reveals.

Stephen Nowicki at Duke University in North Carolina and his colleagues recorded 615 adult swamp sparrows in marshes in New York's Hudson valley. The birds memorise the songs they hear in the first eight weeks of life. The following spring, they develop precise renditions of around three specific clusters of notes.

These final chirps are winnowed down as the birds listen to the songs around them. More common note clusters are copied more often, the rarer ones less so until they fade away. Sometimes, the young learn from specific tutor birds that may sing more often, or from males with larger territories. They may also copy songs that are easier to sing.

Nowicki and his colleagues developed a model based on the frequency, vibrato and length of the recorded songs. Factoring in the possibility of song mutations arising through error or innovation, or migrating birds introducing songs, their simulations showed that the average age of the oldest note cluster in swamp sparrow song was 1537 years (*Nature Communications*, doi.org/gdnf6k).

ROBERT LACHLAN

Plastic bandage is designed to plug wounds on battlefields

IT'S hard to patch up a bleeding wound on a battlefield. If it's not on a limb, a tourniquet won't help, gauze doesn't absorb enough blood and many blood clotting agents can leave residue behind, resulting in potentially dangerous side effects. A new material that's bendable, easy to apply and remove, and incredibly absorbent may help fix that.

A US Army study found that 80 to 90 per cent of "potentially survivable deaths", in which US soldiers on the battlefield did not make it to a hospital in time, were due to uncontrolled bleeding. Army researcher Erich Bain and his colleagues set out to make a new type of bandage that would control bleeding better to buy more time.

Their material starts with a plastic made of polystyrene and rubber, to which acrylic acid is added. The plastic is strong and flexible, so the bandage can be applied without ripping and removed without leaving anything behind. The acrylic acid is very absorbent, sucking water out of blood to help it clot more easily. Finally, the material is attached to some gauze containing a clotting agent.

In tests, the bandage absorbed two to four times as much water as the gauze alone – up to 800 per cent of the material's weight in water. Death from bleeding can be rapid, so the bandage must work fast. It swelled to its maximum absorption in under a minute.

It will probably be a few years before the material is used in combat. The next step will be animal testing (*Macromolecules*, doi.org/crcv).

Control diabetes with an espresso

A CUP of coffee after a meal might be enough to keep diabetes under control, thanks to cells that have been engineered to release insulin when they detect caffeine.

Type 2 diabetes develops when the body loses its ability to regulate glucose levels in the blood. Some people manage this by frequently measuring their blood sugar levels and adjusting the supply of insulin from a pump worn against the skin.

Meal times are taxing, because people must estimate the sugar they consume and schedule an appropriate dose of insulin. To get around this, Martin Fussenegger at ETH Zurich, Switzerland, and his colleagues have developed an alternative powered by coffee.

The team took human kidney cells and engineered them to produce insulin. They added a receptor that would trigger the release of insulin when caffeine was present, then implanted these cells into 10 mice with type 2 diabetes, and gave them coffee with their meals.

Tests showed this was enough to allow the mice to control their blood sugar levels as effectively as non-diabetic mice (*Nature Communications*, doi.org/crct).

UTE MANS/PLAINPICTURE

A jumper's stretch is all about friction

PULL a comfy, knitted top and it seems to stretch – but close analysis reveals the secret of its give is in the way its stitches "slip".

"You can take your grandmother's scarf and you can stretch it double the length, but the yarn itself doesn't stretch. This is the paradox," says Frédéric Lechenault at École Normale Supérieure in Paris.

Lechenault and his team made a bit of pullover-like fabric using a nylon thread that doesn't warp or twist. One edge was clamped and the other repeatedly pulled as far as it would stretch, then released before being stretched again.

The material had an elasticity a bit like rubber, eventually pinging back to its original shape. The researchers found this is due to the way interlocked stitches spread friction through the fabric. When yanked, the yarn experiences friction in a stick-slip motion: one stitch sticks a bit to its neighbour until the tension is high enough for it to slip. This happens in a cascade.

When the yarn is released, the force lessens, and the stitches return to their original position (*Physical Review X*, doi.org/crc4).

MAIN STAGE

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COSMOS STAGE

DEFENDING EARTH FROM ASTEROIDS

EXOPLANETS, ON THE HUNT OF UNIVERSAL LIFE • THE FATE OF THE COSMOS

GRAVITATIONAL WAVES: SIRENS OF THE COSMOS

JOURNEYS INTO PARTICLE PHYSICS • THE DARK SIDE OF THE UNIVERSE

EARTH STAGE

HOW NATURE IS THRIVING IN THE HUMAN AGE

HOW PRIMATES AND ELEPHANTS PREVENT CLIMATE CHANGE

PLANET ON A PLATE - HOW FOOD CONNECTS US WITH EVERYTHING

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THE SCIENCE AND ART OF THRILL RIDES • THE WORLD'S MOST POWERFUL LASER

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GUT HEALTH: THE SECRET TO HAPPINESS?

IS AUTISM A GIFT? • OBESITY: WHO IS TO BLAME?

GOOD HALLUCINATIONS • WHAT MAKES YOUR BRAIN HAPPY?

PREVENTING AND OVERCOMING CHRONIC PAIN • CAN YOU LIVE FOREVER (AND WOULD YOU WANT TO)?

TECHNOLOGY STAGE

HOW QUANTUM SENSORS CAN IMPROVE OUR LIVES

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The fading American dream

Suicide rates are on the rise in the US at a time when other rich nations are recording a decline. What has gone wrong, asks **Andy Coghlan**

SOBERING statistics published earlier this month show that the annual rate of suicide in the US has risen by almost 28 per cent between 1999 and 2016.

A number of explanations have been put forward, including the 2008 economic crash, the upsurge in addiction to opioid painkillers and the migration of manufacturing jobs to other countries. But none alone explains why the suicide rate is rising so fast in the US as it falls in other rich countries. Is something uniquely American at work?

Figures from the US Centers for Disease Control (CDC) show the country's rate of suicide was 15.6 per 100,000 population in 2016, up from 12.2 in 1999. Of all the states, Montana fares worst, with a rate of 29.2 per 100,000. The global average rate in 2016 was 10.6, according to the World Health Organization.

For comparison, the rate for the UK in 2016 was 8.9 per 100,000, down from 9.1 in 2000, according to the latest WHO data. And although rates are much higher in Russia, at 31 per 100,000 in 2016, this is a dramatic fall from 52.6 in 2000. Clearly, the US is something of an outlier.

Globalisation and automation, which are driving job losses in the US, may partly be to blame, but the same pressures have affected all Western economies without a similar increase in the suicide rate.

"The US rate of suicide was 15.6 per 100,000 population in 2016, up from 12.2 in 1999"

People who work in mental health and suicide risk contacted by *New Scientist* argue that some distinctive elements of US culture may help to explain the rise. "I think the US is unique in a few respects," says Julie Phillips of Rutgers University in New Jersey, who studies suicide risk.

Montana has the highest suicide rate in the US

One of the key drivers could be the American dream itself – the idea that you can work hard and climb out of poverty. A growing mismatch between the life expectations this brings and the increasingly bleak reality for many US citizens could lead to hardship.

This may be particularly felt by middle-aged white Americans, who have the highest suicide rates and the steepest rises. The American dream is deeply ingrained, but it no longer seems to be true for working class, middle-aged people, says Phillips. "I think this disjuncture between norms, expectations and reality is one important factor behind the increase."

Troubled times

This group is also more likely to be negatively affected by divorce, lower education levels and economic inequality. Among US adults over 50, the divorce rate has doubled since the 1990s, says Phillips. In 1999, suicide rates for middle-aged people with a high-school diploma or less were 1.7 times greater than those with a college degree. By 2013, this difference in risk had risen to 2.4 times greater.

It is also likely that recent events, such as the 2008 financial crash and the current opioid painkiller crisis, are contributing to the rise in the suicide rate. "We know suicides increase in times of economic turmoil," says Deborah Stone of the CDC, and lead author of this month's report. "Data also indicate that opioid prescribing rates are higher in counties where there are higher rates of suicide."

Strong individualism in the US and the lack of social welfare schemes found in many other rich countries may also play a role.

Evidence for this comes from a 2013 report that showed people in the US die earlier than those in comparable nations, though not necessarily from suicide. The joint report by the US National Research Council and the Institute of Medicine revealed that by almost every measure, people in the US were unhealthier and more likely to die prematurely than those in 16 other rich nations.

"The problem has deep roots," says Steven Woolf at Virginia Commonwealth University, who headed up the report. "We believe living conditions are producing a growing sense of desperation that's causing people to turn to drugs and alcohol and, when all hope is lost, suicide."

The report also highlights the fact that, unlike the US, governments of rich nations such as Finland, France and Belgium promote healthcare through non-medical support, including housing, education and social insurance. "The US spends plenty, but we spend differently," says Laudan Aron at the Urban Institute in Washington DC.

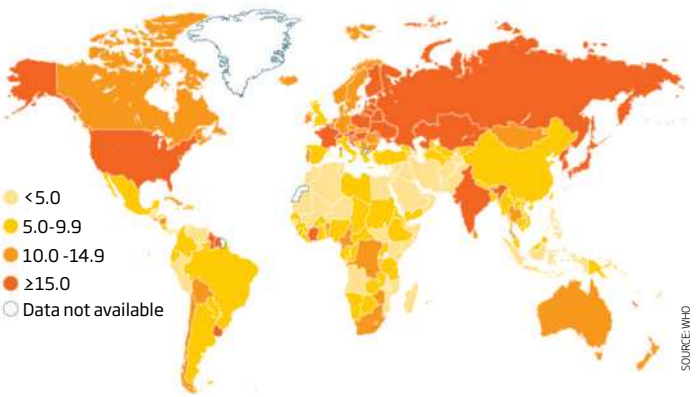
This rejection of the state and the prioritising of individual rights, no matter the potential costs, runs right through US culture. It explains why people in the US are more likely to indulge in risky behaviours such as over-eating and gun-related activity, and tend to defy safety-based but restrictive norms such as wearing seatbelts. So could this attitude also be behind US suicide rates?

Stone agrees it may have played a part. "It is possible that the culture around individualism and stigma around seeking help does leave people vulnerable, perhaps more so than in other Western countries, but that needs additional study," she says.

Others are more convinced. "The group most affected – less educated, white, middle-aged males – grew up with certain norms surrounding masculinity and self-reliance, and this group doesn't seem to be seeking help," says Phillips.

Global suicide rates

The US has one of the highest rates of suicide per 100,000 population in the world



To redress the increasing rates, Stone says the CDC has issued guidance on preventing suicide. It has recommended social and economic support measures such as providing financial help with paying rent, teaching skills for coping with stressful events and relationship problems, and encouraging a sense of belonging and social connectedness among vulnerable people (see "Reporting suicide", left).

"Less educated, white, middle-aged males are most affected by suicide, but aren't seeking help"

But Woolf says more radical interventions are needed. "Policymakers need to address widening social inequalities that are placing a vice on the middle class, and relieve the distressful living conditions that are driving people to their deaths," says Woolf. Instead, they are doing the opposite. "Current elected officials are pulling funding out of such programmes and enacting new policies which, if anything, will tighten the vice," he says. ■

Need a listening ear? UK Samaritans: 116123 (samaritans.org), US National Suicide Prevention Lifeline: 1 800 273 8255. Visit bit.ly/SuicideHelplines for hotlines and websites for other countries.

REPORTING SUICIDE

The recent deaths by suicide of celebrity chef Anthony Bourdain and designer Kate Spade have highlighted the risk that reporting such deaths inspires copycat suicides. "There are already reports of spikes in calls to hotlines in the wake of the suicides," says Laudan Aron of the Urban Institute in Washington DC.

There is some evidence of upticks in suicide rates following celebrity deaths. An analysis in 2011 of 10 studies covering 98 celebrity suicides found that, on average, suicide rates increased by 0.26 per 100,000 population in the month following a death. The increase was higher in a particular region when the celebrity was well-known there: 0.68 in Europe, with similar rises of 0.64 and 0.58 in North America and Asia.

"There's definitely a social aspect to suicide," says Aron, which is why news outlets are encouraged to report on the issue with care.

Social media may be less restrained. "[It] can exacerbate bullying, romanticise suicide and provide harmful content about suicide methods," says Deborah Stone of the US Centers for Disease Control. But it can also support people who are at risk. "It can be used to enhance connections between people, correct myths about suicide and facilitate access to help," says Stone.

Penalties for fair play

A new format for future football World Cups raises the risk of teams colluding. There is a simple fix, says **Ignacio Palacios-Huerta**

AS THE round-robin group stage of the World Cup draws to a close, football fans might want to pause for thought. This might be the last contest to feature a four teams per group format. What will replace it could make the contest less fair.

The 2026 World Cup will open with 16 groups of three teams, and this may also apply in 2022. Julien Guyon, a mathematician, has pointed out that this raises the incentive for teams to collude.

Collusion is already possible in a four-team group. Two teams playing each other in their last group game may know exactly what result will let both advance to the knockout stage at the expense of another team, based on earlier results. FIFA, the sport's governing body, stages final group games simultaneously to mitigate this.

Basic calculations show that moving to three teams per group will in principle worsen the risk

of collusion. Three teams means fewer games, but a proportionally greater number of problematic outcomes are possible. Matches will also have to be sequential.

What to do? FIFA could play the entire tournament on a knockout basis. It would solve the problem, but also mean half the countries playing just one game. If FIFA insists on three-team groups, though, another suggestion is to ban draws by introducing group stage penalty shoot-outs. This would eliminate many scenarios that create incentives to collude.

Unfortunately, this is not fair. Winning a shoot-out after a drawn game does not seem equivalent to winning a game. But there is a simple and sensible variant.

Currently, a win is worth 3 points to the winner and 0 to the loser, while in drawn games both teams get a point. This makes drawn games less valuable in

Flight of fancy?

Planes that run on electricity, rather than fossil fuels, are on the radar, says **Peter Wilson**

TO UNDERLINE its ambition to make all domestic flights electric by 2040, Norway recently showcased a two-seater electric aircraft produced by Avinor.

The demonstration attracted a lot of attention and renewed talk of Norway's bold deadline for the skies, the one domain that has so far largely eluded electrification.

Yes, there was Solar Impulse, powered solely by the sun, and other experimental aircraft. But they aren't mass transit solutions.

Other modes of transport are way ahead when it comes to electric power. By 2025 in Norway, all new cars must be electric. Ships are switching to electric drives, albeit often with diesel generation, and trains are routinely electrified. This is all made possible by high-efficiency electric motors, often combined with advanced batteries. For these forms of transportation, the future is bright.

The reason for the slow progress in aviation can be summed up in one word: energy. The advantage of most conventional propulsion is that liquid fuels can pack far more energy density than even the best batteries. In practice, an electric vehicle has a range

"Norway has a bold ambition for the skies: it wants its domestic flights to be electric by 2040"

defined by how much energy it can carry. For aircraft that is a big deal. Until battery technology improves by an order of magnitude (at least), hopes of large-scale commercial electric flight will be held back by very limited capacity and range.

