New Scientist

WEEKLY August 26 - September 1, 2017

MAGIC NUMBERS
10 wonders of the mathematical world

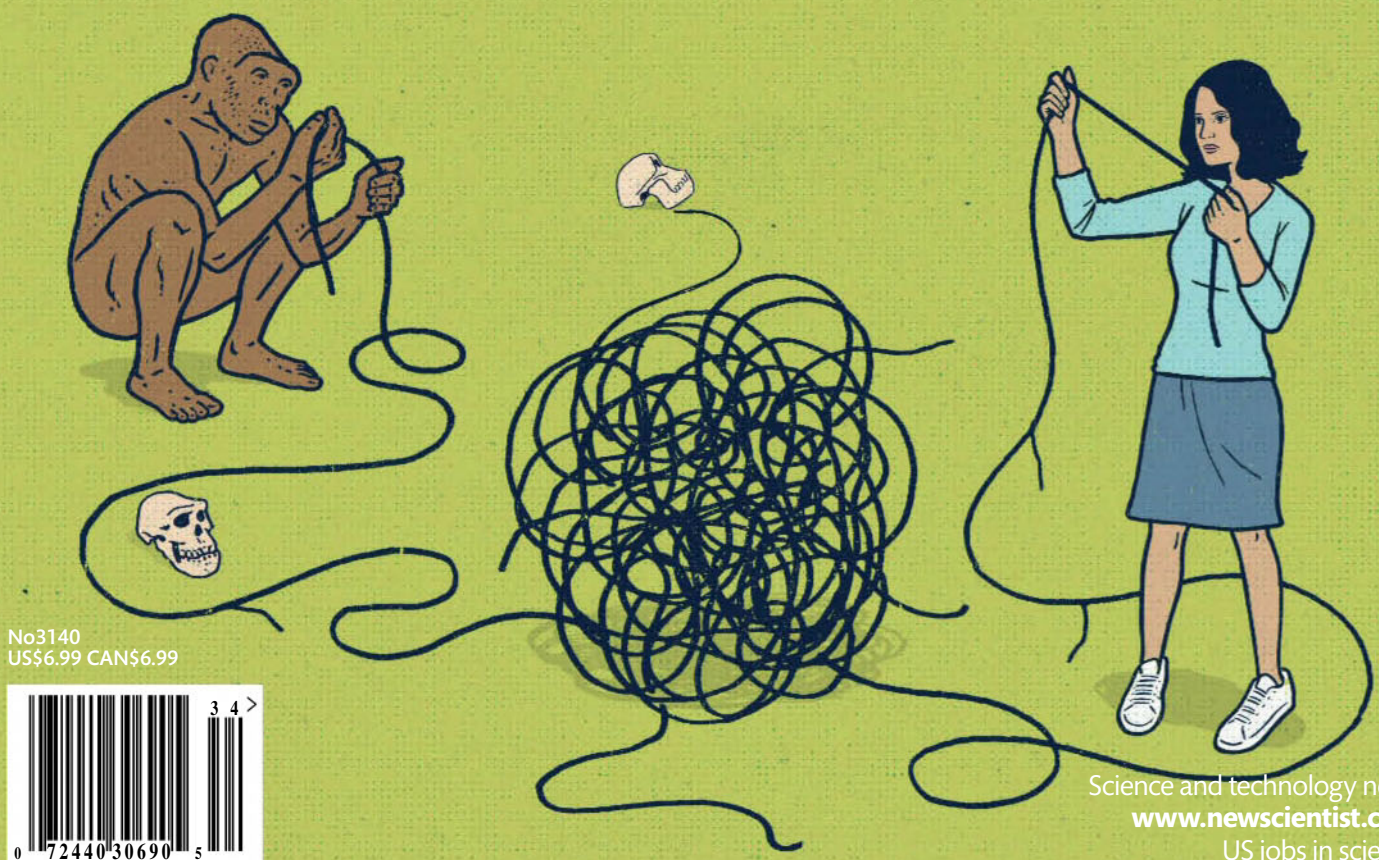
AHEAD OF YOURSELF
Your brain knows your future even if you don't

PET SCANNER
The man who reads your dog's mind

IN THE RED Why we may never be able to afford to go to Mars

WHERE DID WE *REALLY* COME FROM?

Untangling the new story of human evolution



No3140
US$6.99 CAN$6.99

Science and technology news
www.newscientist.com
US jobs in science

PLUS ROBOT FIGHTER PLANES / **STOP PROCRASTINATING!** / SNOW ON MARS / **MORE INCONVENIENT TRUTHS** / VIRUS EVOLUTION / **GRUMPY OLD CHIMPS**

COULD YOU REINVENT FUEL EFFICIENCY PIECE BY PIECE?

University College London, UK
Hydrone | Shell Eco-marathon

DISCOVER THE ANSWERS SHAPING TOMORROW

#makethefuture

New Scientist

Management
Executive chairman Bernard Gray
Publishing director John MacFarlane
Finance director Matthew O'Sullivan
Human resources Shirley Spencer
Non-executive director Louise Rogers

Publishing and commercial
Editorial content director Valerie Jamieson
Customer services manager Gavin Power
Special project manager Henry Gomm
Head of data science Kimberly Karman
HR co-ordinator Serena Robinson

Display advertising
Tel +1 781 734 8773
Email displayads@newscientist.com
Commercial director Chris Martin
Richard Holliman, Justin Viljoen, Henry Vowden, Helen Williams

Recruitment advertising
Tel +1 781 734 8773
Email nssales@newscientist.com
Recruitment sales manager Mike Black
Key account managers
Martin Cheng, Reiss Higgins, Viren Vadgama
US sales manager Jeanne Shapiro

Marketing
Head of marketing Lucy Dunwell
Danbi Cho, David Hunt, Chloe Thompson, Andrew Wilkinson

Web development
Director of technology Steve Shinn
Maria Mareno Garrido, Tuhin Sheikh, Amardeep Sian

New Scientist Live
Tel +44 (0)20 7611 1273
Email live@newscientist.com
Event director Mike Sherrard
Creative director Rowan Hooper
Sales director Jacqui McCarron
Event executive Laura Giddings
Marketing manager Kate Disley
Conference producer Natalie Gorohova

US Newsstand
Tel +1 212 237 7987
Distributed by Time/Warner Retail, Sales and Marketing, 260 Cherry Hill Road, Parsippany, NJ 07054

Syndication
Tribune Content Agency
Tel 1 800 637 4082
Email tca-articlesales@tribpub.com

Subscriptions
newscientist.com/subscribe
Tel 1 888 822 3242 or +1 636 736 4901
Email ns.subs@quadrantsubs.com
Post New Scientist, Rockwood House, Perrymount Road, Haywards Heath, West Sussex RH16 3DH

DAN PAGE

ANDREW BROOKES/GETTY

Volume 235 No 3140

News Your brain knows the future **6**

On the cover

Leader

News

Analysis

Features

Culture

Regulars

New Scientist Live

DISCOVER THE SCIENCE AND TECHNOLOGY THAT WILL CHANGE YOUR LIFE, YOUR PLANET AND HOW YOU SEE THE UNIVERSE

TALKS • DEBATES • EXPERIENCES

28 September – 1 October 2017 ExCeL London

BOOK NOW AT
newscientistlive.com

SPONSORED BY

BAE SYSTEMS INSPIRED WORK · BT · Celgene · Discovery · esa · Shell

Celgene
Committed to improving the lives of patients worldwide

THE FUTURE OF HEALTHCARE NEEDS YOU

The location is deep space. Lost astronaut Nozomi floats, alone, running out of hope that she will hear from Earth again. Until one day, a glimmer of hope flickers through the radio. The fictional story of Nozomi was written by Alastair Clayton and turned into the movie *This Is Axiom*, starring Yuriri Naka as the hapless astronaut. Surprisingly, it was not commissioned by Netflix or Hollywood, but by global biopharmaceutical company Celgene, which was looking for a bold, new way to engage people with the issues we face in healthcare.

"Too often people read a headline about drug prices being too high or patients unable to access the latest medical advances," says Kevin Loth, Celgene's vice-president for corporate affairs for Europe and International markets. "They are not getting the full picture of what is a very complex story with no simple answers."

Healthcare is a truly complex issue. Innovations in medicine have led us to living longer, healthier lives and have brought huge benefits to healthcare systems and society. But healthcare systems are under pressure from increasing demand for new and improved treatments. When resources are tight, too often the first thing to go is innovation. In fact, we could reach the day when it is easier to put a person on the moon than it is to bring a new medicine to the people who need it.

No one is against medical innovation. The problem is that despite sharing a common goal, physicians, health economists, policy-makers, academia, patients, carers, other pharmaceutical companies and the media all have very different views on how to achieve it.

Celgene hopes that the movie will foster the collaboration and dialogue needed to make progress. Nozomi's plight is a metaphor for the future of healthcare. Celgene believes that her story will open people up to thinking differently about a topic they thought they understood. "We all need to share our views and find solutions together," says Loth.

Celgene will be screening the movie premiere in the Humans Theatre and discussing why it took this novel approach. You can also listen to a panel of healthcare experts share their thoughts on the complex issues raised through the film.

Throughout New Scientist Live, you can watch the movie and see how it was made at the Celgene stand. Crucially, you can add your views on the future of healthcare. "Celgene is ready to lead the discussion," says Loth, "but we need your voice too."

Date of preparation: August 2017 UK-CELG170155b

MARK WILSON/GETTY IMAGES

Wilfully blind

There's no going back to a "golden age" of science

IN THE run-up to this week's solar eclipse, there was one message so ubiquitous that it was hard to ignore: don't look at the sun without eye protection. But as the moon moved across the face of our star, one person nonetheless did just that. It was the president of the United States.

Had Donald Trump somehow managed to miss all the warnings? Or had he just blanked them? The 45th president is notorious for ignoring scientific advice. Only the day before, his administration disbanded an advisory committee that aims to help the federal government incorporate climate assessments into its planning.

That comes as little surprise. Trump's administration is widely viewed as irredeemably anti-science, prompting responses like April's March for Science. But that's not strictly correct. Last week it published its first Research and Development Budget Priorities. Its key areas are American military superiority, American security, American prosperity, American energy dominance and American health.

The four-page memo paints science as playing a heroic role in achieving these: it will lead to "tremendous job creation", "drive the economy" and "improve the quality of American lives". In short, science has a role in making America great again.

Bombastic it may be, but at least it comes out in clear support of science. Unfortunately, the science appears to belong to a bygone age – specifically the 1950s, with its thriving military-industrial complex and ambitious space programme (see page 20).

Such nostalgia is not entirely unjustified. Whatever you think of the ethics of the military-industrial approach, it delivered.

"The danger now is that US scientists will settle for being on tap to deliver Trump's priorities"

Today, however, the words don't match the deeds. Post-war research was showered with money and scientists were considered valuable advisors – though were expected to be "on tap, not on top", as Winston Churchill supposedly put it. Trump, in contrast, has sought to cut budgets – even in some of his priority areas – and has not even appointed a presidential science advisor or a science policy director.

The challenges faced by the world have also changed, and yet the memo largely ignores them. The environment, unsurprisingly, doesn't get a mention – in sharp contrast with Barack Obama's final priorities for R&D, which included climate change, Earth observation and Arctic science.

The world is gradually adjusting to the US's dereliction of its role in many areas. That goes for science, too. The danger is that US scientists will accept being on tap to deliver Trump's priorities. In the 1950s, many welcomed their new careers and institutions, and talked up the benefits their research would bring. Few were as vocal about the problems it could detect, or create – some of them the progenitors of today's more intractable troubles.

It took decades for scientists to unify behind the idea that they can be a force for environmental, as well as economic, good. Trump and his like are willing to ignore any amount of evidence to undo that. They must not prevail. Scientists have rarely been so far from being on top. But they must not settle for being on tap. ■

RICK WILKING/REUTERS

Now you see it...

Turn it off and on again

THE sun was there, then it wasn't, and then it was again.

This spectacular solar eclipse was watched by millions of people across the US on Monday. Gazing skywards, viewers saw the moon pass between Earth and the sun, temporarily blocking its light and leaving a black circle in its place.

A total solar eclipse like this is possible by a quirk of geometry. The sun's diameter is 400 times that of the moon, but the sun is also 400 times further away from Earth. This means when everything aligns – around once every 18 months – the moon can completely obscure the sun in the sky.

So why all the excitement with this one? Normally, the eclipse is not visible from areas as populated as the US. The best views are often from the middle of an ocean or a desert.

This was different. On Monday, people within a line stretching from Oregon on the west coast to South Carolina on the east were able to see the best eclipse spectacle, including a few minutes of total darkness.

Those outside this area saw a partial blocking of the sun. Even US President Donald Trump was spotted at the White House peering directly at the eclipse, albeit without appropriate eyewear.

If you missed this total eclipse, don't worry. The next one will happen in July 2019 over Argentina and Chile. People in the US will get another chance to see a total eclipse in 2024, but those in the UK will have to wait until 2090 if they want to observe one on home turf.

Killer robots

ELON MUSK has once again called on the UN to outlaw the development of autonomous weapons.

In an open letter published at the launch of the International Joint Conference on Artificial Intelligence in Melbourne on Monday, the Tesla founder joined 115 other specialists in robotics and artificial intelligence, including DeepMind co-founder Mustafa Suleyman, to warn that autonomous drones, tanks and guns will become the "third revolution in warfare" after gunpowder and nuclear weapons.

"Autonomous weapons are the 'third revolution in warfare' after gunpowder and nuclear weapons"

"Once developed, they will permit armed conflict to be fought at a scale greater than ever, and at timescales faster than humans can comprehend," the signatories write.

Musk is well known for his public statements about the dangers of AI. Two years ago, he and Stephen Hawking were among more than 1000 experts who signed a similar open letter. This helped push the UN to vote to begin formal discussions on autonomous weapons.

These talks were meant to start on Monday, but have been delayed until November for administrative reasons.

The delay prompted Musk to reiterate the warning in the new letter. "We do not have long to act," the signatories warn. "Once this Pandora's box is opened, it will be hard to close."

Microbe gene hunt

IBM has announced plans to study the human microbiome and its role in autoimmune diseases.

We still don't fully understand how the bacteria inside us affect our health. IBM plans to find out more by analysing millions of bacterial genes, starting with those belonging to gut microbes. The hope is that this could shed light on type 1 diabetes, Crohn's disease and ulcerative colitis.

To speed up the project, IBM is crowdsourcing extra computing power, asking anyone with a desktop computer to help.

Researchers from several US universities will oversee the analysis, with the goal of finding new ways to prevent or treat autoimmune disease.

IBM isn't the only technology firm setting its sights on the microbiome. In April, Google's health spin-off Verily launched a project aiming to collect genetic and microbiome data from 10,000 people in the US. Their aim is to better predict the onset of conditions like cancer and heart disease.

MOON EXPRESS

Reach for the moon – but no rush

Lunar delay

THE deadline for the Google Lunar X Prize has been pushed back once again, from the end of 2017 to 31 March 2018.