So is Norway's target realistic? We have seen significant gains in battery performance in recent years in mobile devices and cars, and there are some exciting potential technologies that may offer further improvements, such as solid state batteries. With each step forward in energy storage technology, the likelihood of commercial

terms of overall points awarded.

To equalise things, we could give the winner of penalty shoot-outs in drawn games 2 points, and the loser 1 point. Having 3-2-1-0 possible points in a match means many more combinations of potential points, and this reduces the share of outcomes that might induce collusion. As for the problematic ones that remain, collusion is harder because in many cases teams would have to collude not only on drawing but also on who wins the shoot-out.

To ensure fairness, the shoot-outs must follow the ABBA sequence, rather than the traditional ABAB. My research has shown that the latter gives a psychological advantage to the team that shoots first.

So, potential for collusion exists with four teams per group and gets worse with three. It will never be eliminated unless we move to a full knockout system, but under the 3-2-1-0 point system it would be greatly reduced. Fairness would improve and the shoot-outs in drawn matches will make the beautiful game more exciting. ■

Ignacio Palacios-Huerta is a professor of management at the London School of Economics and author of *Beautiful Game Theory: How soccer can help economics* (Princeton University Press)

electric-powered flight increases.

With engineers far and wide focused on solving the key challenge of higher energy densities for electric propulsion, it is surely possible that this will happen in my lifetime. These aircraft will be incredibly quiet, powerful and fast. With the huge advantage of planes being emission free at the point of use, the airports and skies of the future could be much cleaner and quieter. If Norway cracks it, the way is paved for the world to follow. ■

Peter Wilson is a professor of electronic and systems engineering at the University of Bath, UK

ANALYSIS Australian space agency

IAN CUMING/GETTY

Australia wants a piece of the space gold rush

Dozens of start-up space firms are already operating across Australia

Alice Klein

AUSTRALIA is launching its space agency this week in an effort to capture a share of the booming space market. The Australian government has committed A$26 million ($19 million) over four years to set up its operations and a further A$15 million ($11 million) over three years to invest in research and development.

The funding is fairly small – NASA has an annual budget of $20 billion and the European Space Agency's is $7 billion – meaning that missions to Mars are off the table. Nevertheless, other countries have set up thriving space programmes with equally limited budgets.

For example, the first successful rocket launch from New Zealand came in January, less than two years after the nation set up a space agency with a $3 million-a-year budget. Its latest was due as *New Scientist* went to press.

Luxembourg also joined the space race in 2016, committing $230 million to support asteroid mining start-ups. Already, US companies such as Deep Space Industries and Planetary Resources have set up European headquarters in the tiny nation.

The UK space sector has also flourished since the launch of a national space agency in 2010. Its annual revenue has almost doubled and the number of people it employs has increased by about 6 per cent a year. The agency's annual budget is £370 million ($490 million).

With the global space economy estimated to have ballooned to $340 billion a year, it is easy to see why the Australian government wants in on this new gold rush. But it has some significant catching up to do: to date, only seven Australian-built satellites have entered space, and all were launched from other countries.

"There is plenty of empty space for launch sites and being near the equator will help rockets reach orbit"

Then again, Australia boasts several advantages. It has lots of empty space for launch sites and its proximity to the equator, where Earth's surface is rotating fastest, means rockets will get a boost into orbit. As well as this, Australia spans one-third of Earth's rotation, allowing it to communicate with satellites over a vast area of sky. And it already has a deep-space telescope designed to track spacecraft on long journeys.

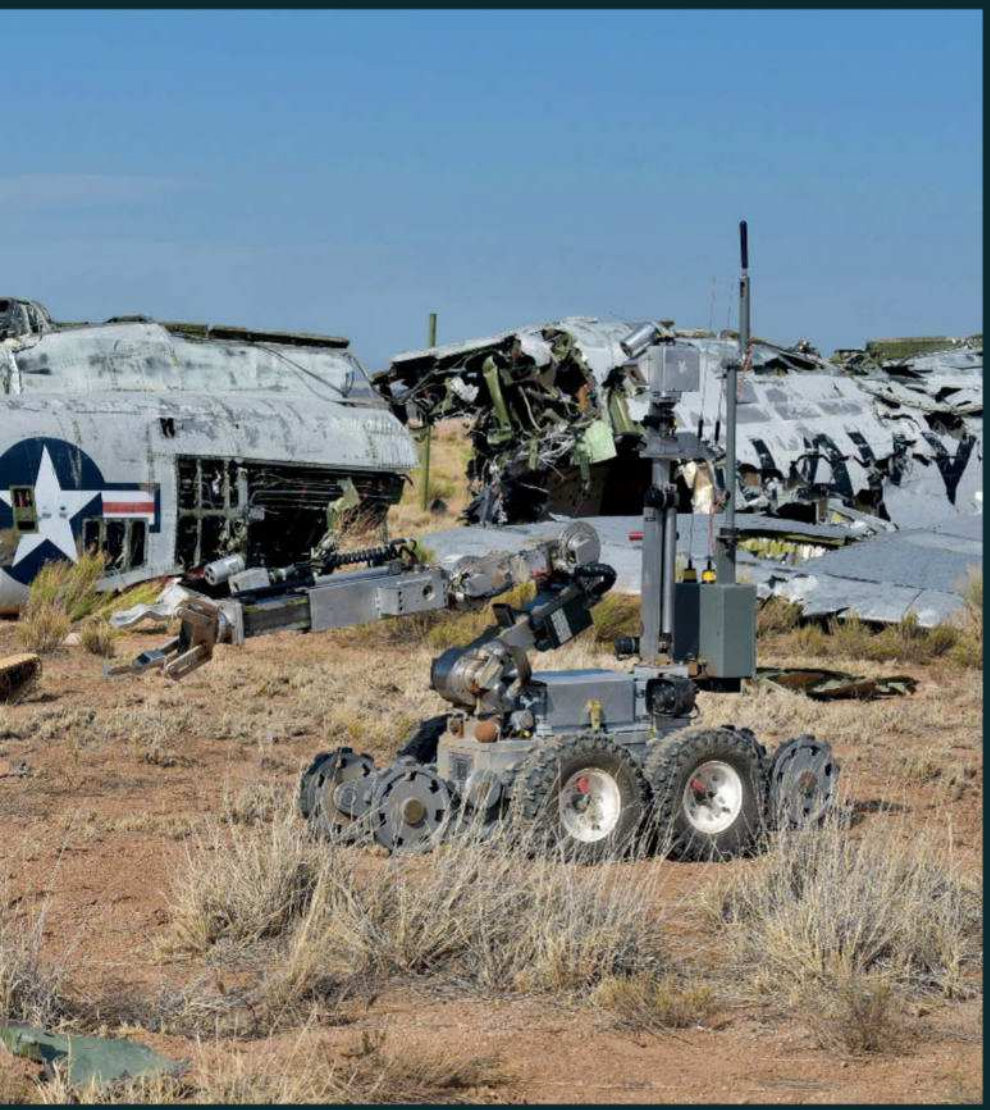
Dozens of space companies have recently popped up in Australia. Adelaide-based Fleet Space Technologies, for example, is building nanosatellites designed to help farmers monitor soil moisture and livestock movements.

Equatorial Launch Australia recently leased 275 hectares in a remote part of the Northern Territory to build a commercial rocket-launching facility. Then there's Sydney-based Saber Astronautics, which has designed a bottle to help astronauts drink beer in microgravity.

Start-ups like these will be able to apply to the Australian Space Agency for seed funding. The agency will help to coordinate their activities and assist with tasks like applying for launch licences. It will also be able to identify opportunities for different projects to collaborate and pool resources.

But perhaps even more importantly, the establishment of a dedicated space agency will inspire the country to think big and to foster innovation and creativity. The initial funding may be modest, but at least it's a foot in the door, and it means that Australians won't be left behind on Earth. ■

A team controls its robot (top left) on the obstacle course (bottom left). Each team had to complete 11 challenges, such as scanning a mocked-up subway station for radiation (middle left, right and far right) and gathering evidence from a downed enemy fighter plane (main image)



Robot rodeo

"WELCOME to Recon Rally. In this scenario, neighbours have been complaining that something smelly is coming from a nearby house. You've been called to the scene. Go!"

This is what you would have heard if you were on one of the eight teams competing in the Robot Rodeo from 11 to 15 June, an annual event hosted by Sandia National Laboratories in New Mexico. In the competition, military and civilian bomb squad technicians must put their skills to the test in various situations they may not regularly encounter.

Most teams used a version of the Remotec Andros, a bomb-defusing robot. As well as four main tyred wheels and a long tread on smaller wheels for extra traction, it has a surveillance camera and a mechanical arm and gripper.

Each team had to complete 10 gruelling challenges over the course of four days, plus a final scenario in which they paired up with another squad they don't usually work with.

One challenge involved collecting evidence and other vital items from a downed enemy fighter plane (main image). In another, teams had to recover hard drives from drones that had attempted to blow up a military truck by crashing into it. A third saw them scanning a fictional subway station for signs of radiation (far left, middle).

"It's stressful," says Zac Cancilla of a team from the Albuquerque Police Department in New Mexico, which won the competition. "We need to complete each scenario in 90 minutes. A post-blast investigation in the real world can take days and days."

Time limits and having only limited knowledge about each situation are meant to put the teams under stress, says Jake Deuel, coordinator of the event. "Our litmus test is if they're not cursing us at some point in the scenario, we haven't pushed them hard enough." Chelsea Whyte

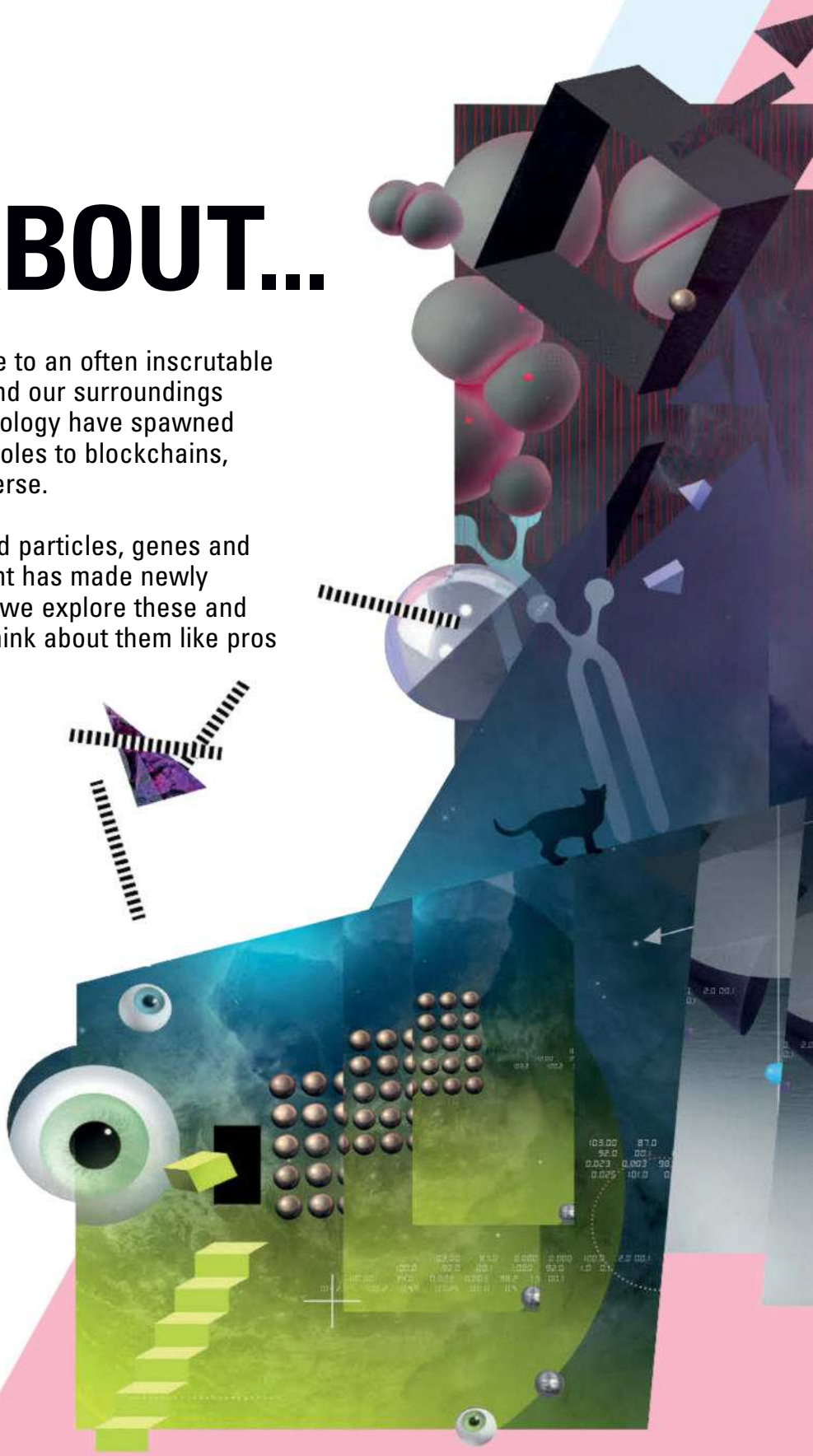
Photographer

Randy Montoya
Sandia National Laboratories

HOW TO THINK ABOUT...

Science is the best guide we have to an often inscrutable world. But in helping us understand our surroundings and ourselves, science and technology have spawned some lofty concepts, from black holes to blockchains, from consciousness to the multiverse.

Then there are ideas, like time and particles, genes and gender, that science's probing light has made newly complex. Over the next 13 pages, we explore these and more – and see how we can all think about them like pros



SKIZZOMAT

01

HOW TO THINK ABOUT...
THE MULTIVERSE

JUST don't say they made it up. "One of the most common misconceptions is that the multiverse is a hypothesis," says Sean Carroll at the California Institute of Technology in Pasadena. In fact, it is forced upon us. "It is a prediction of theories we have good reason to think are correct."

The idea that the already vast universe we can see is just one of perhaps infinitely many we can't is certainly a lot to swallow. And it doesn't stop there. The multiverse itself comes in many guises.

Take the cosmological multiverses. This concept sprouts from eternal inflation, our best explanation for why the universe looks as it does. In the split second after the big bang, the idea goes, space-time expanded ›

exponentially. Random quantum effects brought this inflation to an end in small regions, and these became more sedately expanding bubble universes – like ours – inside a continually ballooning container, budding off more and more bubbles.