The competition offers $30 million to the first privately funded venture to land a spacecraft on the moon. This is the third time its deadline has been extended since the prize was announced in 2007.

Competitors' rovers have to explore at least 500 metres of the

moon's surface and send back high-definition images and video.

Additional prizes have now been introduced, with cash up for grabs for those who do not quite complete the challenge.

The Lunar Arrival Milestone prize offers $1.75 million to spacecraft that either orbit the moon or try landing. The Soft Landing Milestone prize will award $3 million to any craft that successfully lands on the surface.

The original competition offered $20 million to the first company to reach the moon by 2012. The prize money has risen as the deadline has been extended.

Amazon oil row

TO DRILL or not to drill. That is the question hanging over the Foz do Amazonas basin, an oil-rich area of sea 120 kilometres from the mouth of the Amazon in Brazil.

As oil giants such as Total await a final decision from the Brazilian government on whether drilling can go ahead, environmentalists have stepped up their opposition.

Last week, Greenpeace argued that the coastlines of nearby islands – including Trinidad and Tobago and St Vincent – risked being inundated by oil spills, according to Total's own environmental assessments.

But Total told *New Scientist* that those claims relied on "hypothetical" scenarios that the Brazilian environment agency Ibama demanded they simulate,

"Claims that nearby coastlines are at risk of oil spills rely on hypothetical models, says Total"

for locations "where no actual drilling is planned".

Total says some models also showed what would happen if a spill was left untended for 60 days, which it says it would not do.

We see you

THE UK government wants to be able to recognise individuals in live videos quickly, and it is spending big to do so. A contract put out to tender by the Home Office last week offers £4.6 million for an upgrade to its automatic face recognition (AFR) software.

Police forces in England and Wales have databases containing about 16 million images of faces, obtained from mugshots and during questioning, that could be used to identify people. For example, in May, a man whose image is in a police database was arrested in south Wales after AFR spotted him in footage from a van.

Beyond that, AFR hasn't had much success. Police trialled it last year at Notting Hill Carnival, an event that draws 2 million visitors. Of the more than 400 arrests during the event, AFR wasn't used in one. This failure is behind calls not to use it at this year's festival.

It is also opposed by civil liberties groups. Regulations on what governments can do with pictures are less strict than those for DNA and fingerprints. "Widespread use of facial recognition technology in public will have an impact on the freedom we take for granted [in] our daily lives," says Harmit Kambo at Privacy International. "It turns us into walking ID cards."

UK fracking warning

THE UK's shale gas revolution has begun, but it might fizzle out almost immediately.

Last week, extraction company Cuadrilla announced that it had started drilling at a site in Lancashire. Cuadrilla hopes to use hydraulic fracturing to extract gas from shale rocks deep underground.

The hope has been that the UK could undergo a shale gas revolution similar to that of the US, helping the country become less dependent on imported natural gas. However, geologist John Underhill at Heriot-Watt University in Edinburgh, UK, says the UK's wannabe frackers are 55 million years too late.

Underhill has found that the island of Britain was lifted and tilted around 55 million years ago, in many places by more than a kilometre. This means much of the UK's shale may be too cold to host significant amounts of gas. Rocks need to be at 80°C or more to hold gas, and that can only happen if they are buried at 2 to 3 kilometres, Underhill told *New Scientist*.

What's more, the tilting of the island means that the UK's rocks are structured in a complex way, so will be harder to drill through than those in the US.

"There's a possibility that shale gas might work [to] a local extent," says Underhill. But he says the idea that it could work on "an industrial scale", enough to reduce the UK's dependence on imports, is highly questionable.

FLPA/REX/SHUTTERSTOCK

Too little, too late

60 SECONDS

Pick the right statins

Statins are a safe way to reduce cholesterol and prevent heart disease, but many people give up taking them because of muscle pains, a common side effect. A new form of genetic screening can help people avoid statins that might cause problems for them, allowing them to take their statins with confidence.

Western Canada ablaze

Wildfires in British Columbia are now the worst on record for the Canadian province, surpassing the previous largest blaze in 1958. As *New Scientist* went to press, hundreds of fires had burned some 8900 square kilometres in total. About 45,000 people have been forced to leave their homes.

Gene clue to typhoid

A mutation in a single gene makes people more susceptible to infection by *Salmonella enterica*, which causes typhoid fever. The mutation increases the cholesterol content of cells, something that makes it easier for the bacteria to get in (*PNAS*, doi.org/cb27). The finding also hints that cholesterol-lowering drugs might help protect against typhoid.

Bat-killer fungus traced

White-nose syndrome has killed millions of bats in the US since 2006. Now it seems the fungus that causes it was circulating in Europe a century ago: of 138 museum specimens tested, one French bat from 1918 was a carrier. US bat specimens of the same age tested negative, however, suggesting the fungus originated in Europe (*Emerging Infectious Diseases*, doi.org/cb28).

The upside of dying

Mass deaths in nature are not always a bad thing. Experiments show that if one population of a species dies out, other groups survive longer. It may be because this cuts migration between groups, making them less likely to all crash at once (*Nature Ecology and Evolution*, doi.org/cb2s).

Your brain knows the future

Which companies will people invest in? Neuroforecasting may tell us

Helen Thomson

OUR brains seem better at predictions than we are. Activity in a particular brain region can foresee whether projects on a crowdfunding website will succeed, even if we consciously decide otherwise. The finding suggests that neuroforecasting by scanning people's brains may provide ways to improve voting polls or even predict changes in financial markets.

To see if it is possible to predict market behaviour by sampling a small group of people, Brian Knutson at Stanford University in California and his team asked 30 people to consider whether they would fund 36 projects on the Kickstarter website. The brain scans took place as the participants were taking in the pictures and descriptions of each campaign. They were then asked to decide if they would want to fund the project.

When the Kickstarter campaigns ended a few weeks later, 18 of the projects had gained enough funding to go ahead. Examining the participants' brain scans, the team discovered that activity in a region called the nucleus accumbens had been different when they considered projects that later went on to be successful.

The team trained an algorithm to recognise these differences in brain activity, and found it was able to forecast which Kickstarter campaigns would be funded with 59.1 per cent accuracy – more than would be expected by chance.

This contrasted with what the volunteers had consciously thought. When considering each proposal, the volunteers had been asked to rate how much they liked each project, and how likely they thought each one was to reach its funding goal. These ratings predicted funding outcomes with only 52.9 per cent accuracy.

Knutson's team was so surprised by the findings that they repeated the experiment with new participants and new Kickstarter campaigns – and got the same results (*Journal of Neuroscience*, doi.org/cb26).

"This could be a great step forward in the field of neural prediction of population behaviour"

"This is highly fascinating," says Stefan Bode at the University of Melbourne in Australia, "But I feel like one is left with a rather strong paradox: how can the brain 'know' what will be successful but the person doesn't?"

This may be because you have to weigh up various factors to make decisions. For example, your nucleus accumbens activity – which is associated with expecting a reward – might increase at the prospect of buying a chocolate biscuit, but other regions of your brain may weigh in, telling you that you're supposed to be on a diet.

Even if you don't buy the biscuit, says Knutson, the nucleus accumbens might prevail in other people, or drive you to buy the biscuit at a later date. "If we can deconstruct the decision-making process in the brain, then we can identify the activity that represents the intention of what a person – on average – will eventually do," says Knutson.

"If we start to understand the origin of this phenomenon, this could be a great step forward in the field of neural prediction of population behaviour, and possibly be applicable to other areas, such as health and financial decisions," says Bode.

Taking other parts of the brain into account may further boost the predictive power of brain scans. When Knutson's team trained an algorithm on whole-brain neural activity, they were able to predict Kickstarter outcomes with 67 per cent accuracy.

Knutson says neuroforecasting might be used to improve polls predicting how people will vote, or in situations where it is not clear who a target audience is. "There are areas in which taking a representative sample doesn't always predict the outcome well – voting is a great example. Perhaps neural activity could help." ■

ANDREW BROOKES/GETTY

Tell me the future, oh brain of mine

Bacterial fibre shines lasers through water

ADDING a smattering of bacteria can help a laser beam travel further through murky water. The finding could help us perform non-invasive medical diagnostics or image deep tissue without causing any damage.

Particles in a liquid normally cause light to scatter – that's why your car headlights don't penetrate far in dense fog. But when Zhigang Chen at San Francisco State University and colleagues shone a high-intensity green laser through seawater containing a cyanobacteria called *Synechococcus*, they found the light travelled further than they expected.

This boost is the result of a known effect: light exerts a force on the cells because their refractive index differs from that of the seawater they are sitting in. In this case, the force pulls the cells toward the centre of the light beam. Once there, another force aligns the cells along the direction of the beam while also pushing them away from the centre.

This forms a bacteria "fibre" surrounding the beam, says Chen, which can act as a waveguide – constricting and guiding light travelling inside it. The effect lets the laser travel an extra few centimetres through water (*Physical Review Letters*, doi.org/cb2v).

The effect could be used to create environmentally friendly optical components that can be tailored to a range of applications, says Chen.

Despite being hit by a high-power laser, most of the cyanobacteria survived. The team is now studying whether human red blood cells can produce a similar waveguide effect. If so, it would open the technique up to medical applications, such as imaging through biological fluids.

However, it remains to be seen whether this works in practice. The high-power laser could destroy mammalian cells, says Christof Gebhardt, a biophysicist at Ulm University in Germany.

Lakshmi Supriya ■

BAE SYSTEMS

Just let the AI do the work

Future fighter jets will need no cockpit or pilot

I'M IN the cockpit of a Typhoon fighter jet. It's an overwhelming sea of buttons, twiddly knobs and square screens displaying various diagrams and measurements.

Suddenly, the whole scene dissolves. A few hovering virtual screens have replaced everything. I can grab them and arrange them as I want. One is shaking to get my attention: important information from mission control.

This isn't a real cockpit – yet. It's a scene created by an Oculus Rift virtual reality headset at the new Training and Simulation Integration Facility belonging to defence company BAE Systems. Here in Warton, UK, the firm is trying to design the fighter jets of 2040 and beyond – starting with the cockpit. "Cockpits are not flexible enough," says Chris Hepburn, one of their engineers, who is talking me through the demonstration.

Pilots' helmets already have visors that augment their view with additional information. With a few modifications, they could replace instrument-panel displays altogether.

That wouldn't just change the cockpit; it would change the whole experience of flying a plane. To illustrate, Hepburn presses a key and the floor falls away, leaving nothing between me and the ground thousands of metres below. It's disconcerting, until I realise this is as close as I'll ever get to flying Wonder Woman's invisible jet. Hepburn tells me that it's simply a matter of overlaying the video feed from cameras under a plane.

"It's disconcerting, until I realise this is as close as I'll ever get to flying Wonder Woman's invisible jet"

It seems that to make the next great fighter jet, you start by working out what ideas you can pinch from the big consumer tech firms. "These companies have research budgets equivalent to nations," says Mark Bowman, a former Royal Air Force pilot and now BAE's head of flight operations. "If Microsoft can plough billions of dollars into the HoloLens [headset], we'd be foolish not to see if there are ways that we can use it," says.

The question on my mind, though, is how BAE could even consider replacing cockpit controls with an augmented view of the landscape. This is where Bowman disabuses me of my assumptions. It has been a long time since fighter pilots have been in control of the cockpit, he says. In most jets, basic forms of artificial intelligence are already the co-pilot.

Exotic jets like the Typhoon are so manoeuvrable because they are engineered to be perpetually on the brink of losing control without ever actually doing so. Humans set the overall direction, but in a Typhoon, four computers calculate the best way to execute a move and vote among themselves before going ahead. All this happens in an imperceptible fraction of a second, so the pilot retains the impression of having called all the shots.

In the future, AI will play an even bigger role, from working out what information to show the pilot to taking full control of the plane. But Bowman thinks that rather than being replaced, pilots will become managers. For example, he envisions a human controlling a swarm of 20 drones from a plane being flown by AI.

Eventually, the pilot will probably be managed by a computer, too – something that happens very little at present. Defence companies are looking at ways of doing this, using anything from eye tracking to brain-monitoring devices.

"We want to see exactly how much information the pilot can deal with at any time, and then use artificial intelligence to manage the cognitive load," says Bowman.

Before I leave, I take a Typhoon jet for an incredibly realistic spin around an aerial racecourse over rural Wales. AI is my co-pilot.

Timothy Revell ■

Reason for magic mushroom's trip

Josh Gabbatiss

THE hallucinogenic effects of magic mushrooms are well documented. But nobody knows what psilocybin, the chemical responsible, does for the mushrooms themselves.

Now, one of the first genomic analyses of hallucinogenic fungi has deciphered psilocybin production, and even suggested a function for it. By messing with insect neurochemistry, psilocybin may act as a psychedelic repellent.

A team of researchers led by Jason Slot at Ohio State University compared the genomes of three hallucinogenic fungi with three non-hallucinogenic relatives. By doing so, they identified the cluster of genes responsible for making psilocybin (*bioRxiv*, doi.org/cbx2).

The gene cluster is found in several distantly related groups, suggesting that the fungi swapped genes in a process called horizontal gene transfer. This is uncommon in mushrooms: it is the first time genes fora compound that is not necessary for the fungi's survival – called a secondary metabolite – have been found moving between mushroom lineages.

Since these genes have survived in multiple species, Slot thinks psilocybin must be useful to the fungi. "Strong selection could be the reason this gene cluster was able to overcome the barriers to horizontal gene transfer," he says.

Hallucinogenic mushrooms often inhabit areas rich in fungi-eating insects, so Slot suggests psilocybin might protect the fungi, or repel insects from a shared food source, by somehow influencing their behaviour.

The specific purpose of many secondary metabolites is unknown, says Peter Spiteller at the University of Bremen, Germany. But that's not to say they don't have a use. "Secondary metabolites are not just produced for fun," he says.

However, while psilocybin has been shown to affect the brains of mammals including mice, there is little evidence that it affects insects or other invertebrates – barring a famous 1962 study showing that it changes the way spiders build webs.

That said, other fungi use similar substances to influence insects, "for example the zombie ant fungus," says Slot. And insects have nervous system receptors similar to those affected by the psilocybin successor molecule psilocin in humans.

In a second study, a group led by Dirk Hoffmeister at Friedrich Schiller University Jena in Germany was able to go one step further. After obtaining a legal permit, they have developed a way to make psilocybin using enzymes (*Angewandte Chemie*, doi.org/gbp6hh).

This has never been done before and could set the stage for commercial production. In recent years there has been a revival of interest in psilocybin's potential as a therapeutic drug, an area of research that had stalled due to tough 1970s drug laws. ■

JURGEN FREUND / NATUREPL

Psychedelic insect repellent needed

Bizarre star could host an exo-Saturn

THE "alien megastructure" star that has been puzzling us for the past few years might have a more ordinary explanation: an orbiting Saturn-like planet, complete with wobbling rings.

In 2015, a group led by Tabetha Boyajian, then of Yale University, found that a star called KIC 8462852 had dimmed several times over a few years in a way they couldn't explain.

The star had been observed by the Kepler space telescope between 2009 and 2013 as it hunted for exoplanets by staring at a patch of sky. When a planet passes in front of a star, an event called a transit, the light intensity dips slightly and then returns to normal.