Even if we travelled at close to the speed of light, we couldn't reach the boundary of our expanding bubble, says Alexander Vilenkin, a theorist at Tufts University in Massachusetts – let alone cross over into another part of the multiverse. If we could, we probably wouldn't find a place friendly to life like us. "The so-called constants of nature, like the mass of the electron or Newton's gravitational constant, will have different values in different bubbles," says Vilenkin. Or at least so says string theory, our best stab at a theory of everything, which predicts a vast landscape of at least 10^{500} different configurations of physics.

Then there is the quantum multiverse, predicted by the "many worlds" interpretation of quantum theory (see "How to think about… "Schrödinger's cat", page 34). It says that when we make a measurement of the quantum world, forcing it to snap out of its accustomed fuzzy state, the other possible measurement outcomes persist in worlds parallel to our own.

Things get really hairy when you ask where these worlds are. "If the bubble universes exist in the same physical space, the many worlds are truly parallel universes, completely separate from one another," says Vilenkin. "There is a bigger mathematical structure that they're all inside, but in no sense does it look like space," says Carroll.

What's more, copies of ourselves would exist in all these worlds, although their universes would have absolutely no physical connection with our own. So we needn't worry about the fate of our doppelgängers. "Many worlds has no impact whatsoever on my decisions," says Carroll. "You're talking about a person I can never talk to. You might as well worry about the people who live a million years from now, or those who lived a million years ago."

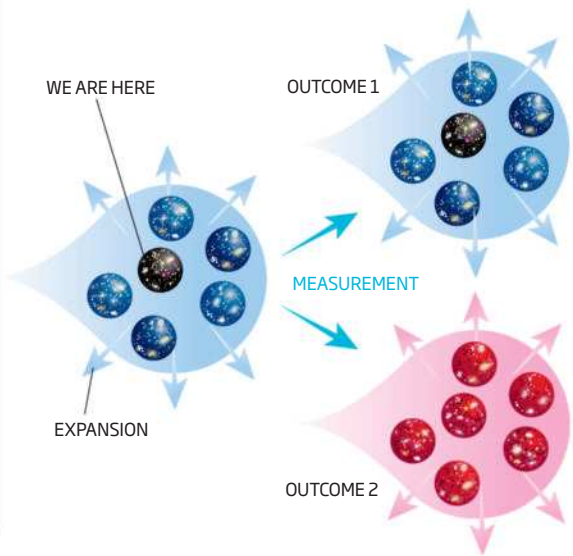
Daniel Cossins

Multitude of multiverses

The idea of many parallel universes pops up in both cosmology and quantum theory

Cosmological multiverse
Breakneck expansion of the universe creates a series of causally disconnected bubble universes separated in space

Quantum many worlds
Every time a quantum measurement is made, the existing multiverse splits into copies containing all the possible outcomes of the measurement



HOW TO THINK ABOUT…

CONSCIOUSNESS

IT IS a concept so intrinsic to the fabric of our reality that starting to pick away at it leaves us feeling quite unravelled. "We can come closer to defining what it is to be an elephant than what it is to be conscious," says Nicholas Shea, who researches philosophy of the mind at the University of Oxford.

Consciousness is the essence of what it is to be "you". It is all your subjective experiences – from the feeling of the sun's warmth on your skin to the desolation of grief – conjured up somehow by your brain. "It still seems to many people, sometimes to me, very hard to see how things happening in the physical world could give rise to any sort of conscious experience at all," says neuroscientist Anil Seth at the University of Sussex, UK.

Explaining this phenomenon has been dubbed the "hard problem", and the worry is that we may be too close to it to ever figure it out. Thinking about consciousness means you have to be conscious – but can the human brain ever understand itself?

Shea thinks so. "It looks deep and complex and intractable, but people are applying the scientific method," he says. One school of thought is that if you can work out the physical brain activity that leads to, say, the visual experience of something being red, then you can generalise to other conscious experiences.

Another approach is what Seth calls a "divide and conquer" strategy. The aim here is to break consciousness down into different types of experience, he says: "what happens when you fall asleep and wake up; the relationship between visual perception and what's really out there; and you can also think about self and emotion." Tackling these problems one by one makes consciousness seem easier to grasp. "If you do that then, after a while, there'll be no remaining mystery," says Seth.

But others believe that even if you could map out the entire brain and what it was doing, you would still be in the dark about consciousness. "When it comes to explaining what it is to be me or you, we seem to want the kind of answer that we don't really ask for

02

in other parts of science," says Seth. That may be because if we can crack how consciousness works, it threatens our sense of self and our notions of free will. "When you start to explain that voluntary actions and the experiences of intending to do things are just another kind of experience that depends on the brain, then you get quite a lot of resistance," he says.

One way out of this rabbit hole, says Seth, is to keep in mind what kind of free will is important. We want to be able to behave according to our beliefs and desires, which is possible no matter where conscious experience comes from. In other words, "I can choose what I want to do, but I can't choose what I want," he says. **Catherine de Lange**

03

HOW TO THINK ABOUT...
TIME

NEVER trust a physicist to tell you the time, says Marina Cortes at the Royal Observatory in Edinburgh, UK. "Physics has a slightly different idea about what time is."

We used to think we had it nailed: time was the tick-tock of a clock somewhere outside the universe against which all processes within it could be measured. This appealing, intuitive idea of an absolute time underpins things like Newton's classical laws of motion, and even the distinctly non-intuitive workings of quantum equations, our best description of the nitty-gritty of reality.

Never mind where these external readings of time would come from, Einstein's theories of relativity blew away the whole idea. Einstein showed that space and time are, well, relative. Both are part of a unified space-time that is warped by both gravity and motion so that no two observers can ever fully agree on what happened when.

The discrepancies are imperceptible to us because we live our whole lives in roughly the same gravitational field and at roughly the same low speeds. We are deceived into thinking time is absolute by an accident of circumstance, says physicist Carlo Rovelli at Aix-Marseille University in France, author of *The Order of Time*. "In our experience, time passes at the same rate. But this is only true in the non-relativistic approximation in which we live."

So rule one in thinking clearly about time: cast off the idea that it always ticks at the same rate. Rule two: be prepared to deny it ticks at all.

In our experience, we are carried in the coracle of an eternal present down an inexorable stream of time from past to future. But physics says "no" to time's flow. Quantum theory indicates that things should work just as well backwards as forwards. Meanwhile, relativity's difficulty putting events in any one unambiguous order leads physicists to suggest that reality is a static four-dimensional block of space-time, in which all of time exists all at once.

Most physicists explain away the illusion that time flows by appealing to the ineluctable rise of entropy (see "How to think about...entropy", page 37). The universe must have started in ›

an implausibly ordered configuration, and what we experience as time is the constant drift away from this state.

So while things may be flowing in the block universe, time isn't. "Time is the direction on that block in which physics tells its most compact, powerful narrative," says philosopher of science Craig Callender at the University of California, San Diego. Reality as we are experiencing it "now" is like the page of a book. "You turn pages in the direction the laws evolve," says Callender.

Sorted? Not quite. Conceptions of time in modern physics are at odds not just with our intuitions, but with each other. That's hardly any surprise, given that relativity and quantum theory famously fail to agree on anything.

"RULE 1: FORGET TIME FLOWS AT THE SAME RATE. RULE 2: FORGET IT FLOWS AT ALL"

A more precise idea of how time works depends on finding a theory of quantum gravity to unify them – still a distant dream.

But that might not matter. "We can use our approximate notion of time in everyday life and it is fine," says Rovelli. "Just like we can think that Earth is flat in everyday life, and that it doesn't rotate." When it comes to deeper answers, your guess is as good as anyone's, says Cortes. "Time is for me the most mysterious aspect of nature," she adds. "If I knew how to think about it, I'd retire."
Richard Webb

KYOSHINO/GETTY

04

HOW TO THINK ABOUT...
PARTICLES

WHEN picturing particles, David Kaiser freely confesses to physically incorrect thoughts. "With great respect to my forebears, I personally still do start off picturing marbles," says Kaiser, a physicist at the Massachusetts Institute of Technology. "Little round objects spinning around and around."

The picture has intuitive appeal. Surely the fundamental particles that make up matter are tiny, indivisible objects with concrete properties such as position and mass? Since the dawn of quantum mechanics, the theory that governs their workings, we have known that particles do spin – or at least possess a property superficially similar to the rotation of spherical bodies that we call spin.

Peer any closer, though, and you rapidly start losing your marbles.

The rot started in experiments that shot supposedly fundamental particles at other particles and saw them shatter – rather unlike what you would expect for indivisible units of matter. In fairly quick succession in the 20th century, atoms turned out to be nuclei orbited by electrons, nuclei turned out to be protons and neutrons, and protons and neutrons got subdivided into even smaller particles, known as quarks and gluons.

But those smaller particles are just smaller marbles, right? Perhaps, except that other quantum experiments show that these particles can sometimes pass through walls, move through space and time without taking a detectable path and be in more than one place at once.

The conclusion we must draw is as simple as it is baffling. Material particles are simultaneously also immaterial waves that, left to their own devices, have no particular position, and can be described only by a probabilistic "wave function". "This is the quantum mechanical aspect of particles," says particle theorist Frank Wilczek, also of MIT. "They have wave-like properties as well as this classic idea of a ball that's in a definite space."

It is a duality no one can quite explain. It is why chemistry textbooks sometimes depict an electron as a point and sometimes as a diffuse cloud orbiting an atomic nucleus.

And it contains a further conundrum. Not only are particles waves, waves are particles. Something as immaterial as a light wave is made of units, photons, that have no mass or charge but nonetheless can sometimes be said to be localised in one place, like an ethereal marble.

PONDS, NOT MARBLES

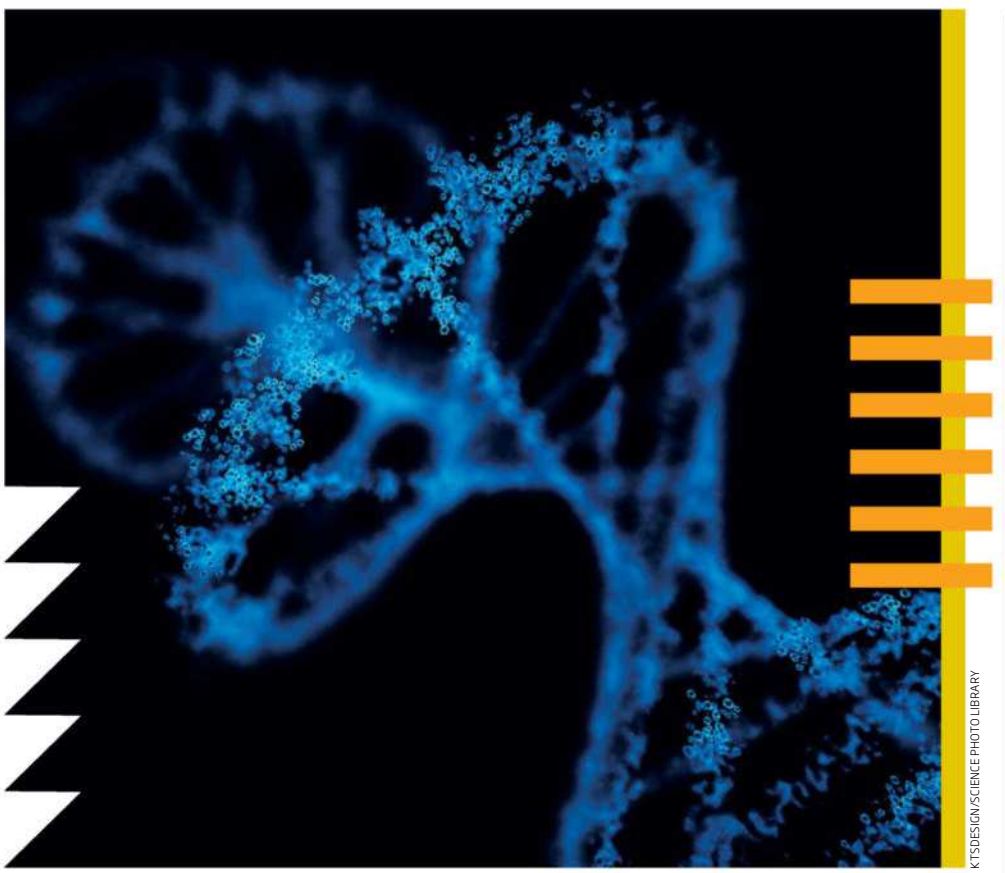
These particles do not constitute matter, but are associated with fields that suffuse space and determine how matter particles behave. Photons, for example, embody the electromagnetic field that acts on electrically charged particles; the invisible Higgs field fills all of space to give particles their mass. Inject enough energy into this field, as researchers did at CERN near Geneva, Switzerland, in 2012, and you prove it exists by getting it to pop out a particle – the Higgs boson.

Ultimately, because matter works on levels we cannot directly see, both particles and fields are just imperfect mathematical crutches to support our understanding of it. But when it comes to the properties of matter, it's fields and the forces they generate that call the shots. They determine why protons and neutrons huddle together in the atomic nucleus, and why electrons, whether diffuse or point-like, orbit it.

So here's a clue: drop the marbles and think of reality as a pond. "The fundamental thing is the water," says Wilczek, "and the particles are disturbances in that water." Whatever those particles are. **Catherine Brahic** and **Richard Webb**

HOW TO THINK ABOUT...

GENES



KTSDESIGN/SCIENCE PHOTO LIBRARY

WHETHER they are humans or pea plants, the way living organisms look and behave is intimately connected with their genes. But ideas of genes and their workings have evolved hugely in the century since the word was coined.

In essence it is simple. "A gene is the stretch of DNA letters that encodes individual functional units or proteins," says Stacey Gabriel of the Broad Institute in Cambridge, Massachusetts. Within our cells, double-stranded DNA is continually unzipped and transcribed into single-stranded RNA, which performs cell functions itself or can be used as a template to assemble the proteins that make us what we are.

As such, genes are basic, universal units of heredity. You generally have two copies of each, one from your mother and one from your father. Each gene has different versions that vary slightly at the molecular level, generating different outward effects – brown or blue eyes, for example.

We long thought there must be one gene for each outward characteristic, but that belief hasn't stood the test of time. The Human Genome Project, completed in 2003, revealed that genes account for just 1 per cent of our DNA; the rest is "junk". We have only 20,000 genes in total – far too few for the one gene, one function idea.

It turns out that genes do different things depending on factors like when and where they are expressed. "Genes can be alternatively spliced, which means that different chunks of them can be encoded into a protein," says geneticist Tim Frayling at the University of Exeter, UK. In other words, rather than a gene coding for only one protein, different bits of the genetic code can get chopped out to create different proteins. All this is regulated by non-gene DNA, RNA molecules and other proteins, further diluting a gene's autonomy in determining a protein.

This means it can be very hard to pin down which genes are responsible for any given thing. "It's very rare that there's a gene for something," says Gabriel – even a trait as seemingly simple as eye colour.