But KIC 8462852, since dubbed Tabby's star, didn't behave that way, with the amount of dimming varying wildly. Speculation abounded, with explanations ranging from exoplanetary comets to a vast orbiting "megastructure" built by an advanced alien civilisation.

Now Mario Sucerquia and his colleagues at the University of Antioquia in Colombia have proposed another possibility: a ringed planet, similar to Saturn, orbiting close to the star. Such a planet would dim the star's light in an irregular way during a transit.

First, the rings would block some of the star's light, followed by the planet, which would dim it further. Then, after the planet passes, the rings would block some light again.

But because the rings would be at a different angle each time, the small dips at the beginning and end of the transits would be larger or smaller. Without seeing many transits, there would be no obvious pattern to this.

"Explanations for the odd dimming ranged from exoplanetary comets to a vast alien megastructure"

To test this idea and measure the irregularity, Sucerquia and his colleagues simulated a light curve from a ringed planet about one-tenth the Earth-sun distance from its star. They found another effect: the star would tug on the rings, making them wobble. This would make the silhouette of the rings as seen by an earthbound observer even more irregular from transit to transit (arxiv.org/abs/1708.04600).

A ringed planet has been floated to explain Tabby's star before, but that would have required a world many times the mass of Jupiter, enough to make it a small star. This new-found wobble means the planet could be the mass of Neptune. Jesse Emspak ■

New submarine detector for contested seas

COULD China soon have the world's most sensitive submarine detector? On 21 June, the Chinese Academy of Sciences hailed a breakthrough – a major upgrade to a kind of quantum device that measures magnetic fields. Then the announcement vanished, after a Hong Kong newspaper pointed out the potential military implications: the invention could help China lock down the South China Sea.

Magnetometers have been used to detect submarines since the second world war. They do this by measuring an anomaly in Earth's magnetic field – like one caused by a giant hunk of metal.

But today's devices can only detect a submarine at short range. You could extend this if you had a magnetometer based on a superconducting quantum interference device, or SQUID. These are highly sensitive, but they are also quickly overwhelmed by background noise.

The new device, built by Xiaoming Xie and colleagues at the Shanghai Institute of Microsystem and Information Technology, uses an array of SQUIDs. The idea is that by comparing their readings, researchers can cancel out some forms of error due to motion – for example, when SQUIDs are put on aircraft.

David Caplin at Imperial College London, who works on magnetic sensors, says this "would be relevant to an anti-submarine warfare device". The breakthrough points to an airborne system that can detect submarines from several kilometres away rather than just a few hundred metres.

SQUIDs are only one of the ways China has been upgrading its anti-submarine capability over the past few years. The "Underwater Great Wall", a string of submerged sensors, buoys and drone submarines, is thought to be close to completion. The project will help China extend its offshore surveillance zone.

David Hambling ■

PLAINPICTURE/BLEND IMAGES/SAM BLOOMBERG-RISSMAN

Mini mathematician in the making?

Newborns have a sense of how numbers work

NEWBORN babies seem to have a rudimentary sense of numbers, and we may be born with a left-to-right number line in our minds.

We visualise most of our thoughts in space. "Anything you want to remember that has a sense of order – be it days of the week or musical tones – you tend to map that to a spatial continuum," says Koleen McCrink at Barnard College, New York.

In Western cultures, people tend to think of numbers increasing in value along a mental number line from left to right, while people who speak Arabic or Hebrew picture numbers running in the opposite direction.

To see if number lines are innate or determined by culture, Rosa Rugani at the University of Padua, Italy, and her colleagues looked for mental number lines in babies that were an average of 55 hours old.

They showed each of the babies a series of images in which white squares contained a number of smaller black squares. Half the time, the babies were shown two white squares each containing four black squares, side by side. The rest of the time, they were shown two white squares that each contained 36 black squares.

A tracking device revealed that the babies looked towards the left more when shown the images with fewer black squares, and towards the right more when shown the larger number of black squares (*bioRxiv*, doi.org/cb2t).

"Seeing this mental number line in newborns is a powerful suggestion that this is innate"

"Seeing this [left-to-right mental number line] in newborns is a powerful suggestion that it is innate," says McCrink. She thinks our innate sense of order might run from left to right because the right side of the brain, which receives visual information from the left eye, is larger in babies. "Maybe that's why we pay more attention to the left side first," she says.

"It's pretty impressive to have data from a newborn, where there is very little possibility for cultural influence," says Martin Fischer at Potsdam University in Germany. But even spending just 5 minutes with an adult could influence children, he says. For instance, the adults that were holding the babies during the experiment might have moved slightly in response to the images, potentially affecting the direction of the babies' gaze.

All the babies were born in Italy, so it is possible that an experiment in an Israeli hospital, for example, might produce different results.

But if further evidence is found of an innate mental number line, the next step will be to figure out what it means for our cognition and maths skills, says McCrink. Previous research found that 6-month-old babies who prefer to watch sequences of changing number values rather than repeating ones are more likely to have a better grasp of early maths skills three years later, for instance. **Jessica Hamzelou** ■

Adult chimps are less consoling

Sam Wong

THERE, there! Adult chimpanzees are less likely than young ones to console companions in times of distress. The finding raises questions about how the capacity for empathy changes with age in our closest relatives – and us.

When a chimpanzee gets upset, companions often sit with them and offer reassurance by kissing, grooming or embracing them.

We know chimpanzees have personalities: lasting individual features in their behaviour. But it was unclear whether their empathetic tendencies are part of their personality, and whether they change over time.

Christine Webb at Emory University in Atlanta, Georgia, and her colleagues studied eight years of observations of a group of 44 chimpanzees at Yerkes National Primate Research Center. They found that individual differences were consistent over lifespan: chimps who consoled more in their youth, relative to their peers, also consoled more than their peers later in life. This is the first evidence that chimps have "empathetic personalities", says Webb.

But they also found that juvenile chimpanzees console others more than adults, and infants console most of all the age groups (*Nature Communications*, doi.org/cbz5).

This doesn't mean older chimps have less empathy than younger ones, says co-author Frans de Waal, also at Emory University. "I think they become more selective in how they express it. They focus on individuals they're close to – offspring or friends – whereas the young ones respond to everything emotional."

Similar patterns have been found in bonobos and gorillas. In contrast, humans become more empathetic through childhood and adolescence.

There is evidence that human empathy increases until middle age and then drops, but it comes from self-reporting questionnaires, so some researchers are sceptical. Still, Mariska Kret of Leiden University in the Netherlands proposes a possible explanation: "It may be that older individuals console less, but when they do, they do better."

Webb and de Waal suggest an alternative. They point to previous studies on agreeableness, which involves a sensitivity towards others; and extraversion, a tendency to actively engage with others. In humans and chimpanzees, agreeableness increases with age but extraversion decreases more markedly. The changes in consolation behaviour might simply reflect the latter trend.

In addition, a 2013 study measured brain activity while volunteers watched videos of people getting hurt. Older people had weaker emotional responses, but they processed intentionality – whether someone inflicted pain on purpose – similarly. It may be that older people can understand others' feelings without becoming distressed, which might improve their own well-being. ■

DLILLC/CORBIS/VCG/GETTY

Creature comforts

Snowstorms may rage on Mars at night

IF HUMANS ever reach Mars, they may need to beware of blizzards. Violent snowstorms can form in the dead of night, shows a model based on weather data from the Red Planet.

Previous simulations suggested that Mars may have had snowstorms when it was wetter in the distant past, and the Phoenix lander saw some gently falling flakes in 2008. But there were few indications that blizzards could happen there now.

"It's the first time anyone has shown that snowstorms, or water-ice microbursts, occur presently on Mars," says Aymeric Spiga at Pierre and Marie Curie University in Paris. "Any snow particles formed were thought to fall only very slowly through their own weight."

Spiga and his colleagues created a model based on data on water-ice clouds from the Mars Global Surveyor and the Mars Reconnaissance Orbiter. They also included observations from the Phoenix lander of an apparent "virga" snowfall, in which snowflakes turn from solid to gas before they reach the surface (*Nature Geoscience*, DOI: 10.1038/ngeo3008).

The model showed that snowstorms form only at night, mainly through cooling of the water-ice particles in clouds once the sun sets. The resulting cold zone creates strong, turbulent plumes of wind as it builds up over warmer, ice-free air.

Ice particles get caught in the descending currents and form snow that falls hundreds of times faster than was predicted from the Phoenix observations. Spiga says that although the snow flurries could be violent, many are likely to peter out before any flakes reach the ground. But if a cloud is low enough, the snow could survive long enough to settle.

"It's the first time anyone has shown that snowstorms occur presently on Mars"

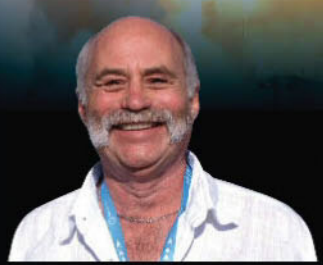
Spiga says his team's simulations of the Martian atmosphere and clouds were in unprecedented detail. "We happened to discover the occurrence of snowstorms because we used much more sophisticated and fine-scale modelling than done before, allowing us to reinterpret existing measurements that posed mysteries," he says.

"Like on Earth, these clouds play a role in the overall water cycle," says Scot Rafkin at the Southwest Research Institute in Boulder, Colorado. "They could impact human activities on the surface, whether it be a picnic on Earth or a future science excursion on Mars." Andy Coghlan ■

NEW SCIENTIST DISCOVERY

Space flight: A history

A two-week, action-packed tour in the US with astronomy and space experts



Nigel Henbest

DEPARTURE:

25 SEPTEMBER 2017

VISIT THE TRINITY SITE

Join a small group *New Scientist* readers and local experts on 7 October at the Trinity site in New Mexico, the desolate spot where the first atomic bomb was tested. Seldom open to the public, it will be a rare opportunity to get close to some of the key science behind space flight engineering.

AN APPOINTMENT WITH APOLLO 11

Gaze at the Apollo 11 capsule as you enter the Smithsonian Air and Space Museum before studying the Viking lander and the Gemini and Mercury capsules. Venture into the Spaceport Operations Center at Virgin Spaceport America and interact with crewmembers. Explore the US Space and Rocket Center where the Saturn V Moon Rocket is displayed.

QUIZ AN ASTRONAUT

Chat with an astronaut at the NASA Kennedy Space Center and enjoy expert talks from astronomer and astronaut-in-training Nigel Henbest. You'll also have time to soak up the local atmosphere in Washington DC, Orlando, New Orleans and Houston.

WHAT'S INCLUDED

- All hotels and internal flights*
- Lectures and talks from space and astronomy experts
- Entry to museums and tours, including VIP experiences

14 nights from £5045 per person

FIND OUT MORE ABOUT THIS UNFORGETTABLE TRIP

Call now on **+44 (0)203 3089 917** or visit **newscientist.com/travel/spaceflight**

INTREPID real life experiences...

* BAGGAGE COSTS ARE NOT INCLUDED ON INTERNAL FLIGHTS

CHIP SOMODEVILLA/GETTY

Tiny robots treat mouse stomach ulcers

ROBOTIC drug deliveries could soon be treating diseases inside your body. For the first time, they have been used to tackle bacterial infections in the stomachs of mice.

Stomach acid can destroy antibiotics before they have time to work, which is why ulcer medicines are augmented with proton pump inhibitors that suppress gastric acid production. But this can lead to some nasty side effects, including headaches, diarrhoea and anxiety.

Now a team led by Joseph Wang at the University of California, San Diego, has found that using micromotors to deliver a dose of antibiotics to mice with ulcers is a more effective treatment than regular pills (*Nature Communications*, doi.org/cbz6). These autonomous vehicles are the width of a human hair, and they delivered antibiotics every day for five days.

The vehicles consist of a spherical magnesium core coated with several different layers that offer protection, treatment and the ability to stick to stomach walls. In the stomach, the micromotors used the free protons in the acid to produce a stream of hydrogen bubbles that propelled them around and temporarily altered the stomach's acidity.

This reduced acidity also allowed the antibiotic to get to work. "The movement itself improves the retention of antibiotics on the stomach lining where the bacteria are concentrated," says Wang.

After 24 hours with the robots, the stomach acid of the mice returned to normal levels. The micromotors also dissolved, leaving no harmful residues.

"Micromotors are still new, but their impact will be big," says Thomas Mallouk at Pennsylvania State University.

The next steps are to look at a larger animal study, followed by eventual trials in humans. "There is still a long way to go, but we are on a fantastic voyage," says Wang.
Timothy Revell ■

RICKY JOHN MOLLOY/GETTY

Hard at work

The end of painful procrastination?

Jessica Hamzelou

EVER find yourself doing just about any other task to avoid something more urgent? Behaviour-tweaking therapy may be able to help.

"Everybody procrastinates," says Alexander Rozental at Stockholm University in Sweden. "It's an everyday phenomenon. Usually it doesn't cause more than annoyance and frustration."

But people who procrastinate a lot often say it affects their lives, and can make them feel anxiety and shame. "And procrastination can affect your health if you put off exercise or going to the doctor," says Rozental.

Rozental and his team have been exploring whether cognitive behavioural therapy can help. CBT aims to replace problematic behaviours with more useful ones. It can work for some mental health disorders, including phobias and post-traumatic stress disorder.

To develop CBT for procrastination, Rozental's team focused on behaviours like setting goals, removing distractions and rewarding successes. The team identified procrastinators among student volunteers, selecting people who scored 10 or more points above average on a 60-point procrastination scale.

"People who procrastinate a lot say it affects their lives, making them feel anxiety and shame"

The group tried two methods. A weekly, internet-based therapy was given to 48 participants, which provided them with reading materials, exercises to do and advice. Another group of 44 people received fortnightly in-person sessions in groups of 12, led by a pair of therapists.

After eight weeks, all volunteers had improved. "Their scores dropped by around 10 points, and by the end of the treatment, 34 per cent had scores similar to the average population," says Rozental.

When the group assessed the students' wider lives using questionnaires, they found moderate improvements in academic performance, anxiety and well-being (*Behavior Therapy*, doi.org/cbvd). "The results are promising," says Rozental.

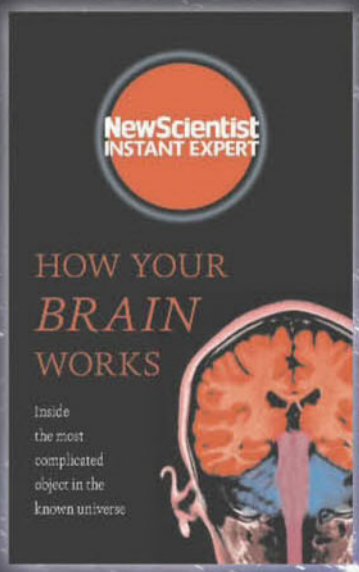
Six months later, the students who received the group therapy had improved by a further four points, while those using the internet version slipped closer to their old ways. Rozental thinks group therapy may be more effective because it can help to hear from and support others who have had similar experiences.

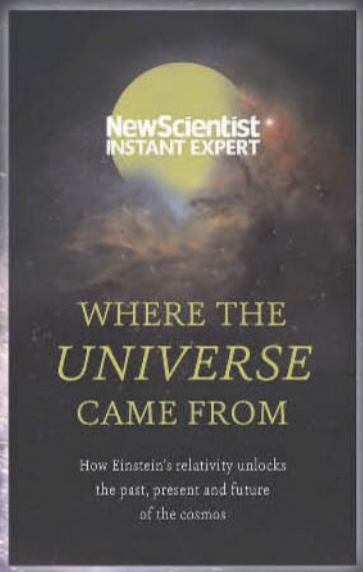
Bruce Fernie at King's College London thinks treatments for procrastination are a good idea, as long as they are given only to problematic procrastinators. Some people intentionally choose to delay tasks because they think their performance will be better in the long run. It is the unintentional kind of procrastination that causes problems, says Fernie. "This can affect exam performance and interpersonal relationships. It is important to treat this type."

Teenagers and young adults seem most likely to procrastinate, perhaps because the part of the brain involved in long-term planning doesn't mature until our twenties. Rozental hopes that procrastination CBT could be offered by schools and universities. The student health centre used for their experiment has already decided to continue providing the therapy, he says. ■

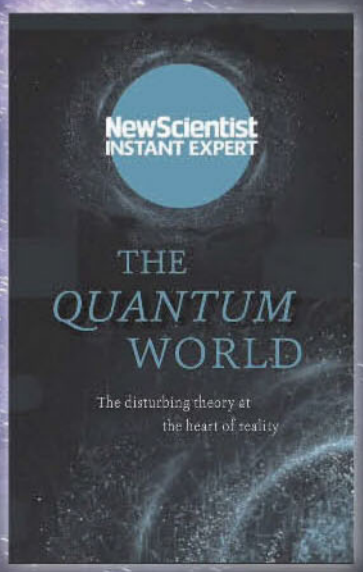
INTRODUCING THE
New Scientist
INSTANT EXPERT SERIES

DEFINITIVE, ENGAGING AND ACCESSIBLE GUIDES TO THE MOST IMPORTANT SUBJECTS IN SCIENCE.





MARCH 2017



APRIL 2017

NewScientist newscientist.com/instant-expert-books

Clue to evolution of the first viruses

Michael Marshall

AN ODD Antarctic microbe might hold the answer to one of the biggest mysteries in evolution: the origin of viruses. The microorganism is host to a fragment of DNA that can build a capsule around itself. It may help explain how viruses first arose.

Viruses are not like other life forms. Arguably, they are not alive at all. All other living things are made of cells: intricate machines that can feed and reproduce independently. A typical virus is simpler – a small piece of genetic material encased in a shell called a capsid. On its own, a virus can do little. But if it enters a living cell, it starts copying itself, and can harm its host.

Biologists have long puzzled over whether viruses are an older, simpler form of life or parasites that arose to prey on cells.

Ricardo Cavicchioli of the University of New South Wales in Australia and his colleagues have found a microorganism in the lakes of the Rauer Islands off the coast of Antarctica that might shed some light on the question. The organism, *Halorubrum lacusprofundi* R1S1, is an archaean: a single-celled organism a bit like a bacterium.

Viruses play a big role in Antarctic ecosystems, so team member Susanne Erdmann looked for viruses in the cells and found something unexpected: a plasmid.

Plasmids are small fragments of DNA, often circular, that reside in living cells. They are not part of the cell's main genome, and replicate independently. Often, a plasmid will carry a gene that is useful to the cell: antibiotic resistance genes are often found on plasmids.

The plasmid Erdmann found, which the team calls "pR1SE", is unusual. Its genes allow it to make vesicles – essentially bubbles made of lipids – that enclose it in a protective layer. Encased in its bubble, pR1SE can leave its host cell to seek out new hosts (*Nature Microbiology*, doi.org/cb2r).

pR1SE looks and acts like a virus. But it has genes found only on plasmids, and lacks telltale virus genes. "There really are no major distinctions left between plasmids and viruses," says Cavicchioli. He suggests that viruses could have evolved from plasmids like pR1SE, by acquiring genes from their host that allowed them to make a hard capsid shell rather than a soft vesicle.

The three leading theories of how viruses came to be are that either they originated before cells, or that some cells evolved into viruses, or else genes "escaped" from cells and became viruses. The new work adds to growing support for the escape hypothesis.

Such escapes may have begun a long time ago, says Patrick Forterre of the Pasteur Institute in Paris. "Traditionally, the escape hypothesis has been associated with the idea that viruses are recent," he says. "Now the escape hypothesis should be viewed in a broader context." The first viruses may have escaped from some of the first cells on Earth. ■

SEBASTIAN KAULITZKI/SPL/GETTY

Escaped genes, ready to infect you?

Monkeys know if something is old news

SEEN it, seen it, seen it. Most of us instinctively know whether objects are familiar or not. Now we may know how we know. It turns out monkeys have a cluster of neurons in their brains that decides whether or not they have seen objects before.

The primary visual area, at the back of the brain, does most of the work in perceiving an object. This is particularly true of its physical attributes, such as the direction it is moving. However, the temporal lobes – the bits just above our ears – are also heavily involved.

In particular, a region of the temporal lobe called the perirhinal cortex has been linked with object recognition, memory and even helping primates recognise familiar faces. But researchers weren't sure what aspects of an object were encoded by this region.

To investigate, Yasushi Miyashita at the University of Tokyo, Japan, and his colleagues trained macaques to indicate whether an object was familiar. The monkeys saw some objects once a month, or once every 12,000 trials, and so categorised them as "new". Meanwhile, other objects were shown in every trial, and so categorised as "old".

Then the researchers stimulated parts of the perirhinal cortex during the recognition tests. They used optogenetics: modifying neurons so they fire when exposed to light.

When they stimulated the entire perirhinal cortex with light, the monkeys categorised all objects as old – regardless of whether they really were (*Science*, doi.org/cbz9). This suggests perirhinal neurons produce a "familiar" signal when they fire.

However, stimulating different parts of the perirhinal cortex had varying effects: the front prompted the monkeys to see everything as familiar, while the rear sometimes caused them to identify more objects as new.

"A cluster of neurons in monkeys decides whether or not they have seen objects before"

Miyashita says perirhinal neurons help convert the perception of an object – what it is – into its meaning.

A better understanding of this conversion process could help improve machine learning, says David Sheinberg at Brown University in Providence, Rhode Island. "Any realistic robot would not only need to know what it's looking at, but also need to know if it's seen that thing before," he says. "The computer vision world is still stuck looking at that first part." Aylin Woodward ■

BECOME AN EVEN BETTER YOU

How to… boost your brain, eat better, hack your senses, tune your life skills and get the best rest

Buy your copy from all good magazine retailers or digitally.
Find out more at **newscientist.com/thecollection**

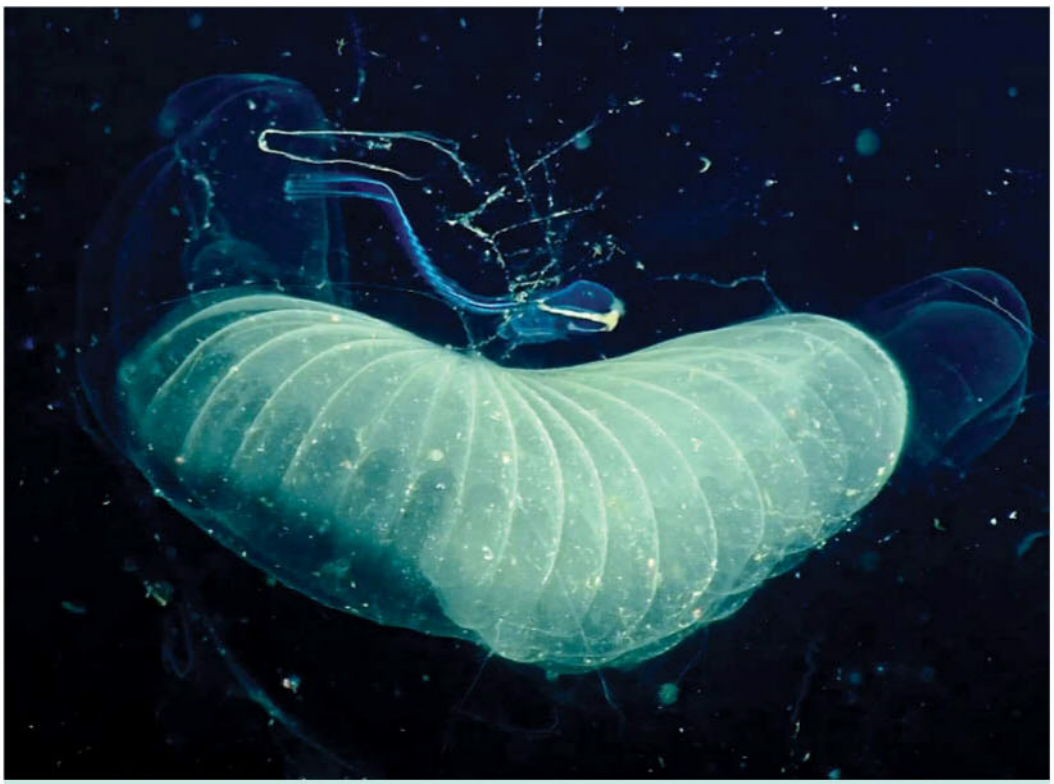
NewScientist

Where did we come from?
How did it all begin?

And where does belly-button fluff come from?
Find the answers in our latest book. On sale now.

Introduction by **Professor Stephen Hawking**

New Scientist



RAHKENDRA ICE/AAAS

Weird creatures spread plastic across the sea floor

SMALL animals in the world's oceans take in bits of plastic and excrete them in pellets that sink to the sea floor.

These "larvaceans" may transport vast amounts of microplastics from the upper layers of the ocean to the depths. It could explain why surveys have found less plastic floating in the oceans than expected.

Most of the plastic in the oceans consists of tiny pieces invisible to the human eye. To find out what happens to it, Katija and Choy studied larvaceans: filter-feeding animals that build mucus "houses" around themselves.

They used a remotely operated vehicle to squirt tiny plastic pellets near larvaceans. Some of the pellets stuck to the animals' mucus houses, which are regularly discarded. Others were ingested and incorporated into fecal pellets. Both the discarded houses and fecal pellets sink to the sea floor, but may be eaten by other animals on the way down (*Science Advances*, doi.org/cbxw).

Removing plastic from surface waters may sound like a good thing, but it just spreads the problem, says Kakani Katija of the Monterey Bay Aquarium Research Institute in California. "It has the potential to affect the inhabitants at various depths throughout the ocean."

It could also affect us, says her colleague Anela Choy. We eat a lot of animals that live on the sea floor, like crabs.

However, it is still unclear how microplastics affect the organisms that eat them.

Stem cells get around male infertility

TURNING skin cells into sperm may one day help some infertile men have babies.

Most men have two sex chromosomes – one X and one Y – but some have three, which makes it difficult to produce fertile sperm. Around 1 in 500 men are born with Klinefelter syndrome, caused by having an extra X chromosome, while roughly 1 in 1000 have double Y syndrome.

James Turner of the Francis Crick Institute in London and his team have found a way to get around this infertility. They bred mice that each had an extra X or Y chromosome, and then induced cells from their skin cells to become stem cells. To their surprise, around a third of the cells lost the extra chromosome.

When these cells were coaxed into forming sperm and used to fertilise eggs, 50 to 60 per cent of the resulting pregnancies led to live births (*Science*, doi.org/cbxt).

But there was a problem. We don't yet know how to turn stem cells into mature sperm, so the team got around this by injecting the cells into mouse testes for the last stages of development. This led to fertile sperm, but it also caused tumours in many mice.

"What we really need… is being able to go from [stem] cells to sperm in a dish," says Turner.

Tell tail signs of super swimmers

THE secret of swimming is a tail of two parts – how fast a fish whips its tail back and forth, and how far.

Mehdi Saadat at Harvard University and his colleagues modelled the swimming styles of fish, dolphins and whales. They found that many were remarkably similar.

Previous studies have related the speed and length of a tail's oscillations to the animal's forward motion. But Saadat's team identified a second factor: how far the tail goes to and fro relative to the length of the fish.

Almost all fish and cetaceans swam in a narrow optimum range of this parameter, with the length of each tailbeat between one and three-tenths the length of the animal (*Physical Review Fluids*, doi.org/cb2b).

The finding may help us create energy efficient underwater robots that swim just like the real thing.

How adding water enhances whisky

PUB lore says that adding a dribble of water to your whisky makes the flavour pop. Now this has been confirmed using a computer simulation of ethanol, water and a molecule called guaiacol, which provides some of Scotch's distinctive flavour.

Using the model, researchers at Linnaeus University in Sweden found that guaiacol tends to stick to ethanol. When liquor is above 40 per cent alcohol by volume, ethanol tends to stay in the body of the liquid. But when the simulated whisky was diluted to 25 per cent alcohol, the ethanol spread more uniformly and allowed some guaiacol to reach the surface, wafting its smoky scent and taste (*Scientific Reports*, doi.org/cbx5).

Robot hand can regenerate itself

HEAL thyself. A fresh technique can create soft robots that repair themselves after damage or attack.

Roboticists have long aimed to use soft, flexible materials, but these are too easily damaged. Now, researchers at the Free University of Brussels (VUB) in Belgium have used rubbery polymers that resemble jelly to create a gripper, a robot hand and an artificial muscle (see photo). When ripped or cut, the material was able to knit itself back together completely. All it needed was a little heat.

"The polymer has lots of different strands that lock together to form the material. When you add heat, they reorganise to stick back together without leaving any weak spots," says Bram Vanderborght, who led the research (*Science Robotics*, doi.org/cb2c).

These soft materials are ideal for picking up delicate items such as fruit or veg, so could find uses in the food industry. They would also be useful for working alongside humans in factory lines, where softer robotic arms would be safer.

Vanderborght and his team plan to make the self-healing properties automatic, either by altering the material or by making robots that can apply heat themselves. "At the moment, when ordinary robot parts break, they have to be replaced, but that's soon going to change," he says.

VRIJE UNIVERSITEIT BRUSSEL

Speeding star may have survived rare type of supernova

SUPERNOVAE don't always spell destruction. A white dwarf star racing through our galaxy may be the first remnant we've seen of a rare, weak type of supernova.

Type Iax supernovae are fainter than their type Ia relatives, which are so reliably bright that we use them as "standard candles" to estimate cosmic distances. Both occur in systems where two stars orbit each other: a white dwarf sucks away the outer layers of a larger companion star until the smaller star reaches a critical mass, causing an explosion.

Type Ia supernovae leave nothing behind, but recent studies suggest that type Iax supernovae may be weak enough for the white dwarf to survive and be sent flying by a high-velocity kick.