Other discoveries have changed how we think about things, too. A single gene is comprised of segments of DNA, but one segment can contribute to more than one gene, meaning that genes can have overlapping boundaries. In some organisms, segments of the same gene are found far apart, scattered around the genome. In addition, not all genes code for proteins – many simply code for a variety of RNA molecules.

To cap all that there is the emerging science of epigenetics: the realisation that genes can be switched on and off in response to environmental factors such as stress or diet, meaning that the effects of some genes disappear in some generations only to reappear in subsequent ones.

Given all this, is it even useful to think of genes at all? "Definitely," says Gabriel, given all they do. But some people believe we need to redefine them. Petter Portin, a geneticist at the University of Turku in Finland, argues that thinking of a gene as a universal unit of heredity is too simple. "In many situations it would be more helpful to think about genes as small cogs in a much larger machine," he says. **Julia Brown**

HOW TO THINK ABOUT...

SCHRÖDINGER'S CAT

IT IS the most famous case of animal cruelty in physics. Or is it?

When, back in the 1930s, physicist Erwin Schrödinger dreamed up his notorious thought experiment about a cat that is simultaneously dead and alive, he could hardly have imagined how it would enter the popular consciousness. Or how many terrible jokes it would spawn.

How's this for a punchline, though: we still don't know exactly what Schrödinger's cat means. What you make of it will depend on where you stand on the fundamental question of where reality comes from.

In the basic set-up you take a cat and stick it in a box rigged up with a radioactive atom, a hammer and a vial of poisonous gas. The atom decays, and this triggers the hammer to fall and break the vial, suffocating the cat.

Or not. Radioactive decays are random processes described by quantum theory, so we can't say when one will happen. And quantum theory strongly suggests that before you observe or measure an object, it exists in a "superposition" of all its possible states. Before we open the box, the atom is both decayed and undecayed – and the cat both dead and alive.

TWO WAYS AT ONCE

For Schrödinger, this situation highlighted the absurdity of the dominant "Copenhagen" interpretation of quantum theory, which permits things to be two ways at once until a measurement kills off the ambiguity (and possibly the cat). "He was trying to find a hyperbolic example that brought to light conceptual difficulties he was struggling with," says Robert Schoelkopf at Yale University.

It's not just him: the notion is profoundly alien to our everyday experience. "We don't live that way," says Andrew Briggs at the University of Oxford, "in a superposition of having poured the milk on our cornflakes and not."

And there are more fundamental problems. The Copenhagen interpretation implies that an observer "collapses" underlying quantum uncertainty into a concrete reality just by

Who killed Schrödinger's cat?

Inside a sealed box, a random radioactive decay may release poison gas from a vial, killing a cat. If you discover a dead cat when you open the box, how you interpret that finding will depend on your interpretation of quantum mechanics

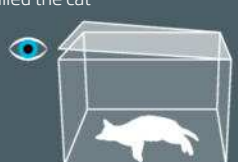
STANDARD (COPENHAGEN) INTERPRETATION

Before observation

The cat was simultaneously alive and dead

On observation

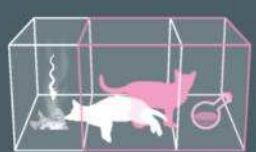
The cat is dead. Your measurement killed the cat



MANY WORLDS INTERPRETATION

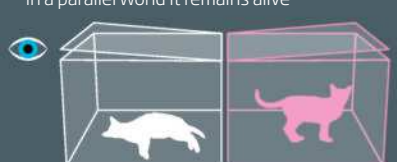
Before observation

The cat was simultaneously alive and dead



On observation

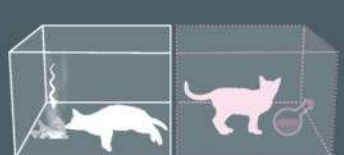
The universe splits. The cat is dead, but in a parallel world it remains alive



QUANTUM BAYESIANISM

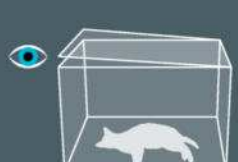
Before observation

The cat is what it is: you just don't know what it is yet



On observation

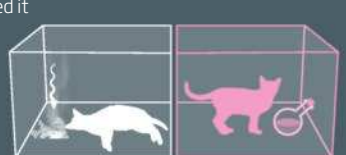
Your brain processes it as dead



OBJECTIVE COLLAPSE THEORY

Before observation

The cat was either alive or dead until spontaneous wave function collapse killed it



On observation

The cat is dead. You don't know when it died

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observing it. Must that observer be human? Would any other organism with conscious thought do? Or a camera on a stick? And how did anything even become definite in the early universe, with nothing around to observe anything? "For me, it is still a profound mystery," says Briggs.

The alternatives certainly have their own wrinkles. The quantum many worlds

"WE DON'T LIVE IN A SUPERPOSITION OF PUTTING MILK ON OUR CEREAL AND NOT"

hypothesis, for example, suggests that at the very moment an observer has enough information to conclude whether Schrödinger's cat is dead or alive, the world sloughs off a parallel universe that contains the alternative outcome (see "How to think about... the multiverse", page 29).

Then there is quantum Bayesianism. According to this idea, the cat's state isn't uncertain, our state of mind is – in which case we must accept fundamental limits on what we know about reality. Vlatko Vedral at the University of Oxford, meanwhile, plumps for objective collapse theory. In this picture, superpositions aren't destroyed by observation; instead, they naturally leak into the surroundings and eventually disappear. Fair enough – but what does that mean for the cat?

We might eventually find out the true state of this indeterminate moggie. Today, experiments suggesting we've put molecules and electrical circuits into superpositions are commonplace. The scale of the delicate quantum superpositions we can maintain is growing all the time. Researchers have even proposed trying out the same thing on viruses, organisms which teeter on the edge of life. "Making macroscopic superpositions could just be a question of money," says Vedral. Then curiosity really might kill the cat. Gilead Amit

07

HOW TO THINK ABOUT...

LOGIC

ALL men are mortal. Socrates is a man. Therefore Socrates is mortal. By inventing logic, Aristotle wound up Western thought and sent it clattering down a 2000-year path to science.

Little of what we know about the world comes from direct observation (see "How to think about... scientific truth", page 40). It is based mostly on drawing inferences from other things we know. Aristotle never had to ID a body to infer that Socrates was mortal. Crick, Franklin and Watson never saw a DNA helix, just its X-shaped X-ray diffraction pattern. Molecules that produce X-shaped diffraction patterns are helical. DNA has an X-shaped diffraction pattern. Therefore DNA is helical.

Logic, from Aristotle's syllogism onwards, gives us scaffolds for trustworthy reasoning that help us structure our thoughts. But logic doesn't by itself guarantee truth. All yellow things are made of cheese. The moon is yellow. Therefore the moon is made of cheese. If your premises are false, your conclusions are likely to be, too.

Pushing the boundaries of logic further into truth is the job of logicians such as Dov Gabbay at King's College London. "When the Almighty created us, he had a big lump of logic and he sprinkled bits of it into our heads," he says. "I regard my job as reconstructing that big lump."

To capture messy human thought more precisely, in the 19th century logicians began to abandon natural language with all its potential ambiguities. George Boole, a self-taught English mathematician, developed a kind of algebra in which variables had truth values – true or false – rather than numerical ones.

That set the course for the next 100 years. Today, Boole's logic is the on-off, 1 or 0 beat at the heart of every digital computer. "Mathematical logic led directly to computing," says Gabbay. "Logic serves computer science in the way that maths serves physics."

That's what you might call applied logic, though. In many a university philosophy department, the pure logicians are still beavering away, burrowing further down into what logic actually can say about truth.

One major work-in-progress is an assumption Aristotle called "the most certain of principles": that things are either true or not true. Inconveniently, this makes conventional logic blow up on occasion. Take the sentence "this sentence is false": is that true or false?

NEITHER TRUE NOR FALSE

Many-valued logics get round this by allowing statements to be true, false, possible – and more. Paraconsistent logics provide ways to deal with statements that are both true and false, contradictions that would yield nonsense in more traditional logic.

As logic evolves, it is becoming closer and closer to what's really in our heads – and, paradoxically, harder to understand. Logic has also suffered as the internet and other media have sped up the spread of emotional arguments, says Gabbay. "Illogical arguments are more effective now than logical ones."

His own pet project is to bring logic out of our heads and closer to our hearts, by developing a formal system of logic, plus rules for reasoning with it, that can capture emotional aspects of argumentation, including personal attacks, appeals to "common sense", straw-man arguments and so on. "All of the things that were considered to be logical fallacies up to now urgently need to be modelled," he says – the next stage in the evolution of logic as our guide to truth. **Douglas Heaven**

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HOW TO THINK ABOUT...
LIFE

MOST people agree that for something to be alive, it must be able to make copies of itself. But by that rationale, a crystal growing in a solution is alive. So biologists studying how life began 4 billion years ago look for characteristics shared by all living things and absent in minerals.

This approach yields three distinct features: all organisms on Earth have a code that, like a builder's blueprint, allows copies to be made (see "How to think about... genes", page 33); they can generate energy to power the copying process; and they have the machinery to build the copies. Crystals have none of these, so are firmly dispatched to the realm of minerals.

This list kicks up other sticking points, however – notably certain parasites. Viruses, the ultimate example, have a code in the shape of DNA or RNA, but rely entirely on the cells they have invaded for energy and copying machinery. The debate over whether they are alive is decades old.

Synthetic biology raises even more basic questions. Floyd Romesberg at the Scripps Research Institute in San Diego has spent 20 years trying to hack life's code. His team has created two "unnatural" genetic letters similar in molecular structure to the five used in all living organisms on Earth: four in DNA and an additional one in RNA. Last year, they used this unnatural code to coax a cell to produce proteins not found in nature.

For Romesberg, this calls into question whether the chemistry of life is any different from inert chemistry. "All you have is parts. All you have is carbon, nitrogen, phosphorus, oxygen," he says. Yet some of these parts end up being living and some don't. "In a really weird way, maybe there's just not that much difference between living and non-living things."

NASA, in its hunt for life on other planets, has its own definition. Extraterrestrial life may look very different but will, it says, be a "self-sustaining chemical system capable of Darwinian evolution". It is a definition that humans might be about to bust. The pinpoint gene-editing method known as CRISPR could soon allow us to place DNA sequences into our eggs and sperm, so creating children that are fitter by design, rather than evolution. If we ever succeed, are we still living things – or have we transcended that state?

Catherine Brahic

NICHOLAS TOH/ALAMY STOCK PHOTO

HOW TO THINK ABOUT...
GENDER

AT FIRST it seems straightforward. After a brief inspection of its genitals, a baby is assigned a gender.

But look more closely, and this simple idea begins to unravel. For a start, biological sex isn't always clear-cut. Around 1 in 2000 people are born intersex, with reproductive organs or sexual anatomy that don't fit the typical male/female pattern.

Beyond biological sex, gender as a concept is also tough to pin down. The term originates from the Latin word genus, meaning "type" or "kind". Before the 1950s, it was only really used to describe different classes of nouns in certain languages. It acquired a new meaning largely due to sexologist John Money, whose work with people who are intersex led him to distinguish between a person's sex, as determined by genes and hormones, and their gender. For him, gender meant the social, psychological and behavioural aspects of being male or female. In the 1970s, work by feminist anthropologist Gayle Rubin helped to morph this into the idea of gender as a social construct, a socially imposed division of the sexes.

Today, the terms "gender" and "sex" are often used interchangeably, and for many people they are synonymous – someone is born female and identifies as a woman, for instance. But some people, often from a young age, have a strong sense of being a different gender to the sex they were designated at birth: a study in 2016 concluded that 0.6 per cent of US adults identify as transgender. Some people don't identify as either gender.

The extent to which this gender identity – our internal sense of being male, female, neither or both – is down to nature or nurture is a hot research topic, and dominates much of today's

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thinking about gender more generally. How much of, say, men's supposed talent for engineering is down to biological factors such as a male fetus experiencing a surge of testosterone in the uterus, and how much is due to societal conditioning?

Studies often show that things regarded as biological facts of life aren't straightforward. Take the idea that boys are more active than girls, and that girls are better talkers than boys. Anne Fausto-Sterling, a biologist specialising in gender development who recently retired from Brown University, Rhode Island, has shown that mothers engage male babies in more physical activity than girls, and talk more to their daughters than their sons. "Mothers are bringing a social sense of gender into the way they play with their babies, and this affects the development of the baby's nervous system," she says.

IN THE SAME BUCKET

Clear biological boundaries between men and women are difficult to define, as the International Association of Athletics Federations discovered following the case of Caster Semenya, a female South African runner with unusually high testosterone levels who won the 800 metres world title in 2009. There is also no clear distinction between male and female brains. "Whatever brain measure we look at – structure, connections, activity – there is way more overlap than difference between male and female brains," says neuroscientist Lise Eliot at Rosalind Franklin University of Medicine and Science in Chicago.

So perhaps it is time to ditch binary thinking about gender. "Gender differences fall on a continuum, not into two separate buckets," says Fausto-Sterling. **Alison George**

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HOW TO THINK ABOUT...
ENTROPY

PLACE 20 coins, heads up, on a tray and film it as you give it a shake. Then play the film backwards. From a jumbled mess, the coins all jump and come to rest with the same side up – an unreal, slightly creepy sequence. "It seems like a mundane observation, but actually this is very profound," says physicist Sandu Popescu at the University of Bristol, UK.

This little experiment illustrates the power of perhaps the most essential, implacable field within physics: thermodynamics, the science of heat, energy and, most crucially, entropy.

The roots of thermodynamics lie in efforts to understand the steam engines that powered the industrial revolution of 18th and 19th-century Europe. The French engineer Sadi Carnot realised that their heat always tends to dissipate, moving to cooler regions. Anything that goes against this grain requires additional energy to power it.

This movement from hotter to cooler is an expression of a more fundamental drive in the universe: disorder, as measured by entropy, always increases. The specifics don't matter – heat always flows, flipped coins always jumble, burning logs always turn to ash. "If we discover a new force tomorrow, thermodynamics will be fine," says Jonathan Oppenheim at University College London.

Entropy increase is so universal that many physicists propose it is why we see time flowing (see "How to think about time", page 31). It is certainly why our hearts must constantly pump blood, supplying our cells with energy as a temporary stay against the inevitable onset of decay and disorder.

Is there any way out? Perhaps. The laws of thermodynamics only hold true as statistical averages. As a result, some see an escape route from entropy's inevitable rise in the small-scale workings of the quantum world: rules based on statistics don't mean much when you're dealing just a few particles.

There are concepts akin to entropy that tend to increase in the quantum world, says Oppenheim – uncertainty over a particle's position, for one. The science of quantum thermodynamics is in its infancy, and any hopes of using its fuzzy rules to make batteries more efficient than conventionally possible will not be realised any time soon. Oppenheim is sceptical that we will ever override traditional thermodynamic restrictions. But one instance where quantum thermodynamics comes into play is at the event horizon of a black hole (see

"OUR HEARTS PUMP BLOOD TO STAY THE RISE OF DECAY AND DISORDER"

"How to think about... black holes", page 39) – so it could help solve the enduring riddle of how to unite general relativity with quantum theory.

That's unlikely to help out much with the bleak future predicted for the universe, in which it slides into a long, slow "heat death", eventually turning all order to disorder. "Our present understanding is that things will become more and more disordered until life becomes very, very boring," says Oppenheim.

Or will it? Even within that disordered soup at the end of the universe, in theory "all kinds of interesting things can still occur", says Oppenheim. Perhaps the most bizarre of these was first expounded by Ludwig Boltzmann in 1896. Boltzmann argued that, given enough time in a large enough universe, fluctuations might randomly create a sub-universe that looks like ours. More plausibly, it might create a brain that thinks it exists in just such a universe – and that thinks entropy is always on the up. Joshua Howgego

HOW TO THINK ABOUT…

THE BLOCKCHAIN

RARELY before has such an obscure and complex technology captured the popular imagination quite like the one announced in a nerdy corner of the internet in 2008 by its inventor, Satoshi Nakamoto, a mysterious person or persons whose real identity still isn't known for certain.

The metaphors used to describe the blockchain are appropriately grabby, too. It's a mind virus. It's the internet of money. It's the end of capitalism.

Or think of it like a bicycle, says Nolan Bauerle of the cryptocurrency news site Coindesk. "We had wheels and chains and saddles, but the magic happened when the thing was made to roll on two wheels and everyone said, 'Oh my goodness, I didn't think that was possible'."

All clear? Well, this much we do know: the blockchain was invented to build trust in the first cryptocurrency, bitcoin, a digital and decentralised way to move money. Bitcoin's roots are in anarcho-capitalism, a movement that aspires to reproduce the mechanisms of the free market without the need for banks or state bodies to enforce rules. "It was designed to get governments and law enforcement out of the way," says William Knottenbelt at Imperial College London.

BLUE-CHIP BUZZWORD

In effect, the blockchain is simply a database. It stores arbitrary information such as bitcoin transactions in units called blocks. New blocks get stuck to the end of an ever-growing chain via some heavyweight number-crunching, and are copied to many computers on the internet. This elaborate, distributed process makes the blockchain tamper-proof, an unfalsifiable record of the transactions that made it.

There are now hundreds of different blockchains powering projects from trading solar power and real estate to tracking the provenance of food and diamonds and enabling new forms of voting. Sprouting far from its roots, the blockchain has also been embraced by governments, banks and blue-chip companies as a secure and efficient way to log transactions. In the first week of 2018, Bloomberg counted 110 company press releases using the buzzword, compared with five in the same period the year before.

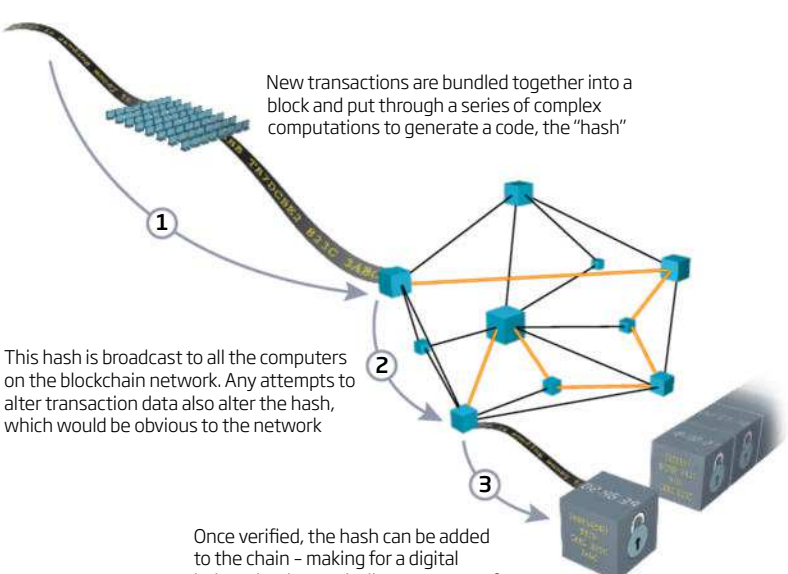
Beneath the corporate hype, blockchains could genuinely bring greater transparency to government spending or banking transactions, for example. And because they cut out middlemen such as estate agents, they could make buying and selling property quicker and cheaper.

A potential bubble-popper, however, is the rise of crypto-crime. Newer cryptocurrencies such as Zcash and Monero run on souped-up blockchains that obfuscate the transaction list, making it hard to see who paid what to whom. Such anonymity makes them an unpoliceable form of money that seems almost an open invitation to criminals looking to make nefarious transactions. "It's almost frightening what they've done there," says Knottenbelt.

But the most dramatic downside may be the technology's propensity to guzzle energy, because of the vast amounts of computing power required to add new blocks to a blockchain. Last November, the bitcoin blockchain alone started to consume more electricity than Ecuador – and appetites have only grown since. **Douglas Heaven**

The trust machine

The blockchain uses cryptography and distributed computing to maintain an unalterable record of transactions



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HOW TO THINK ABOUT…

BLACK HOLES

THE starting point is familiar enough. "A black hole is a part of space-time so incredibly warped, and where gravity becomes so incredibly intense, that nothing can escape, not even light," says physicist Pedro Ferreira at the University of Oxford.

That is also where the problems begin. Black holes are cast-iron predictions of general relativity, Einstein's peerless theory of gravity, and yet they stretch it to breaking point. Its equations fail catastrophically at a black hole's centre, known as its singularity, where the warping of space-time simply goes off the scale. "Everything you calculate goes to infinity," says Ferreira. "It has no meaning."

Even Einstein thought that black holes were too absurd to be real. They emit no light, so we cannot see them. Yet we infer their presence from their influence on nearby matter as they suck in gas and dust and stars, the contortions of which produce awesome light shows. In 2015, when we detected gravitational waves for the first time, the observed ripples in space-time matched the predicted signal from two black holes spiralling into one another and merging.

Actually, black holes are rather common. Space is pockmarked with ones formed when over-massive stars collapse and die: our galaxy alone holds perhaps 100 million of these smaller black holes. Most galaxies also have a humongous one at their centre. The one at the heart of the Milky Way packs over 4 million solar masses into a region that would fit inside the orbit of Mercury.

So how can you think about something so extreme that even abstract mathematics cannot depict it? With difficulty, it turns out. "I have a mental picture of a classical black hole in terms of deformed space-time, like a trampoline with a very heavy weight on it," says Steve Giddings at the University of California, Santa Barbara. "The problem is that this classical picture ultimately fails at a fundamental level."

To get down to the nitty-gritty of what happens at a black hole's point of no return, its event horizon, you need to bring quantum theory into the picture – but quantum theory and general relativity famously don't agree. "When we think about what happens to information that falls into a black hole, we run into a conundrum so severe it suggests there is something deeply wrong with our classical description of space-time," says Giddings.

"BLACK HOLES MIGHT BE FUZZBALLS OF TANGLED SPACE-TIME STRING"

General relativity says that when matter falls into a black hole, information is destroyed; quantum mechanics says it can't be. A unified theory requires us to somehow reconcile the two, probably by reimagining space-time as only an approximate thing, says Giddings. String theory offers one way, and might turn what we think are black holes into "fuzzballs" with no singularity and no event horizon – dense, star-like objects that essentially amount to a tangled ball of space-time string.

Or perhaps not – and that is precisely why black holes are so tempting, says Priya Natarajan, an astronomer at Yale University. "I actually describe them as seductive," she says. "They lie at the margin of what is knowable and what is not." Daniel Cossins

HOW TO THINK ABOUT...

SCIENTIFIC TRUTH

VIENNA, 1919: a city scarred by lost war and empire. Navel-gazing is in order, and Sigmund Freud's new ideas of the subconscious and psychoanalysis are all the rage. One young apprentice cabinet-maker is brooding – how could anyone prove them true, when the subconscious is unknowable?

Karl Popper soon abandoned cabinet-making for a loftier pursuit. He wanted to find a way to demarcate ideas like Freud's from what he saw as a truer kind of knowledge: science.

It still isn't at all easy. By its nature, science can't rely on logical deduction alone, or build up knowledge purely from incontestable truths (see "How to think about... logic", page 35). It must make leaps into the unknown, just as Freud did, formulating hypotheses and searching for evidence of their truth.

This is called induction, and it hides a niggle described by philosopher David Hume 150 years before Popper. The classic example involves checking the colour of as many swans as you can find, then extrapolating a rule to say "all swans are white". That sounds like science. But it can't lead to reliable knowledge, Hume argued, because you can never know a black swan isn't in the next pond.

Popper's resolution seems oddly negative: science is about proving not truth, but falsehood. The crucial thing is that when you find evidence that disproves a scientific hypothesis, you discard or amend that hypothesis. You can never find truth exactly, but by slowly ruling out ideas, you edge closer to it. When at some point the weight of evidence seems overwhelming, your hypothesis becomes a scientific theory, like the general theory of relativity, the theory of evolution by natural selection or the theory of human-induced climate change.

The thing is, scientists don't stick to Popper's strict criteria in practice, and often follow their hunches or look to confirm rather than refute their theories. "The thing about scientific methodology is that it defies simple summary," says James Ladyman, a philosopher of science at the University of Bristol, UK. "You always have to apply the principles in a context-specific way."

MARTIN NANCEKIEVILL/GETTY

ALTERNATIVE FACTS

With no way for us to say "this theory is definitely true", the door is left wide open for alternative facts – especially where the conclusions of empirical study are unpalatable, as with climate change. And things can easily sound scientific when they're not, especially when they play to your prejudices or make the news. Take a study from last year that claimed to have found genes that determine whether people like Marmite, a yeasty breakfast spread popular in the UK. It involved DNA tests, statistics and a sample of 261. So far, so scientific, but the way the study was conducted meant it had no power to connect cause and effect.

In 2015, indeed, one study found that a third of research papers in psychology appear to have reached spurious conclusions. Ladyman's answer is that science is not one thing, but a set of related disciplines. When it comes to the ability to purvey truth, we should distinguish clearly between the utterly reliable physics of tide tables, say, and the messier end of psychology.

That said, how did we uncover the crisis in psychology research? Through science, when scientists sought to replicate results and failed. Without blemish it ain't, but science is at least uniquely willing to stare at itself in the mirror. To corrupt a Winston Churchill quote, it is probably the worst way of seeking truth – apart from all the others that have been tried from time to time.

Joshua Howgego ■

U.S. NAVY PHOTO COURTESY OF HUNTINGTON INGALLS INDUSTRIES

Creatures of war

It was in the unlikeliest of settings that we began to understand dolphins, writes Arran Frood

WHERE was that damned dolphin? Tuffy was nowhere to be seen. It was 1964, and the military's top brass were assembled on a boat off the coast of San Diego, California, to watch the dolphin prove he was fit to join US Navy operations.

Sam Ridgway had the job of caring for the dolphins in the navy's cetacean research programme, and as the minutes ticked by he began to get nervous. Ridgway was confident of Tuffy's ability to deliver a package to a precise location on the sea floor, one of the tasks he had been set today. But the dolphin was swimming free in the ocean – perhaps he had decided not to come back. Maybe the naysayers were right and these wild animals could never be trusted to carry out the extraordinary and dangerous missions they were being prepared for.

Then, in the distance, a grey dorsal fin broke the surface. Within a few moments, Tuffy was sliding nonchalantly into the holding canvas on the side of the boat for the trip back to base. For around 80 bottlenose dolphins, it was the start of a tour of duty that would see them being deployed to war zones around the world to assist US military operations. It was also when, thanks to Ridgway, humans began to really learn about dolphins and their biology.

The US military first took an interest in dolphins in the 1950s – as templates for torpedo design. But their agility, trainability and incredibly sensitive sonar had not gone ›

unnoticed, and by the 1960s a new, more ambitious programme was in the works.

There was a problem, though. In captivity, the animals kept dying after just a few months. Back then, very little was known about how dolphins lived. Ridgway was a veterinary officer in charge of guard dogs when he was asked to carry out an autopsy on one of the dolphins. Although he knew as little about cetaceans as anyone else, he agreed, eventually concluding it had died of pneumonia. Impressed, his superiors tasked him with caring for the new arrivals.

The dolphins thrived under Ridgway's care, but he had to start from scratch. "Improvement of dolphin health was a long and slow process of learning and paying attention to every detail of their lives," Ridgway recalls. That included studying their social interactions to prevent injurious fights. "All dolphins are individuals and each one must be managed according to their own personality," he says.

Deep divers

Over the next decade, dolphins at the Naval Missile Center at Point Mugu, California, were taught a number of tasks. Handlers were brought in, some fresh from training animals for Hollywood movies, others from the Sea Circus show at Pacific Ocean Park in nearby Santa Monica. The dolphins started out in pools, graduating to a nearby lagoon. Operations in the open ocean began after Tuffy proved that the dolphins would return to base.

For Ridgway, this was a time not just of looking after the dolphins but of pioneering research. Everyone had previously assumed, for example, that dolphins lived mainly at the surface. Ridgway established that they could dive to more than 300 metres and hold their breath for up to 10 minutes. That meant they could be trained to locate objects deep underwater, such as mines or lost ordnance. He also showed they could dive to those depths in less than a minute without getting the bends, something that a human can avoid only by descending over several hours.

When the handlers taught Tuffy to operate an underwater camera – producing what was possibly the first ever mammal selfie – Ridgway began to understand why. A picture taken at depth revealed an eerie image of the dolphin's sunken ribcage, lungs partially collapsed to counteract the high pressure. When Ridgway wanted to collect air from the dolphin's lungs, Tuffy seemed to know what

US NAVY/SCIENCE PHOTO LIBRARY

was wanted, blowing bubbles into a capture device before surfacing to breathe. The sample confirmed that lung collapse prevented nitrogen gas from reaching the bloodstream. This informed research on why humans get the bends and how it might be avoided.

Tuffy was crucial in those early days. "All these questions we started answering because the animal cooperated, swimming free then coming back to us," says Ridgway. "And we needed the animal in good health for that. If they weren't in good health they would leave."

Although their health improved under Ridgway's care, the animals still got sick or injured from time to time, and sometimes needed surgery. Dolphins breathe by opening and closing a nostril, or blowhole, on the top of their heads. To do this, they need a level of

> "There were no seaborne attacks on US ships while the dolphins were on patrol"

consciousness – dolphins even sleep with half their brain at a time for this reason. Under anaesthetic, they simply stopped breathing.

Ridgway found a solution, designing a special respirator to move air in and out of the animals' lungs. He also worked out the correct dose of anaesthetic for dolphins, leading to a landmark *Science* paper in 1967.

By this time, things were hotting up in Vietnam. The US Navy had hitherto been relatively open about the dolphin programme, even releasing a propaganda film in 1964 called *The Dolphins That Joined the Navy,* starring the actor and navy reservist Glenn Ford. That openness changed with the war. The programme was ramped up to include sea lions and orcas – and marked classified.