Stephane Vennes at the Astronomical Institute of the Czech Academy of Sciences and his colleagues believe they have identified the first such survivor. The star's mixed composition and speedy rotation indicate that it probably once had a partner, while its high velocity and trajectory are in line with the kick expected from a type Iax supernova. Vennes says it is probably a remnant from just such a supernova that occurred 5 to 50 million years ago, tens of thousands of light years away (*Science*, doi.org/cbxz).

Surviving white dwarfs like this one could allow us to more precisely determine what exactly causes type Iax supernovae, and maybe also their type Ia cousins, which are crucial to our understanding of the expansion rate of the universe.

Vitamin C holds blood cancer back

VITAMIN C might give cancer treatment a boost – but it would have to be injected at high doses.

Some blood cancers, including chronic leukaemia, often involve problems in a gene called *TET2*. The gene usually helps ensure a type of stem cell matures properly and later dies. Suppressing it allows these cells to divide uncontrollably, leading to cancer.

Vitamin C is known to keep some kinds of cell replication in check, so Benjamin Neel at the New York University School of Medicine probed its effects in mice engineered to have low *TET2* activity and a high resulting cancer risk.

They found that very high daily doses of vitamin C for 24 weeks slowed the progression of leukaemia. By the end of this period, a control group that got no injections had three times as many white blood cells – a sign of pre-leukaemia (*Cell*, doi.org/cbz8).

Neel hopes high doses of vitamin C will become part of cancer therapies, although this would involve injections rather than diet or supplements. "You can't get the levels of it necessary to achieve the effects in this study by eating oranges," he says.

JEFF WILKINSON/GETTY

Fast test catches Lyme in time

AN ALGORITHM can distinguish between Lyme disease and another tick-borne disease with nearly identical symptoms. This could enable doctors to treat the condition sooner, preventing its debilitating symptoms from setting in.

Both Lyme disease and southern tick-associated rash illness (STARI) cause chills and aches, but they need to be treated with different antibiotics. Untreated Lyme disease can lead to facial paralysis and brain inflammation.

John Belisle at Colorado State University and his colleagues wondered whether the diseases could be distinguished by measuring the changes each causes to the abundance of specific metabolites in the blood.

They screened 220 blood samples from people diagnosed with Lyme disease or STARI and compared them with healthy samples. An algorithm was trained to detect the differences revealed (*Science Translational Medicine*, doi.org/cbxx).

When tested on new samples, the algorithm diagnosed Lyme disease and STARI with an accuracy of 85 and 92 per cent, respectively.

DAVID HOWELLS/CORBIS VIA GETTY IMAGES

No time soon

Failure to launch

NASA has been promising to land humans on Mars for decades, but it can't afford the trip, says **Leah Crane**

NASA wants you to know it is on a Journey to Mars. For the last few years, the space agency has done everything it can to work those three words into press releases, public statements and YouTube videos. Nearly all of NASA's current activities, it says, will culminate in landing humans on the Red Planet in the 2030s.

But recently, NASA has admitted this journey is going nowhere fast. Last month, its chief of human space flight, William Gerstenmaier, acknowledged that the space agency doesn't have the cash to put people on Mars, even with small increases in its budget to keep up with inflation.

"I can't put a date on humans on Mars," Gerstenmaier told a meeting of the American Institute for Aeronautics and Astronautics. "At the budget levels we described – this roughly 2 per cent increase – we don't have the surface systems available for Mars."

This admission ruffled few feathers in the world of space policy, where the fact that NASA's Mars plans are vague and unlikely to come off is an open secret. After all, the current Journey to Mars campaign is just the latest in a string of unrealised exploration plans (see timeline, right).

So is it time for NASA to give up on Mars? Perhaps someone else could do it first?

Alongside NASA, countries such as Russia and China have made noises in the direction of Mars. And then there are the private enterprises, like SpaceX. But the chances of them reaching Mars first are small. The reality is, if the world's best-funded space agency can't afford a crewed mission, no one can. Elon Musk has already cancelled plans for an uncrewed SpaceX Mars mission in 2018, so his grander crewed missions are unlikely to blast off soon.

"To make it in the 2030s you would have to add billions per year - the current NASA budget isn't even close"

Without a drastic shift in NASA's space policy, there will be no humans on Mars within the next two decades. So what might that shift look like? Could a massive increase in funding, on the scale of President John F. Kennedy's Apollo programme, revive NASA's ailing plans?

"It would take large bags of cash," says Jonathan McDowell at the Harvard-Smithsonian Center for Astrophysics in Massachusetts. "To make it in the 2030s, you would have to add billions per year – the current budget isn't even close."

That budget was signed by President Trump in March, but in April he was keen to hurry things

along. During a call to NASA astronauts on the International Space Station (ISS), he asked about Mars and seemed surprised to hear the 2030s timeline.

"Well, we want to try and do it during my first term or, at worst, during my second term, so we'll have to speed that up a little bit, OK?" he said.

It remains to be seen if Trump stumps up the cash to make that happen. But even if NASA received billions of dollars more per year, it still wouldn't guarantee success.

"It's not just money, there are a lot of technological uncertainties that need to be addressed," says John Logsdon, a space policy expert at George Washington University in Washington DC. "Pouring money in might make them go away, but you could find out that they're showstoppers."

Prickly problems

The first step in any Mars journey is designing a spacecraft to carry astronauts and a rocket to blast them on their way. NASA already has the Orion capsule and Space Launch System rocket in production for this.

But these aren't enough by themselves for a successful trip. Radiation shielding, life support, a landing system and the supplies astronauts will need to survive on the Martian surface all remain prickly problems that NASA has barely started to tackle. The answers will involve shipping a whole load of stuff to Mars.

If you thought luggage was a problem on an aeroplane, it is a killer when it comes to space flight. Between food, water and life support, humans need a lot more supplies than robots, and every gram of added mass makes a spacecraft harder to launch and land. Even the lighter missions to land robots on Mars don't have a great track record – the majority have ended in failure.

At the bare minimum, a landing crew and all their baggage would weigh 10 times more than the 1-tonne Curiosity rover, the heaviest thing we have landed on Mars, says McDowell. Right now, we just don't know how to do that.

"Things don't scale linearly – you can't just take what we're doing with the robots and scale it up," he says. If NASA were to use a parachute to slow a crewed spacecraft's descent through the tenuous Martian atmosphere, he says, it would have to be the size of New York City. That's why NASA used an ambitious "sky crane" platform to lower Curiosity to the surface, but even scaling this up would be difficult.

Maybe we don't need to solve all these problems at once. While some space advocates say a Mars mission must be fully planned and budgeted from day one, Mary Lynne Dittmar of the Coalition for Deep Space Exploration takes a different approach.

"If that were true, we would have never gotten to the moon," she says. "When they started with the moon work, they had no idea how they were going to do it, and they certainly didn't have the budget to do it."

If your goal is to get to Mars one day, without setting a specific deadline, NASA has its money in the right places for research and development, she says. "It's like we're building a skyscraper. We can start building before we've completely designed the top two floors, which are the most expensive real estate."

And NASA doesn't have to go it alone. The agency already has contracts with SpaceX and other commercial partners to develop technology for an eventual crewed mission, but a larger-scale collaboration like the ISS might be the best way forward.

"The only way for NASA to put humans on Mars by 2050 is to pair up with other countries or groups in industry," says Logsdon.

"A NASA-led international effort could potentially send humans to Mars in the first half of the 2040s"

"A NASA-led international effort could potentially send humans to Mars in the first half of the 2040s."

Ironically, ending one international effort may be necessary for NASA to afford a new one. The agency spends about $1.5 billion a year on the ISS, about 8 per cent of its budget. Right now, all the international partners are committed to the station until 2024. At that point, they could choose to hand it over to industry or decommission it.

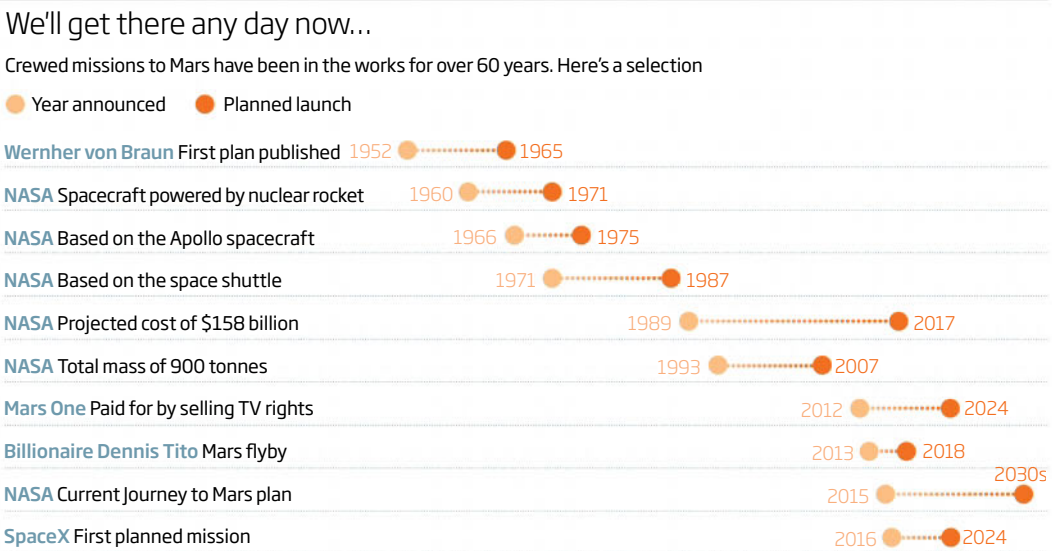
Yet as the home of microgravity experiments, the space station could be crucial to a mission to Mars, especially when it comes to testing technology and figuring out how the human body adapts to being in space.

"You could end up cutting off your nose to spite your face," says Dittmar. "If you decommission the station in 2024 and then realise you need it – oops! What do you do then?"

An alternative approach could be to shift NASA's focus to putting humans in orbit around the Red Planet, rather than onto it. Then the agency could work on how to sustain astronauts so far from home without having to develop a second spacecraft for landing on Mars – a huge cost saving.

"They could decouple the let's-go-to-Mars distance problem from the landing problem," says McDowell. He says that the best plan may be to send astronauts to land on Mars's moon Phobos first, since it isn't big enough to have the gravity or atmosphere that make Mars so difficult.

So while there won't be humans on Mars any time soon, they might get pretty close, says McDowell. "Having astronauts trundling around Phobos with the enormous disc of Mars above them... I think that would be pretty cool." ■



THE GREATEST SCIENCE SHOW IN THE KNOWN UNIVERSE

120+ TALKS

100+ INTERACTIVE EXPERIENCES

6 ACTION-PACKED STAGES

28 September to 1 October 2017 ExCeL London

THE ppa Awards 2017 EVENT OF THE YEAR (CONSUMER MEDIA)

EN WINNER BEST CONSUMER SHOW

British Media Awards 2017 SHOW OF THE YEAR

AEO WINNER BEST CONSUMER SHOW LAUNCH

WHAT HAPPENED AT THE BIG BANG?
Sean Carroll California Institute of Technology

TEN SPECIES THAT CHANGED OUR WORLD
Alice Roberts University of Birmingham

SOLVING INTELLIGENCE: THE FUTURE OF AI
Demis Hassabis founder and CEO of DeepMind

SCIENCE, FICTION AND THE FUTURE
Margaret Atwood author

WHY IS THERE ONY ONE SPECIES OF HUMAN?
Chris Stringer Natural History Museum

ASK AN ASTRONAUT
Tim Peake European Space Agency

CASSINI'S GRAND FINALE
Michele Dougherty Imperial College London

THE FUTURE OF HUMAN SPACE FLIGHT • GRAVITATIONAL WAVES: A NEW ERA IN ASTRONOMY
SEEING BACK INTO DEEP TIME • WHEN WILL WE CURE ALZHEIMER'S AND PARKINSON'S?
THE TWO GREAT MYSTERIES IN PHYSICS • IS THERE A CURE FOR AGEING?
WHAT IS 95% OF THE UNIVERSE MADE OF? • BUILDING ROBOTS: COMPLEXITY, CYBERNETICS, COCKROACHES
THE ORIGIN AND EVOLUTION OF LIFE ON EARTH • HOW TO DISAPPEAR IN THE DIGITAL AGE

COMEDY • MUSIC • ROBOTS • STONE AGE WORKSHOPS • DRONES • VIRTUAL REALITY
INCREDIBLE INVERTEBRATES • POP-UP PLANETARIUM • NAKED MOLE RATS • DROIDS • ASTRONAUTS
DNA SEQUENCING • TUDOR TREASURES • AND MUCH, MUCH MORE

28 September – 1 October 2017 ExCeL London. Standard, VIP, family and four-day pass tickets available

BOOK NOW AT **newscientistlive.com**

SPONSORED BY BAE SYSTEMS INSPIRED WORK BT Discovery Celgene esa gsk

A destructive food fight

Vegan activists will alter nothing if they embrace bad science when arguing the health case for their diet, says **Anthony Warner**

I RECENTLY found myself in a room with a spokesperson for a large vegan advocacy organisation and found that we had something surprising in common. We had both faced abuse from vegan activists after media appearances.

The vitriol aimed at me is perhaps understandable; I have publicly criticised those activists for militantly shaming and judging other people's food choices, after which they ironically line up to militantly tell me how mistaken I am.

The vegan spokesperson receives similar levels of ire, often from the same individuals, keen to inform her that her statements aren't vegan enough. She laughed this off as a consequence of representing a passionate community, but I could see the upset in her eyes. These attacks should never be taken lightly.

Food inspires strong beliefs.

In our secular age, many modern tribes signal their status through diet rather than religious faith, with restrictions on what we eat a particularly potent identifier. Vegans are an especially vociferous tribe. The passions of many can run hot, and it can make them believe some curious things.

The recent film *What the Health*, available on Netflix, is a case in point. A thinly disguised piece of vegan propaganda, it bombards viewers with a stream of misinformation and bad or outdated science; for example equating eating one egg with smoking five cigarettes.

It also muddles the relative and absolute cancer risks of eating processed meat, making the dangers sound greater than they are. Then there are objectionable conspiracy theories and dubious healing anecdotes. It claims that prominent cancer and heart

Right kind of growth

Plant trees to offset Trump? It is an appealing idea, but a tall order, says **Olive Heffernan**

DONALD TRUMP has made good on his promise to put a wrecking ball through environmental protections. Notably, the US president has signed an executive order to rescind the Clean Power Plan, a policy that would cut emissions from US coal-burning power plants, and intends to pull the US out of the Paris Agreement.

It's hard not to feel down. But reports suggest a more productive response: a global tree-planting project aimed at offsetting the president's environmental impact is gaining momentum.

The brainchild of Dan Price, Jeff Willis, and Adrien Taylor – a scientist, a PhD candidate and a sustainable hat maker – "Trump Forest" aims to soak up the 650 million tonnes of extra carbon emissions that would be released over the next eight years as a result of axing the Clean Power Plan.

That's a tall order – it would require more than 10 billion trees. But they have made a start: the project launched in New Zealand with the donation of 1000 native trees, and it now has supporters worldwide.

Reaching the goal would mean a forest area of 100,000 square kilometres; that's about the size of Kentucky. But that would be spread across many regions.