On duty in Vietnam

Cam Ranh Bay was the site of a vast US ordnance store for the escalating war. It was also where Vietcong and North Vietnamese sappers swam up to US ships and planted limpet mines. There were 42 incidents in 1967, and 127 the following year. An attack in November 1968 killed 25 and wounded 27 US sailors – the navy's greatest loss of the war in a single incident. The officer in charge, Admiral Zumwalt, wanted a solution. He got wind of the dolphin programme, which had by then trained dolphins to flag the presence of humans in the water. In December 1970, five dolphins were deployed to comb the harbour area. If they spotted a swimmer, they would return to base and press a red button with their snouts. They also acted as a physical deterrent to anyone trying to reach the ships. "People think twice about getting past them," says Ridgway.

For the nine months that the dolphins were on patrol, there were no seaborne attacks.

Since then, US Navy dolphins have been deployed in Bahrain during the Iran-Iraq war of the late 1980s, and in Umm Qasr harbour during the 2003 invasion of Iraq. They have even guarded nuclear submarines.

In fact, the US Navy's marine mammal programme continues to this day – despite criticism and lawsuits from animal rights and environmental groups over the years. Ridgway says the dolphins like their work: if they didn't, they would swim away. But clearly, many people are uncomfortable with the idea of militarising such animals. In 2012, it was announced that the minehunting arm of the programme would be wound down in favour of a drone system.

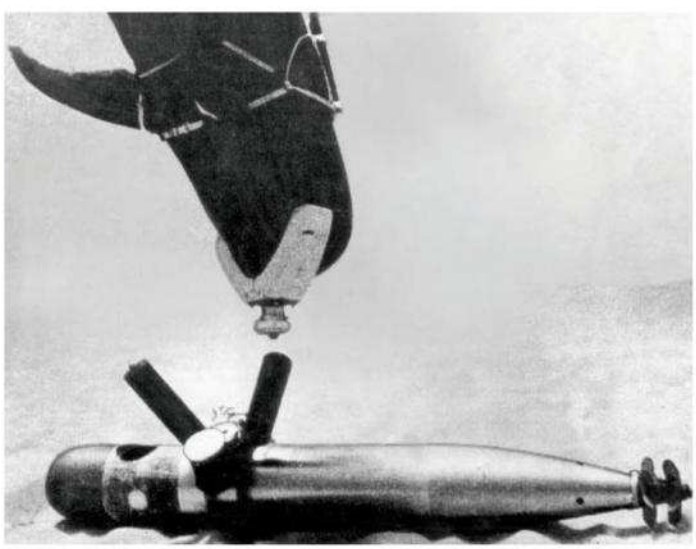
Ridgway doubts dolphins will be replaced quickly. "I think they will be needed for some time because of their sonar and their ability to swim and change course on a dime, characteristics that are very hard to duplicate in a robot," he says.

Now 82, Ridgway is president of the US National Marine Mammal Foundation and still studies dolphins by the Pacific Ocean in San Diego. His latest discovery is that they give victory squeals when they successfully mark a mine target. "We're still recording sounds that the dolphins make when doing their jobs," he says. "We'd like to know more about their communications during their work. We're probably missing a lot."

Ridgway says he still thinks about Tuffy. One of the dolphin's early missions was to locate a lost missile cradle. At dusk on a calm sea, Tuffy swam for several miles beside their boat out to the search area. He found the cradle on the seabed, led navy divers to it and seemed pleased with his achievement. "Tuffy leaped above the surface, and chills ran up my spine," says Ridgway. "I never imagined a time like this. This was a first. Would the world believe such a thing was happening?"

People now call Ridgway the grandfather of marine mammal science. "I really don't think there will ever be another Sam Ridgway, because Sam just did so much in his long and pioneering research," says Paul Jepson at the Zoological Society of London, who studies cetacean biology. "He is a living legend – absolutely." ■

SAM RIDGWAY



HULTON ARCHIVE/GETTY

Left: A US Navy Marine Mammal Program dolphin with a tracker on its fin

Top right: Sam Ridgway taking blood from a Dall's porpoise in 1965

Below: dolphins were trained to attach a clamp to targets, such as missiles, to mark their location

Arran Frood is a science journalist based in Bristol, UK

The art machine

Savvy, old-school patronage may be the only way strange, scientifically complex art can be made now, finds **Simon Ings** at Europe's largest art fair

COURTESY OF THE ARTIST AND AUDEMARS PIGUET

IT'S not often that artists presenting new work ask for the lights to be turned off, but here it makes sense. We hunker in the dark of hall 2 at the Messe Basel exhibition centre in Switzerland as tiny lights spill over the mesh sides of a large mechanical sculpture, producing tracks and spirals, and interference.

There is plenty of noise, too: *HALO* is essentially a gigantic bass harp, playing a score derived from raw data from the Large Hadron Collider (LHC) at CERN near Geneva. In 2015, CERN's art programme hosted Joe Gerhardt and Ruth Jarman, who make art under the name Semiconductor; *HALO* is the most recent work to come out of that residency.

Its construction was commissioned by Swiss watch-maker Audemars Piguet, which has championed some of the biggest names in scientifically inflected art since 2012. In partnership with Art Basel, Europe's biggest art fair, the company has backed the strangest projects. Take Robin Meier's jungle-like installations, inspired by the synchronous flashes of fireflies; or Theo Jansen's *Strandbeests* – eerily lifelike and intentional automata made of recycled plastic.

This isn't mere "sponsorship"; it's Renaissance-style patronage. The company's engagement with and promotion of artists extends well beyond the launch of any individual artwork.

Once *HALO* has stopped reverberating, Jarman talks about how Semiconductor got started 20 years ago. "We were interested in matter, and how science provides us with the tools to perceive matter and material processes that would otherwise be hidden from us," she says.

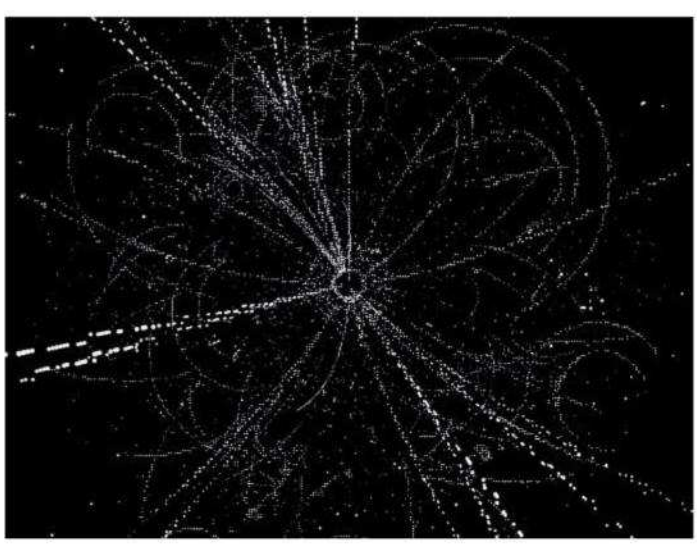
Acts of perception matter to artists, while scientists are more interested in the information

"This is Renaissance-style patronage, extending well beyond the launch of any individual artwork"

those perceptions contain. *HALO* came about, Gerhardt recalls, through the artists' desire to work with readings that were as close to natural perception as possible, before all the artefacts and noise are stripped away. "We spent three months working through the hierarchy – fighting our way to the vault, if you like," he says.

It's a point not lost on Olivier Audemars, *HALO*'s patron. Although neither he nor his colleagues are directly involved in the commissioning process, he is as fascinated with science as with the art his company supports. The first scientists took their measures and concepts of time from the watch-makers, he explains the day after *HALO*'s unveiling. "The greatest names in science used this analogy of the watch-maker to explain their vision of the universe, including Einstein of course, with his claim that God does not play dice with the universe," Audemars says. "Though in that case," he smiles, "it seems he was wrong."

Technical and scientific interests drive a company like his, and shape its culture. "If I have an interest in cosmology and quantum physics, it's because I've had those conversations, with my parents, even my grandparents."



COURTESY OF THE ARTIST AND AUDEMARS PIGUET

The artists who win commissions are invited to the company's headquarters in the Swiss town of Le Brassus, and seem to fall quickly under their patron's spell. Art history is not short of examples of this sort of arrangement going horribly wrong. But then, not every patron is a watch-maker, whose employees must couple art and science, mechanism and craft.

Jansen's *Strandbeests* (on show this week in Singapore) are mechanism personified. Meier's fields of artificial fireflies (last seen earlier this year in Thailand) are governed by how neighbouring pendulums synchronise. And *HALO* is a homage to the LHC – the largest machine in history – and a homage made mostly of one-off, handcrafted parts. The fact that on maps the LHC resembles a giant watch is, surely, just a coincidence.

At this year's Art Basel, the walls of the Audemars Piguet collectors'

Remains (left) is an ultra high-res forest map, while *HALO* (bottom) bears tracks from particle smashes

lounge displayed recent works by the Italian-born, London-based artist Davide Quayola. The company invited Quayola, whose work uses new technologies in unfamiliar ways, to take pictures around Le Brassus. The upshot was *Remains* – outsize, phenomenally high-resolution images of dense woodland, generated by laser scanning.

Quayola says that he wanted to look at the valley, not with his own eyes, but through the eyes of a machine. He goes on: "I wanted to hand over to the machine the traditional activity of walking out into the landscape in search of an encounter with nature. For me, technology is not a tool. I prefer to think of it as a collaborator, engaging with things in ways unique to itself."

It is a collaboration of equals, although initially the machines had the upper hand. "Scanning the valley using lidar technology was much more complicated than I had expected," Quayola admits.

First there was the sheer amount of time required, with each scan taking some 10 minutes as the "camera" turns full circle, shooting out tens of millions of laser beams. And then there are the readings it gathers, which only make sense from one vantage point. To really capture the environment can take up to 60 scans for a single patch of forest. There's a final complication:

"Artists give us new ways of seeing. If that process is out of our hands, good. Why spoil the surprise?"

all those scans must be correctly linked to yield a coherent map of an area constantly being buffeted by the weather.

The resulting images are clearly not photographs, but equally clearly are not the product of the human eye. Get up close to this cloud of points and you can distinguish each constituent; the image can not only be seen, but read. Parallel rays spill from a clump of foliage, an artefact of an uncorrected optical occlusion. And a dark, knotted surface turns out to be built up from strangely wobbly rows and columns of dots representing "thin" data, revealing the raw back-and-forth of the scanning process.

From an ordinary distance, what is startling about these works is the total absence of lines in an image that is so obviously detailed. The lidar eye has no interest in edges and planes, yet it is "seeing" with an acuity we immediately recognise as close to, or even better than, our own.

Quayola, of course, did much more than set his machines running. Since laser scanning results in a vast Excel spreadsheet, he used a computer to render the data as point clouds and then spent a while moving through them digitally, selecting the angles and frames he wanted to work on. It's an odd process – "like being a traditional photographer, stranded somehow in a purely digital realm", he says.

Audemars Piguet does not own what it commissions. "The work belongs to the artist," says Audemars. "That way, the project can continue to grow." *HALO*, for instance, is getting a more flexible tuning mechanism, while camera drones are contributing to the next version of *Remains*. "We can't predict the life course of these projects, and we wouldn't want to," he says. "Artists give us new ways of seeing the world. If that process is out of our hands, good. Why would we want to spoil the surprise?" ■

HALO was on show at Art Basel, Basel, Switzerland, earlier this month. *Remains* will feature at Art Basel Miami Beach, Florida, 6 to 9 December

DON'T MISS

Visit

A new exhibition at London's Science Museum, opening on 5 July, marks the 40th birthday of in vitro fertilisation. IVF: 6 Million Babies Later explores the story, from early opposition and the challenges the pioneers had to deal with right up to today's reproductive science.

Listen

Tune in to the BBC World Service for *The Forum* (schedules online). Anthropologist and linguist Caleb Everett joins presenter Bridget Kendall to explore how numbers and counting shaped the world. Alongside them are historian Tomoko Kitagawa and mathematician Ian Stewart.

Play

Life always finds a way – but try not to let it. *Jurassic World Evolution* for the PS4 promises exciting and novel gameplay, while staying true to its source material. Players bioengineer smart dinosaurs, give them unique behaviours, traits and appearances, then try to contain and profit from them. What could possibly go wrong?

Watch

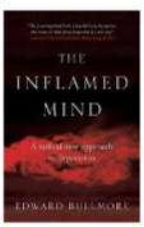
Tune in to BBC4 at 9 pm BST on 5 July for the first part of *The NHS: A people's history*. Look out for the still-roadworthy Invacar (pictured below), a vehicle adapted for disabled drivers that the UK's National Health Service distributed for free in the 1960s.

REX/SHUTTERSTOCK

Laying claim to depression

A provocative look at what causes the condition gets a cautious welcome from **Clare Wilson**

The Inflamed Mind: A radical new approach to depression by Edward Bullmore, Short Books



WHEN a powerful new arthritis medicine called Remicade was first given to patients at a London hospital, the nurses noticed an unexpected side effect. The infusion made people so cheerful, all the staff wanted to be the one to set up the drip. They called it the "Remicade high".

The medicine works by blocking a signalling molecule in the blood called TNF. It was designed to calm the inflammation behind arthritis, so why should it affect people's mood?

This puzzling observation is just one clue that the state of enhanced immune activity we call inflammation could also explain depression, argues Edward Bullmore in *The Inflamed Mind*. Depression is the most common mental illness, but our existing antidepressant treatments are inadequate. A new understanding would be Nobel-worthy.

Bullmore's take on depression is fascinating and provocative, but it didn't leave me feeling that the case is closed. The standard explanation is that depression is caused by some sort of imbalance of the chemicals used by brain cells, such as serotonin. Antidepressants like Prozac boost serotonin levels. But these medicines aren't very effective – indeed, for many, they don't work at all – so it looks as if we are missing something.

Most of us know inflammation as something affecting a small part of the body. For instance, if we cut our foot it becomes red, swollen and painful. This is when immune cells rush to the area and release compounds to fight off invading bacteria. It also encourages us to rest our injured limb.

There is also a whole-body state of slightly raised immune activity called systemic inflammation. This was first identified in clearly inflammatory diseases such as rheumatoid arthritis, but it occurs more widely because it has been linked to obesity and ageing – as well as psychological stress.

The intriguing idea at the heart of this book is that mental adversity causes inflammation, which then causes depression. This mechanism might even be helpful – provided it doesn't persist for too long – because it makes us want to crawl away and rest our whole body, removing us from the stress.

"Even if inflammation isn't the grand theory of everything, understanding it would be a real advance"

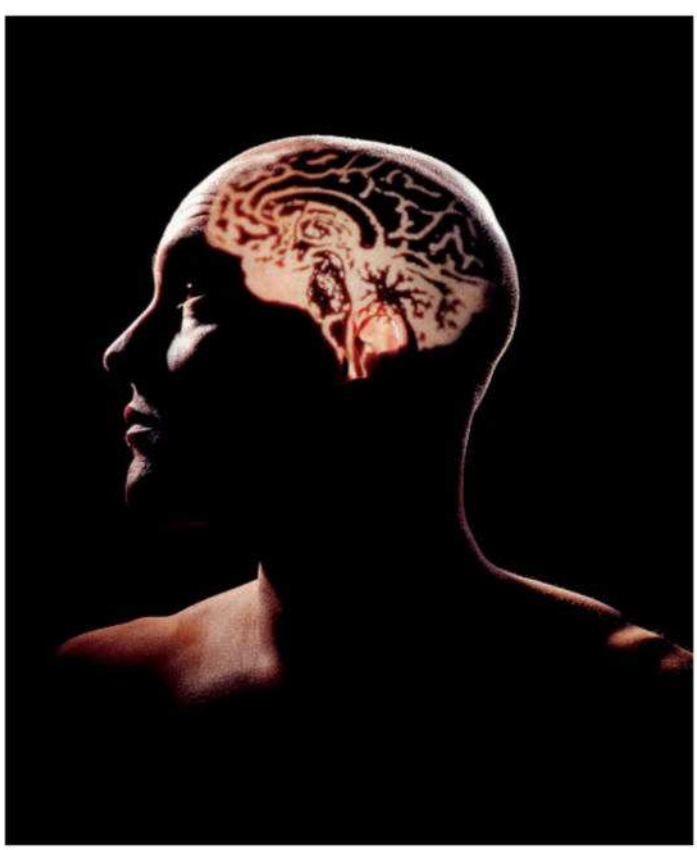
Bullmore takes us on a tour of the growing evidence supporting this idea, such as studies showing that people under stress have higher levels of inflammatory molecules in their blood, as do people with depression. A psychiatrist at the University of Cambridge, Bullmore skilfully interleaves tales of his patients with the science.

But for me, it rings false when he implies that objections to the idea stem from the outdated Cartesian view that the mind exists outside the physical realm, so its maladies could not have physical causes. Today's psychiatrists are happy enough to treat depression with the very physical remedy of Prozac.

And while Bullmore makes a good case that inflammation causes depression, if anything, his advocacy is too strong. I would have preferred a more impartial account of the evidence, both for and against. According to some studies, only a third of people with depression have raised levels of inflammation – so where does that leave everyone else?

Still, even if inflammation isn't the grand theory of everything that Bullmore would like it to be, understanding the role it does play would be a real advance. Bullmore hopes for a future when blood tests can indicate whether people have "inflamed depression" and, if they do, they will receive anti-inflammatories, perhaps including some of today's arthritis medicines, rather than Prozac.

Despite my caveats, anyone interested in how the mind works will enjoy this book. With concerns growing over the risks and benefits of existing antidepressants, this is one area that desperately needs an infusion of new ideas. ■



Mental stress causes inflammation. Can this lead to depression?

HANS NELEMAN/GETTY

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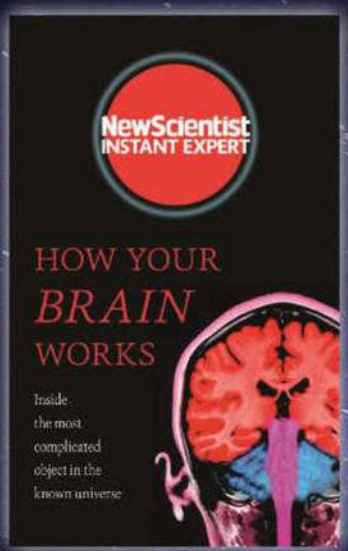

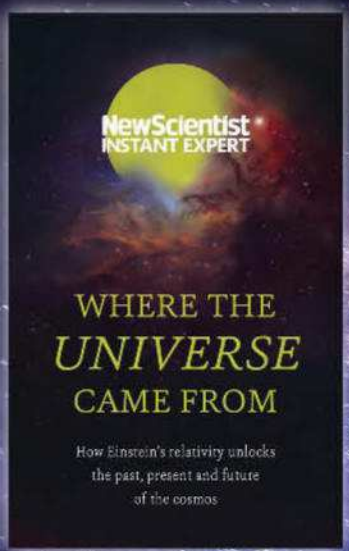

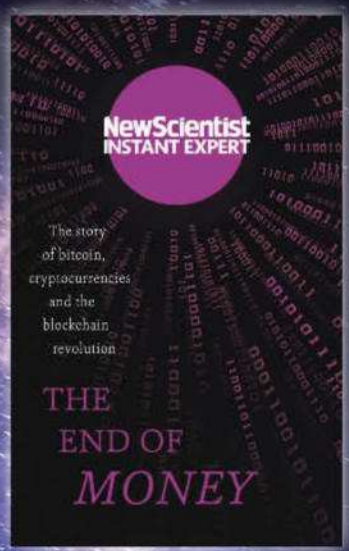

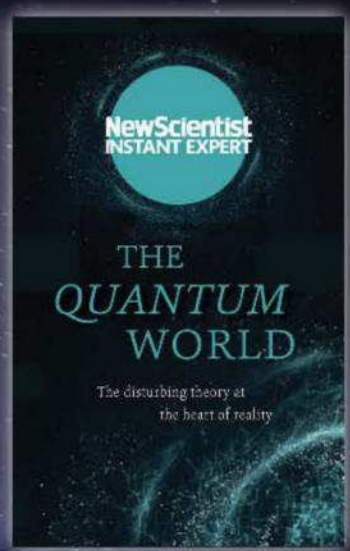

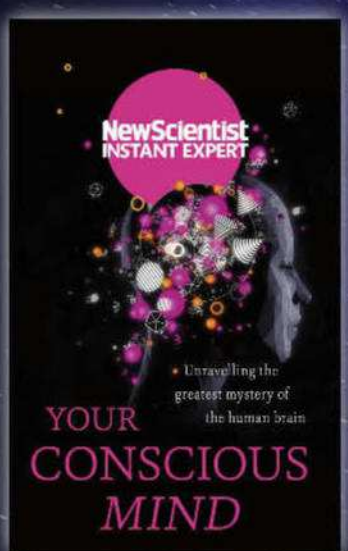

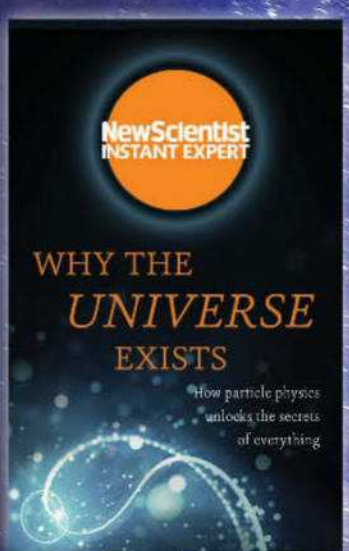

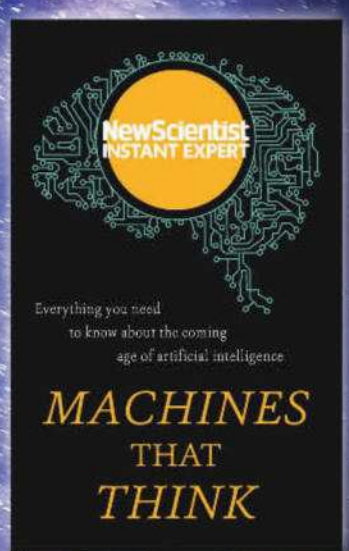

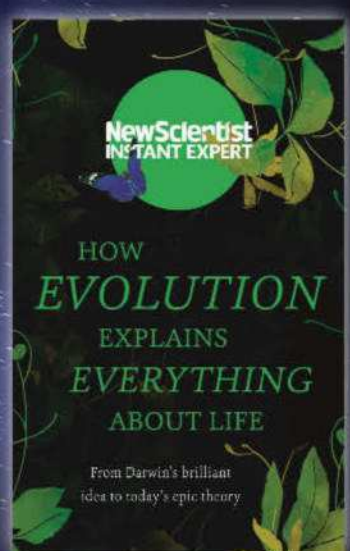

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- Maintain an understanding of all the key contacts for each account. This includes Corporate Sourcing plus the Customer's Business, Marketing, Production, and Research Organizations. Reach high, wide and deep into the organization at all accounts.
- Develop, maintain, and implement Key Account plans that will support the business annual plan.
- Present account strategies and progress versus milestones to the sales manager and Fluorochemicals team on a routine basis.
- Communicate and coordinate with the foam and HVAC market managers.
- Implement price and volume strategy for assigned accounts.
- Negotiate contracts along with the Sales Manager and align with strategy guidelines provided by Business Managers.
- Ensure product delivery through coordination with Supply Chain, reconciliation of invoicing issues, and perform as a proactive manager of the collection process.
- Ensure field intelligence gathering and provide relevant account information back to the Sales Manager and the Business Managers through timely direct communication as well as detailed sales call reports for all relevant customer visits. Enter all sales contact activity in the Sales Force web based contact management database.
- Develop and proactively manage monthly and annual sales forecasts and budgets within the scope of product and account importance

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- Being at ease and prepared in front of the customer and/or management, including good presentation skills, negotiating skills, and ability to close a deal/sale.
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- Provide monthly updates to the quarterly and annual forecasts by product line.
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Data Scientist

TRIUMF is Canada's particle accelerator centre, and one of the world's leading laboratories for particle and nuclear physics and accelerator-based science. We are an international centre for discovery and innovation, advancing fundamental, applied, and interdisciplinary research for science, medicine, and business.

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- Writing documentation and manuals on the machine learning techniques supported on the development platform for scientific users
- Supporting researchers in areas such as complex code development, optimizing performance of programs, parallelizing programs, and application support
- Staying connected with the latest developments in research and industry
- Providing training to TRIUMF scientific users, staff, postdocs and students

As our ideal candidate, you have expert knowledge in state of the art machine learning techniques and a demonstrated scientific research record in using them. Your other skills and qualifications include:

- The ability to represent TRIUMF's data science initiative in science and business meetings with good communication and interpersonal skills
- Domain knowledge in at least one of TRIUMF's scientific fields, and previous experience in scientific computing
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EDITOR'S PICK

More problems with the ethics of automated decisions

From Pauline Grant, Beaconsfield, Buckinghamshire, UK

Clare Wilson reports a test of people's responses to the philosophical "trolley problem", now prominent as a way to probe opinions on who a self-driving car should save (19 May, p 14).

There are reasons to be cautious about any interpretation of the results.

As Wilson notes, a problem with this test – which offered the choice of giving five mice an electric shock or acting to divert it to one mouse – is that some subjects did not believe the mice would be hurt. Anyone who has been moved by a dramatic scene on TV will know that strong emotions can be evoked even when we know what we are witnessing is not real. With ethics in science now much debated, the time when one could assume a subject believed a false story is surely past.

So the data can be viewed only in terms of what people think they would do in a hypothetical situation. Similarly, seeing railway workers in danger of being mown down by a trolley car falls into the realm of fantasy. By contrast, seeing a child or dog running into the road is something most of us could imagine happening, and we might say that we would run to save the child yet leave the dog to its fate.

This study involved telling subjects what was about to happen, purposely giving them time to think. Real and sudden emergencies elicit an immediate, instinctive response. A 2014 experiment using a virtual reality version of the trolley problem showed an impulse to do something rather than nothing. Post-hoc rationalisations of impulsive behaviour, such as "I decided to sacrifice one person to save many", can of course be discounted. I wonder what would happen in an experiment where taking action would put a greater number at risk.

Individuals also have a hierarchy of care, so someone might favour a single kitten over several mice. And if so, does this really tell us anything that would help program a self-driving car?

Neanderthals and Denisovans were human

From Guy Inchbald, Upton upon Severn, Worcestershire, UK

In recent years we have learned much about our close relationship with the Neanderthals (26 May, p 44). They looked and behaved so like us that we would not blink if we passed one in the street today. They created cave art and their hyoid bone would have allowed them to produce recognisable speech. We interbred with them and carry their DNA.

The standard definition of a species is that its members can breed together and produce viable offspring. This has obviously happened in our past. Some are already suggesting that there are no such species as *Homo neanderthalensis* or *H. denisova*, only the subspecies *H. sapiens neanderthalensis* and *H. sapiens*

"Please leave our *haldi doodh* alone. Diss it and the aunties will come for you. Love, India"

Dhenuka Ganesh responds to the suggestion that turmeric latte (*haldi doodh*) may not be all it's cracked up to be (16 June, p 35).

denisova. It is high time to recognise that we are members of a single species. They are not extinct; they live on in us.

Homo sapiens' signature trait is really aggression

From Bryn Glover, Kirkby Malzeard, North Yorkshire, UK
Alice Klein says Neanderthals and Denisovans seemingly did not develop the same level of intelligence as us (9 June, p 6). But Neanderthal brains were somewhat larger than those of *Homo sapiens*, and we are reminded in the same issue that there is a subtle relationship between brain size and intelligence (p 18).

As far as I am aware, there is no evidence to distinguish the lifestyles of any of the human species that co-occupied the planet up to around 40,000 to 50,000 years ago, apart from subtle differences in the stone tools that two of them made. There is certainly no evidence to distinguish between any of them in terms of their ability to think and to analyse their environments.

That we are the only species to survive is not evidence of our greater intelligence. Known human history shows intense aggression and continuing genocide. How much more likely is it that the extinction of other human species is because the most virulently aggressive of them wiped out all the others – irrespective of intelligence?

How do we define a species these days?

From Robert Milne, London, UK
Colin Barras discusses chimp evolution being shaped by sex with bonobos and describes them as "close relatives" (2 June, p 4).

When I studied biology many years ago, I was taught that organisms belonged to the same species if, and only if, they could produce fertile offspring together. Horses can mate with donkeys, for example, but because the resulting mules cannot get together to make more mules, horses and donkeys were regarded as belonging to different species.

The distinction seems to have been blurred, with talk of chimps and bonobos benefiting from sex with each other and *Homo sapiens* breeding with other "species".

Has the definition changed and if so, why?

The editor writes:
■ Yes – it seems that the more we discover, the more confused the notion of a species becomes. It is now the subject of intense debate.

The truth about cervical cancer screening

From Barbara Haines, Albuquerque, New Mexico, US
Clare Wilson discusses risks arising from screening for cervical cancer, and says it is caused by human papillomaviruses (2 June, p 20). Not all cervical cancer is caused by HPV. Vaccinations, as amazing as they are, will not eliminate it. Without those facts, women can't evaluate the risks of testing. Procedures done after test results are a separate question.

As a survivor of a non-HPV cervical cancer, I can tell you that if I had not had regular cervical tests over the years I would not be here to remind you of this.