"Trump Forest would require 100,000 square kilometres – that's about the size of Kentucky"

While perhaps the most obvious challenge is the scale of ambition, Trump Forest will also face issues common to all carbon-offsetting schemes. One is verifying trees planted are above and beyond those that would have been grown without the project; another is ensuring they are in the right places. Planting in Earth's snowy northern reaches, for example, can darken the land surface, only serving to hasten warming. Tropical forests offer the most cooling potential.

Other problems are possible.

charities are influenced by the food industry to cover up links between animal products and poor health. That is unfounded and an insult to many researchers fighting cancer and heart disease.

Such extreme passions push the argument away from genuine and important issues. Given the widespread discussion of its shortcomings, *What the Health* risks creating the impression that all vegan campaigners are wild-eyed and scientifically illiterate.

There are real concerns about animal welfare and the outsized environmental toll of livestock in meeting a need to produce more food. If vegans want to engage others in this debate, they need to publicly reject the likes of *What the Health* and the fallacious assertions made in their name.

We are all free to make choices about what we eat. But some vegans are falling into the trap of embracing bad science when making a health-based case for their choice. Real change will only come from many millions of us modifying behaviour in small but significant ways. *What the Health* will do nothing on that front. ■

Anthony Warner works as a food industry development chef and blogs about dietary pseudoscience. He is the author of *The Angry Chef* (Oneworld)

New plantations can deplete water supplies to other areas, reduce soil nutrients and create a monoculture. And when trees die and rot or burn, they release their carbon, so the fix could turn out to be relatively short-term unless planting is maintained.

Regardless of whether Trump Forest reaches 10 billion trees, its message has instant appeal – that despair is a dangerous response to ignorance. We're better off sowing the seeds of change than sitting complacently until the US gets a leader who listens to science. ■

Olive Heffernan is an environment writer

INSIGHT Extremist internet

EDU BAYER/THE NEW YORK TIMES

Killed by hatred

Should web firms decide what we see online?

Sally Adee

WHO is responsible for the content of the internet? Social media firms have long been under fire to protect their users from accounts that spew hate speech. But companies that host websites and offer other web services have been given a free pass.

That may have changed following violence between white nationalist marchers and counter-protesters in Charlottesville, Virginia. After the neo-Nazi site The Daily Stormer mocked a protester killed at the rally – which it had organised – and urged its readers to target her funeral, several web hosts refused to carry the site's content. Then Cloudflare, which provides security services for websites hosted by other firms, did the same.

Cloudflare's CEO, Matthew Prince, acknowledged that by taking a moral position, he had set what he saw as a dangerous precedent: in hosting content or merely providing other services, any tech company is now implicitly endorsing the views of their customers. Is this a tenable position?

The debate on hate speech has so far been dominated by social media firms. It makes sense from a philosophical perspective, says Bharath Ganesh at the Oxford Internet Institute in the UK. On Twitter and Facebook, you are talking in someone else's house, so they define the terms of your conduct while you are there.

But for web hosts, this logic is trickier. On your own site, you are considered to be in your own house, and it is harder to make the case for policing your speech, unless it is illegal – images of child abuse, for example.

Except, of course, it isn't really your house. You are putting all your content on to a server that is the physical property of your web host. It's no wonder, then, that The Daily Stormer's hosts decided to kick them out.

"Pushing extremist sites into the shadows could make it hard for authorities to monitor them"

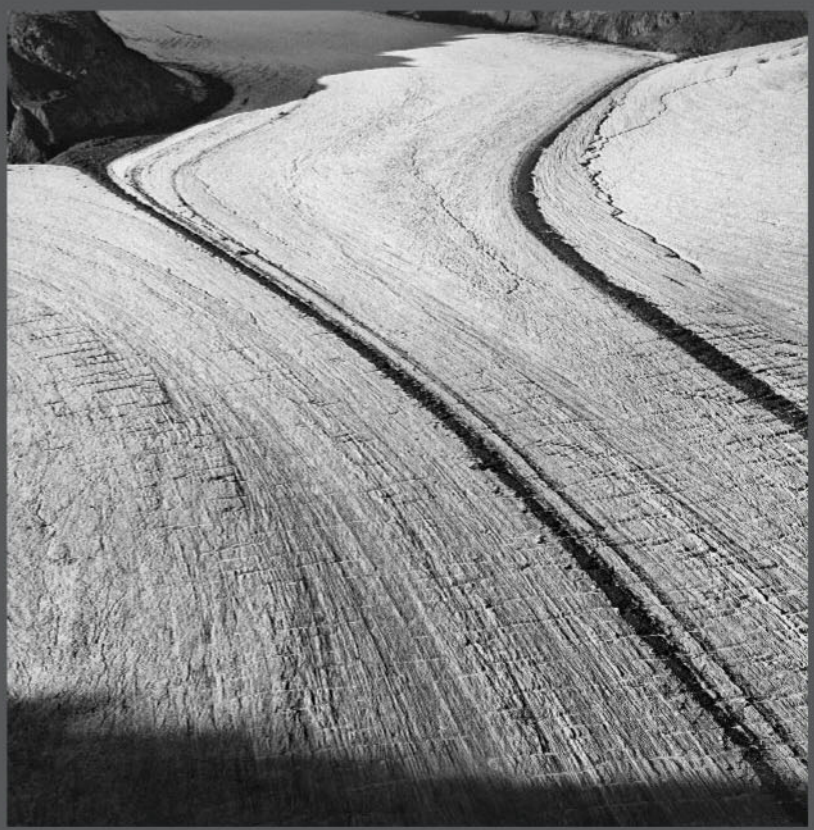
Cloudflare is different. It acts as hired muscle for websites, denying malicious traffic intended to take them offline through distributed denial of service (DDoS) attacks. When Prince dropped The Daily Stormer, it was like a security guard deciding that it was no longer morally defensible to protect your house.

Maybe this isn't a bad thing morally. Perhaps free speech and US law can no longer be the sole arbiter of whether or not a tech company chooses its customers, says Ganesh – they should be more discerning. "Maybe it's time to wonder whether tech companies have a responsibility to stop profiting from things that destabilise democracy."

But if mainstream companies won't provide these services, others will. We could see the fragmentation of the internet into an open, public web and an immoral dark web run by those with no qualms about content. And what happens if web firms start rejecting less obviously disagreeable sites, such as those dealing in contentious moral issues like abortion?

Ganesh isn't sure moral activism of the type practiced by Prince will have the consequences we want. Pushing such sites into the shadows will cut them off from polite society and could interfere with their ability to radicalise everyday people. Or it could have unintended consequences, such as making them harder for the authorities to monitor.

In any case, we don't know if shutting down The Daily Stormer's protection against DDoS attacks will have an effect on its ability to radicalise people. It could just become a badge of honour. ■



Swallowed by ice

IN MARCH 1926, three brothers and a friend climbed up from their village in Switzerland to a hut overlooking the Aletsch glacier. Around lunchtime, they told people at the hut they planned to walk to a place a few kilometres away, where the glacier joins three others.

But that afternoon the weather worsened and it began snowing heavily. The young men were never seen again.

Then, in 2012, their bones, boots, binoculars, sticks and other items were found on the surface of the glacier. The remains had probably been exposed for a few summers before their eventual discovery.

A computer model suggests the ice rivers carried the Ebener brothers around 10 kilometres through space as well as 86 years through time. Based on where the model suggests their bodies are likely to have entered the glacier, it appears the men got lost on the way back, veering right and remaining on the Aletsch glacier instead of continuing straight on towards the hut. They froze to death on the ice and were buried by snow.

Only the brothers were found, says Daniel Schwartz, whose photographs – taken with the permission of the men's family – show their possessions, as well as the glaciers that carried them. The body of their friend, who may have left the brothers to find help, has yet to turn up.

The images are from Schwartz's book *While the Fires Burn: A glacier odyssey*, which seeks to highlight the plight of the world's glaciers, many of which are disappearing due to global warming. It features images of glaciers on four continents, including a powerful photo of a swastika from a German expedition in Pakistan lost in the 1930s.

The glaciers in Pakistan remain largely intact, Schwartz says, while those in Peru are melting even faster than the Swiss ones. And those in the Rwenzori mountains between Uganda and the Democratic Republic of the Congo are mostly lost already. Michael Le Page

Photographer

Daniel Schwartz

These images are from the forthcoming book *While the Fires Burn: A glacier odyssey* (Thames & Hudson)

ANDREA UCINI

Losing the plot

Everything we thought we knew about who we are and where we came from needs a major rethink, finds **Colin Barras**

WHO do you think you are? A modern human, descended from a long line of *Homo sapiens*? A distant relative of those great adventure-seekers who marched out of the cradle of humanity, in Africa, 60,000 years ago? Do you believe that human brains have been getting steadily bigger for millions of years, culminating in the extraordinary machine between your ears?

Think again, because over the past 15 years, almost every part of our story, every assumption about who our ancestors were and where we came from, has been called into question. The new insights have some unsettling implications for how long we have walked the earth, and even who we really are.

Once upon a time, the human story seemed relatively straightforward (see blue text in timeline, page 30). It began roughly 5.5 to 6.5 million years ago, somewhere in an east African forest, with a chimpanzee-like ape.

Some of its descendants would eventually evolve into modern chimps and bonobos. Others left the forest for the savannah. They learned to walk on two legs and, in doing so, launched our own hominin lineage.

By about 4 million years ago, the bipedal apes had given rise to a successful but still primitive group called the australopiths, thought to be our direct ancestors. The most famous of them, dubbed Lucy, was discovered in the mid-1970s and given arch-grandmother status. By 2 million years ago, some of her descendants had grown larger brains and longer legs to become the earliest "true" human species. *Homo erectus* used its long legs to march out of Africa. Other humans continued to evolve larger brains in an apparently inexorable fashion, with new waves of bigger-brained species migrating out of Africa over the next million years or so, eventually giving rise to the Neanderthals of Eurasia.

Ultimately, however, those early migrant lines were all dead ends. The biggest brains of all evolved in those hominins who stayed in Africa, and they were the ones who gave rise to *Homo sapiens*.

Until recently, the consensus was that our great march out of Africa began 60,000 years ago and that by 30,000 years ago, for whatever reason, every other contender was extinguished. Only *H. sapiens* remained – a species with a linear history stretching some 6 million years back into the African jungle.

Or so we thought.

Starting in the early 2000s, a tide of new discoveries began, adding layer upon layer of complexity and confusion. In 2001 and 2002 alone, researchers revealed three newly discovered ancient species, all dating back to a virtually unknown period of human prehistory between 5.8 and 7 million years ago.

Very quickly, *Orrorin tugenensis*, *Ardipithecus ramidus* and *Sahelanthropus tchadensis* pushed a long-held assumption about our evolution to breaking point. Rough genetic calculations had led us to believe our line split from the chimp lineage between 6.5 and 5.5 million years ago. But *Orrorin*, *Ardipithecus* and *Sahelanthropus* looked more like us than modern chimps do, despite predating the presumed split – suggesting our lineage might be at least half a million years older than we thought.

At first, geneticists made grumpy noises claiming the bone studies were wrong, but a decade later, even they began questioning their assumptions. In 2012, revised ideas about how quickly genetic differences accumulate in our DNA forced a reassessment. Its conclusion: the human-chimp split could have occurred between 7 and 13 million years ago.

Not so chimp-like

Today, there is no longer a clear consensus on how long hominins have walked the earth. Many are sticking with the old assumption, but others are willing to consider the possibility that our lineage is almost twice as old, implying there are plenty of missing chapters to our story still waiting to be uncovered.

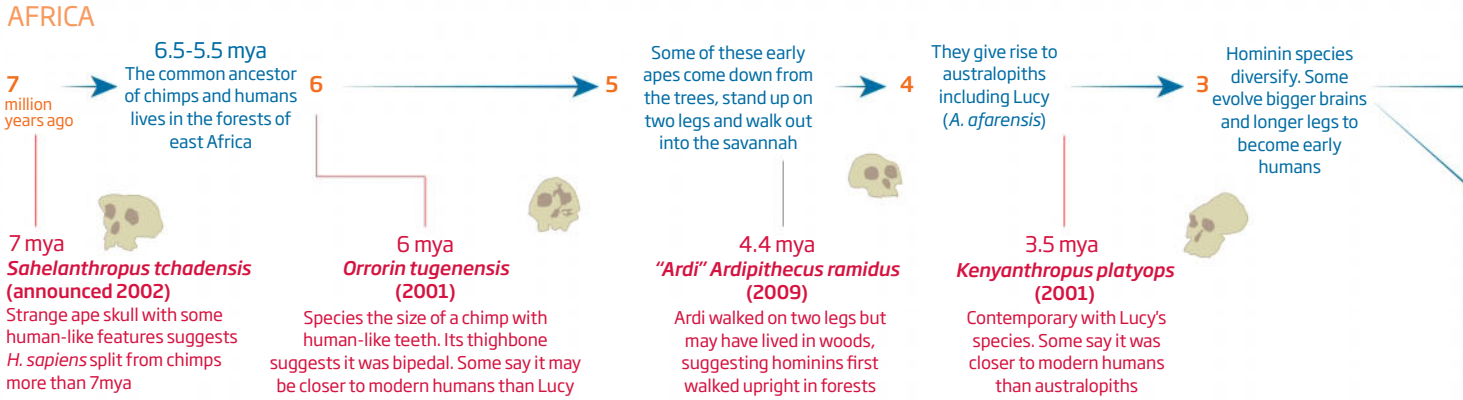
The struggles don't end there. The idea that our four-legged ancestors abandoned the forests, perhaps because of a change in climate conditions, and then adapted to walk on two legs is one of the oldest in human evolution textbooks. Known as the savannah hypothesis, it was first proposed by Jean-Baptiste Lamarck in 1809. Exactly 200 years later, an exquisite, exceptionally preserved 4.4-million-year-old skeleton was unveiled to the world, challenging that hypothesis.

"Ardi", a member of *A. ramidus*, is a jewel in the hominin fossil record. She is all the more important because of the number of key assumptions she casts doubt on. Ardi didn't have a chimp's adaptations for swinging below branches or knuckle-walking, suggesting chimps gained these features relatively recently. In other words, the ape that gave rise to chimps and humans may not have been chimp-like after all.

And contrary to Lamarck's hypothesis, her feet, legs and spine clearly belonged to a creature that was reasonably comfortable walking upright. Yet, according to her discoverers, Ardi lived in a wooded environment. This suggests that hominins began walking on two legs before they left the forests, not after – directly ›

Rewriting our timeline

In the early 2000s, **the standard story of how *H. sapiens* evolved** from a chimp-like ancestor seemed linear and logical. Then came **15 years of relentless and confounding discoveries**



contradicting the savannah hypothesis.

Although not everyone is convinced that Ardi was a forest-dweller, other lines of evidence also suggest we have had the upright walking story back to front all these years. Susannah Thorpe at the University of Birmingham, UK, studies orangutans in their natural environment and has found that they stand on two legs to walk along branches, which gives them better access to fruit. In fact, all living species of great ape will occasionally walk on two legs as they move around the forest canopy. It would almost be odd if our own ancestors had not.