From Ian Rubenstein, London, UK
Your leader article states that "it's time we stopped dismissing ›

women's health problems", with the cervical cancer screening programme as example (2 June, p 3). Under the UK National Health Service women receive HPV immunisation, contraception, antenatal and postnatal care and cervical screening. They are also screened for breast cancer, osteoporosis and, in some areas, ovarian cancer.

By contrast, men are actively discouraged from prostate cancer screening. It is much harder to get men to engage with their health compared with women, meaning women use the health service more than men.

Years ago I bought into the idea that women are short-changed by the health service. But it seems the opposite is the case.

Doubts and hopes for renewable energy

From Colin Reynolds
Marple, Cheshire, UK
Peter Fairley discusses the possibility of 100 per cent renewable energy (9 June, p 26). This throws up at least a couple more considerations we will have to face in the future. What effects on animal and human biology will there be from long-range super-high-voltage direct current transmission from sites where green energy is harnessed? How will the ecology of deserts change if they are shaded by solar cells? Has anyone modelled the effect on weather systems?

From Sandy Henderson,
Dunblane, Stirling, UK
Surely it is not so much a question of whether we can get all our energy from renewable sources, but that we must. The only point to debate is how quickly.

It seems likely to me that production of hydrogen fuel using electricity to split water will be a major part of this process. The resulting supply of oxygen should be extremely useful – for example in the incineration of waste. This would avoid nitrogen being involved in the combustion cycle and could make it easier to keep the process clean. It would also give us electricity as a by-product, not to mention district heating by exploiting the low-grade heat.

Further, much of the biomass we grow, whether for food or energy, captures and stores under 2 per cent of the solar energy striking the land used for cultivation. In comparison, solar panels convert more than 12 per cent and could exceed 30 per cent within 20 years. It is not that plants cannot be efficient, but that they cannot always use what is available. It now seems possible that growing staple crops indoors under artificial lighting can produce more food from less land, even when land use for solar panels to power it is included.

Why freezing of water is lethal to aquatic life

From Peter Watson,
Ottawa, Canada
Your excellent article on water starts off by saying that if it behaved like a normal liquid and became denser as it cooled, lakes would freeze from the bottom up, killing all the fish (2 June, p 26). But freezing kills living things because water expands when it turns to ice and hence breaks the cell walls around it. If it were a "normal" liquid, it would contract, and freezing would be harmless. Those animals that must survive freezing have various ingenious biochemical tricks to keep the water liquid and high density.

The editor writes:
■ We should perhaps have said that cell rupture is not the only problem. Freezing would deprive fish, and the organisms they feed on, of food on the sea or lake floor: they would probably starve.

Computer says 'don't know' – or it should

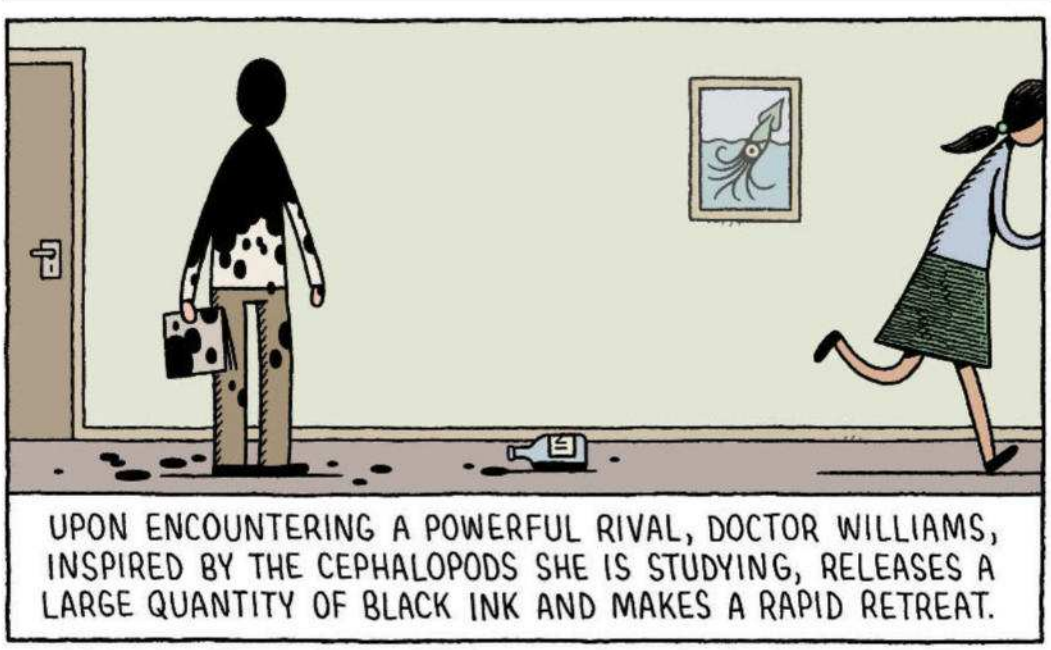
From Michael Harrison,
Wellington, New Zealand
Timothy Revell discusses holding artificial intelligence to account and European Union citizens getting the right to an explanation of AI decisions (14 April, p 40). Should software not be able to say "I don't know"?

I worked on an AI system for use during anaesthesia. We needed to detect one of two states: whether the patient was breathing on their own or their lungs were being mechanically ventilated.

We used a neural network to test for spontaneous breathing and ran a separate test for ventilator breathing. Only if both tests agreed did the software give a decision. If they disagreed, it announced that it did not know which state existed.

None of this is difficult: it just requires more than one test.

TOM GAULD



For the record

■ **In less of a tizzy: the pulsar B1957+20 rotates a mere 600 times per second (2 June, p 17).**

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OLD SCIENTIST

What's in a name?

GIDEON MENDEL/ACTIONAID/GETTY

ALONGSIDE a well-known obsession with nominative determinism, a subject Old Scientist covered on 19 May, *New Scientist*'s Feedback column has had a few other fascinations down the years. One of the most popular has been strange product names.

"Brand names are big business," we wrote. So why, after weeks of brainstorming, pre-planned pre-planning meetings and signing-off sessions, are new products so often desperately misnamed? Who thought that Fartek babywear, Krapp toilet paper, Bums biscuits, Nora Knackers crackers or Dribly lemonade might succeed?

Of course, one could argue that these were products from nations where English isn't the first language – which indeed they were – and we should cut them some slack. But our immature side just finds them too amusing. In the early 1990s, we discovered Cyprus's Cock Drops cocktail bitters, Spain's Arses red wine, Germany's Plops savoury snacks and an aftershave from France called Kevin. Did we say childish? Well it's true.

It went on with readers sending more examples from their travels. There is a toilet paper in Germany called Bum, a tool shop in Pagnacco, Italy, called Smut, a soft drink in Ghana called Pee Cola and a French high-fibre breakfast cereal (with, we must presume, excellent laxative properties) called Crapsy. Later, we learned that French cereals are in bitter competition: Crapsy had a rival called Plopsies.

The Dutch, meanwhile, appeared to have an entire marketing strategy devoted to names that play badly to English speakers. When you consider how well most Dutch people speak English, we can only conclude that this is deliberate. Examples include a floor surface called Poxy, a fizzy drink called Prik and aftershaves called Vaccine and Gammon.

So after all that puerile giggling, it was perhaps beneficial to hear that the tables can be turned. In 1993, reader Johan Hjelm of Sweden pointed out that the name of the respected (now former) UK pharmaceuticals firm Fisons sounds the same as the Swedish word for fart.

Sad to admit, but more examples of bizarrely named products are always welcomed. **Mick O'Hare** ■

To delve more into the *New Scientist* archives, go to **newscientist.com/article-type/old-scientist/**

PAUL MCDEVITT

ONGOING eruptions at the Kilauea volcano in Hawaii have sprung a new surprise: showers of gemstones. They are made of olivine, a green mineral formed deep underground long ago, and common in Earth's mantle. When the volcano ejects lumps of basaltic lava, olivine crystals are freed from the syrupy liquid and fall out.

As a gemstone, olivine is known as peridot. Turning to our trusty guide on these matters, Mary Lambert's *Crystal Energy: 150 ways to bring success, love, health, and harmony into your life*, we find that peridot is useful for relieving stress and erasing negative emotions.

The fault lines under Hawaii could certainly do with some stress relief. And now that there is a hard rain of peridot to wash away your guilt, it might be not be a bad time for a restorative visit to the islands.

MEANWHILE in Qingdao, China, residents were recently treated to an altogether different kind of rain. They were showered with a seafood buffet – including shrimp, octopus and squid – after hurricane winds lashed the coastal city.

Manna from heaven, perhaps, but not quite as exciting as events that unfolded in eastern Russia earlier this year, when an unsecured aircraft hatch led to millions of pounds' worth of gold, silver and platinum bullion being scattered over the wilderness.

WHILE Chinese citizens worry about whether they are living in a *Sharknado* sequel, UK students are hunting for pie in the sky.

Last week, pupils at St Anselm's Preparatory School in Bakewell launched a, er, Bakewell tart into the stratosphere using a high-altitude balloon. However, shortly afterwards mission control lost track of the space cake, which was last seen floating over the village of Saxilby to the east. With temperatures in the upper atmosphere dropping to -46°C, anyone who finds the cake would do well to defrost fully before serving.

AND flying saucers are vanishing from Germany. A Nazi UFO model kit was withdrawn from sale there following accusations that it was not historically accurate.

Sold by toy-maker Revell, the kit featured the mythical Haunebu II craft, emblazoned with the insignia of the Third Reich. The accompanying description noted it was the first aircraft capable of space flight, and that it could reach a top speed of 6000 kilometres per hour.

"At that time it was technologically impossible to build something like this," Jens Wehner of the Military History Museum in Dresden told the *Frankfurter Allgemeine Zeitung* newspaper. "Enthusiasts can use this as a strategy to cast doubt on what we know today about National Socialism."

OUR colleague at Make recently programmed a handy helper for the uninspired author, to conjure up possible titles for children's books (26 May, p 55).

"The joke is on Hannah Joshua," writes Tamara Joseph. "She wasn't convinced by most of its efforts but thought 'Avocado Baby' was sure to appeal to millennial parents'."

Tamara points out that there is already a book with this title, released back in 1982, when avocado was a bathroom colour and not a toast topping. "Avocados have appealed to parents since long before the millennium," says Tamara.

Feedback can't help noticing that the first of the millennials were born in the early 80s. Could this book lie at the root of their avocado fixation?

BONING up on the history of surgery, Edmund Marr reads about cardioplegia, a technique that involves temporarily paralysing the heart during an operation.

"A young biochemist at St Thomas' Hospital, London, performed some open heart surgery using it and felt that the procedure could be much improved," says Edmund. "After several years of research, he developed a drug combination that could allow the heart to be stopped for 90 minutes. The mixture is known as St Thomas' solution."

Why was the cocktail not named after the man himself? "The researcher was called David Hearse," says Edmund. A drug called Hearse mixture which stops hearts… we can see why that name was dead on arrival.

ANYONE attempting to overturn the notoriously lax US gun control laws could be accused of wishful thinking. Perhaps that's why one group of lobbyists has resorted to witchcraft.

Pagan news site The Wild Hunt reports on a coven who performed

a spell to end gun violence in the US. Using candles, pentagrams and a slip of paper emblazoned with the letters NRA, the witches put a curse on gun dealers.

Staff at the National Rifle Association were unspooked, writing on their website: "We can report that the NRA has not experienced any uptick in paranormal activity or supernatural suppression of our affairs in the interim."

It seems that witches' incantations are no more effective than politicians' thoughts and prayers.

Perry Bebbington wonders if he got himself turned around on the motorway. The lorry he was following had a banner on the back reading: "Behind you all the way"

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Peculiar pretzels

Walking in Halswell Quarry Park in Christchurch, New Zealand, we found these geometric objects by the path (pictured). They look human-made, but are apparently natural. Can anyone identify them?

■ This is the reproductive structure, or fruiting body, of the iconic New Zealand fungus *Ileodictyon cibarium*, the basket fungus; it also has several Maori names, including *te matakupenga*. It was scientifically named in 1844 by Étienne Raoul, a surgeon on the ship L'Aube, based at the French colony of Akaroa on South Island.

The fungus grows below ground on decaying plant material including wood mulch. To reproduce, it forms egg-like structures at the surface. At maturity, they rupture and then the compressed, convoluted fruiting body expands into a hollow, net-like structure.

Its polyhedral form has been compared to the geodesic domes that were popularised by the designer Richard Buckminster Fuller. These in turn inspired the name buckyballs or buckminsterfullerenes for carbon molecules such as C_{60}. In New Zealand, the basket fungus also inspired a children's climbing frame that once stood in Hagley Park, Christchurch.

Sometimes people notice the fetid smell of the fungus before they see the fruiting body. Its inner parts are coated with a greenish slime that emits a smell resembling rotten meat. This attracts flies that feed on and so disperse the spores contained in the slime.

The basket fungus is most often seen in autumn, especially in mulched garden beds, and it features frequently in photos submitted by the public to New Zealand's NatureWatch website (bit.ly/2thkXeF).

Peter Buchanan and Jerry Cooper
Mycologists, Fungarium PDD
Manaaki Whenua – Landcare Research
New Zealand

■ This is what is known as a basket fungus. It is found in New Zealand and Australia, but specimens have found their way into Europe as well.

Fungi are made up of a network of filaments hidden in the ground. These mycelia often get nourishment from the roots of trees and other plants, either parasitically or symbiotically. The filaments can extend for great distances – kilometres in the case of the honey fungus.

"The solid, ovoid fruiting body is said to be edible early on, although it is not very tasty"

The fruiting body pictured first develops within a solid, ovoid shape. This is known as a volva, and it is said to be edible early on, although not very tasty. Once the outer envelope bursts, the cages that are crumpled within spring into shape and roll free.

When the basket forms, the inner surface transforms into viscous, putrid-smelling slime. This attracts carrion flies that act as vectors for the fungal spores produced on the inside.

Terence Hollingworth
Blagnac, France

Winding up

Is there a physical limit to the wind speed of a hurricane? If so, what is it?

■ There is an upper limit on the velocity of any fluid, namely the speed of sound in the fluid, representing the speed at which a pressure wave propagates through it. Because such waves cause the molecules to move, they cannot travel faster than this (one can regard this as analogous to how information cannot travel faster than the speed of light).

For air at typical temperature and sea level pressure, the speed of sound is around 340 metres per second or 1224 kilometres per hour. However, winds in real weather systems never travel that fast. Apparently, the greatest sustained wind speed ever recorded was during Hurricane Allen in 1980, at 305 km/h – about one-quarter the speed of sound.

Simon Iveson
The University of Newcastle Callaghan, New South Wales Australia

This week's question

TIPPLE TUMMY

The beer belly is a particular form of (usually male) weight gain. Is there credible evidence that beer is capable of producing this localised fat deposition? If not, what actually causes it?

John Hickman
Clyde, Michigan, US

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