Whether before or after standing on two legs, at some stage our ancestors must have come down from the trees. We can depend on that, at least. Entering the 21st century, we knew of just one group that fitted the transition stage: the australopiths, a group of ape-like bipedal hominins, known from fossils found largely in east and south Africa and dating to between 4.2 and 1.2 million years ago. They lived in the right place at the right time to have evolved into humans just before 2 million years ago. Lucy would have showed up in the middle of that period, 3.2 million years ago. Since her discovery, she has served as a reassuring foundation stone on which to build the rest of our hominin family tree, a direct ancestor who lived in east Africa's Rift Valley.

DIDIER DESCOUENS

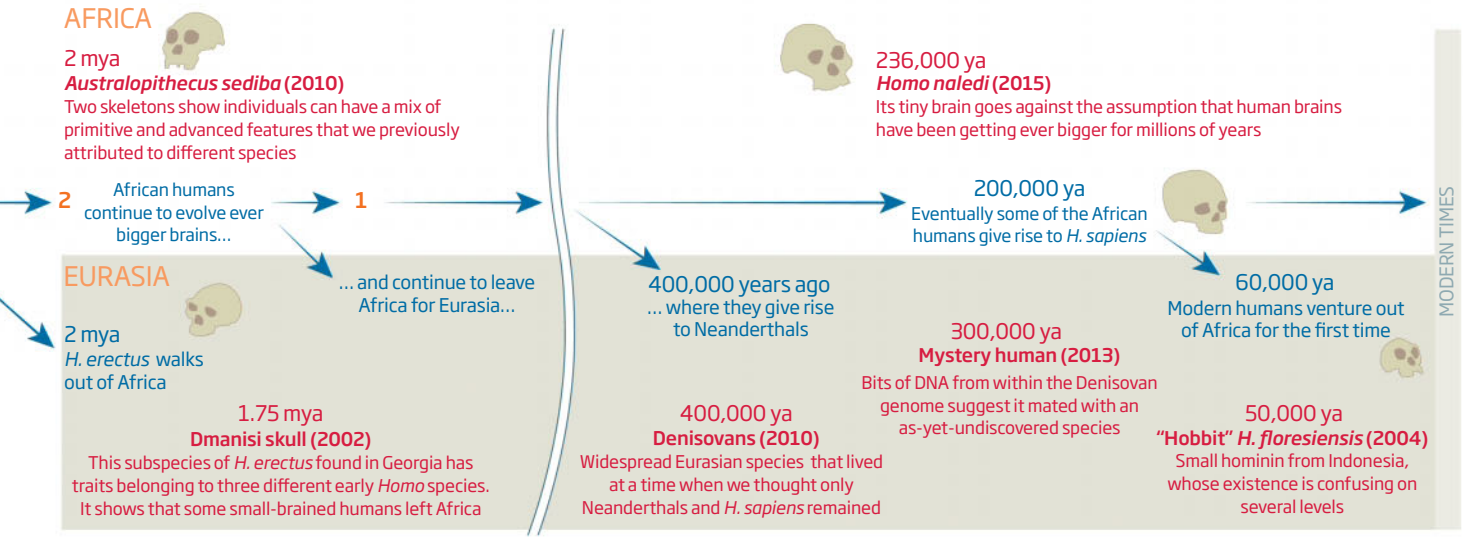
***Sahelanthropus* adds half a million years to our human lineage**

Then, in 2001, researchers unveiled a 3.5-million-year-old skull discovered in Kenya. The skull should have belonged to Lucy's species, *A. afarensis*, the only hominin species thought to be living in east Africa at the time. But its face didn't fit. It was so flat that it could barely be considered an australopith, says Fred Spoor at University College London, who analysed the skull. He and his colleagues, including Meave Leakey at Stony Brook University in New York, gave it a new name: *Kenyanthropus platyops*.

On the face of it, the suggestion that Lucy's species shared east Africa with a completely different type of hominin seemed only of marginal interest. But within a few years, the potential significance of *Kenyanthropus* was beginning to grow. After comparing the skull's features with those of other hominin species, some researchers dared suggest that *K. platyops* was more closely related to us than any australopithecus species. The conclusion pushed Lucy on to a completely different branch of the family tree, robbing her of her arch-grandmother position.

If that wasn't confusing enough, other researchers were making a similar attack from a different direction. The discoverers of *O. tugenensis*, the 6-million-year-old hominin found in 2001, also concluded that its anatomy was more human-like than that of australopiths, making it more likely to be our direct ancestor than Lucy or any of her kin.

Most of the research community remains unconvinced by these ideas, says Spoor, and a recent announcement that a human-like jawbone 2.8 million years old had been discovered in Ethiopia once more shored up Lucy's position. "In many respects it's an



ideal transitional fossil between *A. afarensis* and earliest *Homo*," says Spoor.

Even so, Lucy's status as our direct ancestor has been formally challenged, twice, and Spoor says it's not inconceivable that the strength of these or other challenges will grow. "We have to work with what we have and be prepared to change our minds if necessary."

Lucy (reconstructed, right) may not be our arch-grandmother after all

STUART ISETT/ POLARIS / EYEVINE

Tiny brains and alien hobbits

Intriguingly, in 2015, a team announced the discovery of the oldest known stone tools. The 3.3-million-year-old artefacts were found in essentially the same deposits as *Kenyanthropus*. "By all reasonable logic *Kenyanthropus* would be the tool-maker," says Spoor. Perhaps that hints at a tool-making connection between *Kenyanthropus* and early humans – although there is circumstantial evidence that some australopiths used stone tools too. In any event, determining which hominins evolved into humans is no longer as clear-cut as it once was.

Other important parts of the human evolution narrative were untouched by these discoveries, in particular, the "out of Africa" story. This idea assumes that the only hominins to leave Africa were big-brained humans with long legs ideally suited for long-distance travel.

But discoveries further afield have begun to chip away even at this core idea. First came news, in 2002, of a 1.75-million-year-old human skull that would have housed a brain of no more than 600 cubic centimetres, about half the size of modern human brains. Such a fossil wouldn't be an unusual find in east Africa, but this one turned up at Dmanisi in Georgia, in the Caucasus region. Clearly, small-brained hominins had left Africa.

In other respects, the Dmanisi skull and several others found at the site did not threaten the standard narrative. The Dmanisi hominins do seem to be early humans – perhaps unusually small-brained versions of *H. erectus*, conventionally regarded as the first hominin to leave Africa.

A discovery in 2003 would ultimately prove far more problematic. That year, researchers working on the Indonesian island of Flores found yet another bizarre skeleton. It had the small brain and small body of an early African hominin, from around 2 to 3 million years ago. To make matters worse, it seemed to have been alive just a few tens of thousands of years ago in a region thought to be home only to "true" long-limbed and large-brained humans. The team named the peculiar species *Homo floresiensis*, better known by its nickname: the hobbit.

"I said in 2004 that I would have been less surprised if they had found an alien spacecraft on Flores than *H. floresiensis*," says Peter Brown at the Australian National University, who led the analysis of the remains. The primitive-looking skeleton was, and still is, "out of place and out of time".

There's still no agreement on the hobbit's significance, but one leading idea is that it is evidence of a very early migration out of ›

REUTERS

Circular patterns that Neanderthals made with stalagmite pieces remain a mystery

NOT SO SPECIAL AFTER ALL

Our species, *Homo sapiens*, is special. We have achieved things beyond the capacities of all others in our family tree. Even with their wanderlust, the ancient humans that came before us probably never made it to the Americas, let alone reaching for the moon, of course. Ancient human species never learned to write, or compose symphonies, nor did they develop the scientific nous to explore their own evolutionary roots.

But the distinction between our species and those that went before may not be quite as stark as we once thought. In 2014, for instance, researchers found a zigzag that had been etched in a shell 500,000 years ago. We had thought we were the only species to produce abstract symbols, yet here was *H. erectus* doing so more than 200,000 years before *H. sapiens* even evolved.

Researchers are also becoming increasingly convinced that Neanderthals had advanced behaviour, like using watercraft to reach islands or exploiting simple chemistry to start fires. Some suggest they carved a hashtag sign on to a rock in Gibraltar. In a cave in France, they built mysterious stone circles out of stalagmites (pictured above). Were these symbols too?

And then there's *H. naledi*, with a brain less than half the size of our own. According to the team that excavated its remains, *H. naledi* might have deliberately disposed of its dead in deep, inaccessible cave chambers. Such behaviour seems strikingly modern, not at all the sort of thing expected of a hominin with a brain only marginally larger than a chimp's.

H. sapiens still stands out as a truly exceptional hominin – but the deeper we dig, the more we see echoes of our sophisticated behaviour in some of our ancient relatives.

Africa involving prehuman australopith-like hominins. In fact, the entire out-of-Africa narrative is in flux, with genetic and fossil evidence suggesting that even the once widely held opinion that our species left Africa 60,000 years ago is hopelessly wrong. Some lines of evidence suggest *H. sapiens* may have reached China as early as 100,000 years ago.

The hobbit was just one bizarre hominin, and could reasonably be discounted as a simple anomaly. But within little more than a decade of its discovery, two more weird misfits had come to light, both in South Africa.

Australopithecus sediba and *Homo naledi* are quite unlike any hominin discovered before, says Lee Berger at the University of Witwatersrand in South Africa, who led the analysis of both. Their skeletons seem almost cobbled together from different parts of unrelated hominins. Significantly, the mishmash of features in the *A. sediba* skeleton, unveiled in 2010, is very different from those in the *H. naledi* skeleton, unveiled in 2015.

A. sediba's teeth, jaws and hands were human-like while its feet were ape-like. *H. naledi*, meanwhile, combined australopith-like hips with the skull of an early "true" human and feet that were almost indistinguishable from our own.

"Our human history made great sense – right up to the moment it didn't"

No other ancient species seems quite as strange – but, as Berger points out, very few other ancient hominins are preserved in so much detail. Perhaps that's just an interesting coincidence. Or perhaps, he says, it's a sign that we have oversimplified our understanding of hominin evolution.

We tend to assume that ape-like species gradually morphed into human-like ones over millions of years. In reality, Berger thinks, there may have been a variety of evolutionary branches, each developing unique suites of advanced human-like features and retaining a distinct array of primitive ape-like ones. "We were trying to tell the story too early, on too little evidence," says Berger. "It made great sense right up until the moment it didn't."

Earlier this year, Berger announced the age of the *H. naledi* remains. They are just 236,000 to 335,000 years old. Weeks later, news broke that 300,000-year-old fossils from Morocco might belong to early members of *H. sapiens*. If correct, the fossil extends our species' history by a whopping 100,000 years.

BRENT STIRTON/GETTY IMAGES REPORTAGE

Australopithecus sediba **has a bewildering mix of human and ape-like traits**

H. naledi's relatively young age is also a striking example of how complex and confusing the human evolutionary tree might really be. Human brains didn't grow and grow for millennia, with smaller-brained species falling to the wayside of the gradual evolutionary road. Instead, our species occupied an African landscape that was also home to humans with brains half the size of theirs.

We can only speculate on how (or whether) the small-brained *H. naledi* interacted with the earliest *H. sapiens*. Tantalising but controversial evidence from Berger's team suggests that *H. naledi* intentionally disposed of its dead – perhaps a sign that even "primitive" hominins could behave in an apparently sophisticated way (see "Not so special after all", left).

Another independent line of evidence suggests that different behaviour was not necessarily a barrier to inter-species interactions.

In the late 1990s, geneticists began to show an interest in archaeological remains. Advances in technology allowed them to sequence a small chunk of mitochondrial DNA (mtDNA) from an ancient Neanderthal bone. The sequence was clearly distinct from *H. sapiens*, suggesting that Neanderthals had gone extinct without interbreeding ("admixing") much with our species.

But mtDNA is unusual. Unlike the nuclear DNA responsible for the bulk of human genetics, it passes intact from a mother to her children and doesn't mix with the father's genes. "Mitochondrial DNA is the worst DNA you can choose to look at admixture," says Johannes Krause at the University of Tübingen in Germany.

By 2010, a very different picture was emerging. Further advances in technology meant geneticists such as Krause could piece together a full nuclear genome from Neanderthal bones. It showed subtle but distinct evidence that Neanderthals had interbred with our species after all. The behavioural differences between humans and Neanderthals were evidently not enough to preclude the occasional tryst.

Arguably, this wasn't the biggest genetics announcement of the year. In their searches, Krause and his colleagues had examined genetic material extracted from a supposed Neanderthal bone fragment unearthed in a Siberian cave in 2008. To everyone's surprise, the DNA in the bone wasn't Neanderthal. It came from a related but distinct and entirely new hominin group, now dubbed the Denisovans.

To this day, the Denisovans remain enigmatic. All that we have of them are one finger bone and three teeth from a single cave. We don't know what they looked like, although *H. sapiens* considered them human enough to interbreed with them: a Denisovan nuclear genome sequence published in 2010 showed clear evidence of sex with our species. The DNA work also shows that they once lived all across East Asia. So where are their remains?

Slap and tickle

Fast-forward to 2017, and the interbreeding story has become more complex than anyone could have imagined in 2000. Krause reels off the list. "Neanderthals interbred with *H. sapiens*. Neanderthals interbred with Denisovans. Denisovans interbred with *H. sapiens*. Something else that we don't even have a name for interbred with Denisovans – that could be some sort of *H. erectus*-like group…"

Although weird bones have done their bit to question our human history, it's the DNA inside them that may have done the most to shake up our evolutionary tree. With evidence of so much ancient interbreeding, it becomes far more complicated to decide where to draw lines between the different groups, or even if any lines are justified.

"How do you even define the human species now?" says Krause. "It's not an easy discussion." Most of us alive today carry inside our cells at least some DNA from a species that last saw the light of day tens of thousands of years ago. And we all carry different bits – to the extent that if you could add them all up, Krause says you could reconstitute something like one-third of the Neanderthal genome and 90 per cent of the Denisovan genome. With this knowledge, can we even say that these species are truly extinct? Pushing the idea one step further, if most living humans are a mishmash of *H. sapiens* DNA with a smattering from other species, is there such a thing as a "true" *H. sapiens*?

Having dug ourselves into this philosophically troubling hole, there's probably only one way to find our way out again: keep digging for fossils and probe them for more DNA. ■

Colin Barras is a consultant for *New Scientist* based in Michigan

Wonders of numberland

The world of numbers may be abstract, but it contains creatures that, in their own way, rival those of nature. Here are some of them...

Zero

The number that's not a number

YOU could be forgiven for thinking that zero is not a proper number. After all, numbers are the things we use to count, and you can't count nothing.

We have evidence for counting going back five millennia, but the history of zero only began with the Babylonians in about 1800 BC. Even then, it was not a fully fledged number. The point of zero for them was like the zero in our modern representation of a number like 3601 – it's a position-setting symbol that distinguishes the number from 361.

The Babylonians' symbol was two diagonal arrows; the familiar squashed egg shape only came into being around AD 800, still as an accounting symbol. It was the work of Indian mathematicians that sparked the genesis of zero as a number, when they first appreciated that numbers can have an abstract existence distinct from counting physical objects. The astronomer Brahmagupta, for example, laid out a number line that included positive and negative numbers and zero.

This line of thought wasn't embraced in the West until much later, partly because zero was considered a gateway to the negative numbers, where debt and fraud lay. By the late 19th century, however, mathematicians had become interested in establishing rules of mathematical logic. When the Italian mathematician Giuseppe Peano set out a list of rules for arithmetic, his first axiom insisted that zero must be a number. Otherwise how would you perform a calculation that traverses the boundary between positive and negative, like 7 - 9?

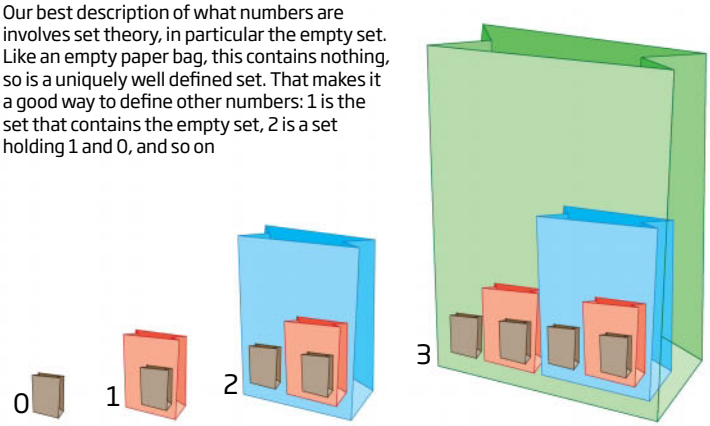
Zero's number status was secured, but it had an even greater role still to come, in defining what numbers really are. Our best answer to that question involves set theory. The set, first conceptualised by Georg Cantor in 1874, is an abstract mathematical container; it might be the set of dwarfs in *Snow White* or the set of days in a week. If you could define a unique set that had intuitively 7 elements, that would help explain what we mean by the number 7. It turned out the best way involves a totally unique set: the empty set, which has zero members (see diagram, left).

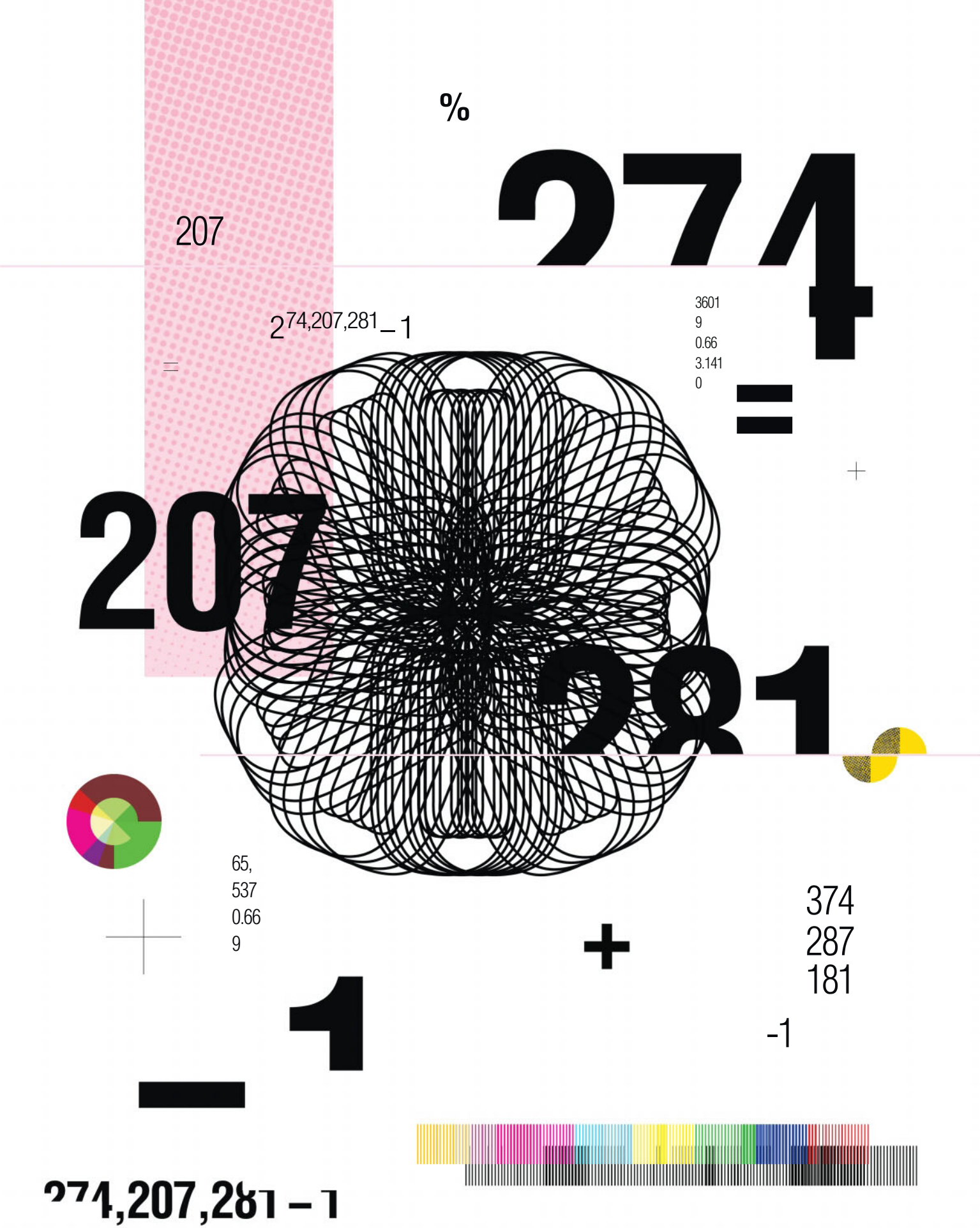
That's not to say everything is wrapped up. But that's another story, for which we must visit the other end of the number line (see "Infinity", page 39).

Michael Brooks

How to make a number

Our best description of what numbers are involves set theory, in particular the empty set. Like an empty paper bag, this contains nothing, so is a uniquely well defined set. That makes it a good way to define other numbers: 1 is the set that contains the empty set, 2 is a set holding 1 and 0, and so on




%
207
274
$2^{74,207,281}-1$
=
3601
9
0.66
3.141
0
207
281
65,
537
0.66
9
374
287
181
-1
1
274,207,281 – 1

Euler's number

Why things don't grow forever

PUT a pound in the bank. If the yearly interest were 100 per cent, then a year later you would have £2. That's simple enough. But what if instead of calculating the interest at the end of the year, the bank worked it out more regularly? It turns out this question leads us to one of the most subtle numbers in mathematics.

Say your bank paid interest twice a year but halved the rate to 50 per cent. That would take your £1 to £1.50 after 6 months, and at the end of the year you would get another 50 per cent, making £2.25 – a nice gain. If you got interest monthly but scaled down the rate accordingly, you'd end up with £2.61. Do the same thing daily, reducing the interest rate in the same fashion, and you'd get £2.71. The improvements get ever smaller as this process continues, and the most you could have turns out to be about £2.71828.

This number is actually a special irrational, which, like π, keeps on going forever after the decimal point. It's called Euler's number (or simply e), after the Swiss mathematician Leonhard Euler.

Euler's number doesn't just appear when computing compound interest. For instance, mix together the imaginary number i (see page 38) and e and, with a little mathematical nous, you can derive one of the most famous equations ever, Euler's identity: $e^{i\pi} + 1 = 0$. Mathematicians hold it in high regard for its beauty, cramming five of the most important numbers into a single, elegant expression.

Euler's number is also practical. It is crucial to a mathematical technique called Fourier analysis, for example, which is used by researchers who probe crystals by shining X-rays at them. Applying the analysis to the patterns that emerge helps reveal the structure of molecules such as DNA.

But it's not all so serious. Take the mathematical expression e^x and carry out the technique called integration, co-invented by Isaac Newton. Ignoring the usual constant that appears in such a calculation, you get back e^x. This standstill only happens with e^x or multiples of it.

That leads to one of the best-worst maths jokes ever. Why is e^x always stood alone at parties? Because when it tries to integrate nothing happens. *Timothy Revell*

The golden ratio

The most beautiful number ever?

YOU have probably heard of the Fibonacci sequence, that list of numbers where the next digit is given by adding the previous two. It goes 1, 1, 2, 3, 5, 8, 13 and so on. But here's something strange: work out the ratio of each number and its predecessor, and you start edging towards a specific number. Its first few digits are 1.618.

This mysterious beast is the golden ratio, and it crops up a lot. Try drawing a diagonal line connecting two vertices of a regular pentagon. Divide the length of that line by the length of the pentagon's sides and there it is. Something similar is possible with an equilateral triangle.

It turns out to be a quirk of maths. Imagine you have a number, A, and a larger one, B. If you set the numbers so that the ratio of B to A is the same as $A+B$ to B, then that ratio is always the golden ratio.

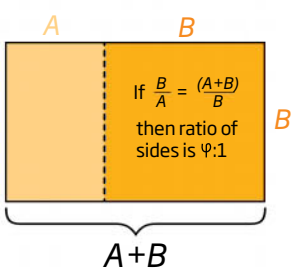
That might have been the end of the matter, but the ratio has taken on a life of its own. Search for it online and you'll be inundated with claims that ancient Greek architecture or the human face exhibit such proportions, and that people find it immensely aesthetically pleasing.

The truth is murkier. The human body has countless different proportions, and some of them seem to be close to the golden ratio, but not for everyone. The ancient Greek architects were aware of the golden ratio, so it is possible that they made use of it. To find out, just measure the ruins, you might say. But then there's the question of which bits you measure – look hard enough and you will find the ratio if you want to.

A similar problem plagues studies that ask people to rate the aesthetics of artworks that incorporate the golden ratio and others that don't. It's not clear whether that judgement is really based on the ratio, or whether the association is learned or innate. Luckily, maths contains beauty enough without magic ratios. *Timothy Revell*

Golden rectangle

The rectangle below was drawn to have sides in the ratio 1.618:1. Some claim that buildings containing this "golden ratio" are especially pleasing to look at



Graham's number

The biggest number with a name of its own

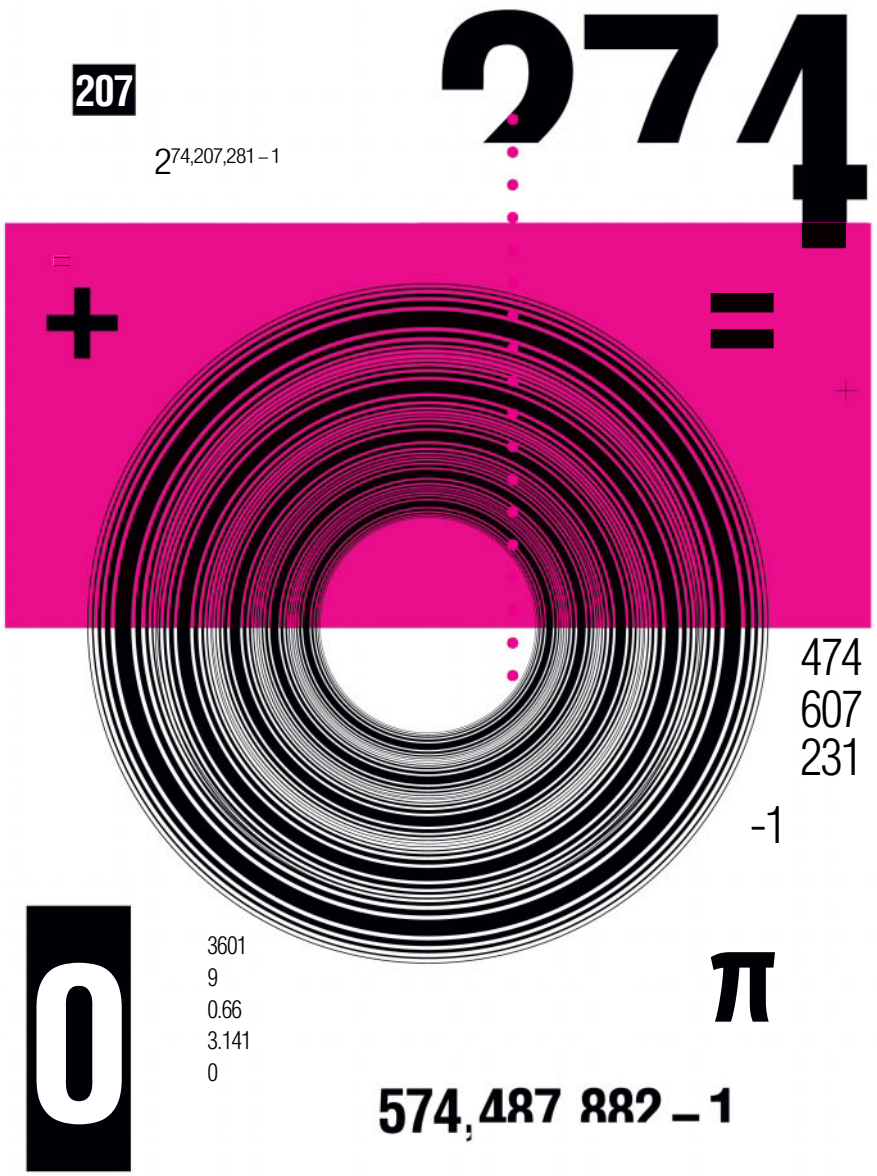
MOST numbers have never touched a human mind. There are an infinite number of numbers, after all, so it stands to reason that we have only bothered with the small ones.

But in the 1970s, Ronald Graham, a mathematician now at the University of Califonia, San Diego, was working on a problem that proved to have a truly gargantuan answer. He was trying to solve a problem to do with cubes in higher dimensions, and when he finally got there, the answer involved a number so large we can't write down its digits – there isn't enough space in the universe.

Yet there is a way to grasp at Graham's number. A more concise way of writing 3×3×3 is exponentiation: 3^3 means "multiply three threes together", giving 27.

We can go further, using something called Knuth's up-arrow notation. $3\uparrow 3$ means the same as 3^3, but $3\uparrow\uparrow 3$ starts a rising tower. The two arrows tell us to repeat the exponentiation, giving us 3^{3^3}, which is around 7.6 trillion.

Add a third arrow, $3\uparrow\uparrow\uparrow 3$, and things



take a major uptick, so that you reach an unimaginable stack of exponentiation upon exponentiation. Graham's number is written as 64 layers of up-arrow notation, with each layer longer than the last. In case you're wondering, its last digit is 7.

Graham's number is a whopper, but we can think of bigger ones still.

Take the function TREE(n), which relates to putting a certain number of labels on mathematical objects similar to a family tree, as part of a proof known as Kruskal's tree theorem. TREE(1) is 1. TREE(2) is 3. TREE(3) is so big it makes Graham's number seem practically zero.

Another function, called Busy Beaver, grows so fast that it has been mathematically proven to be impossible for any computer program to calculate all but its smallest values.

Busy Beaver was recently used to show that some problems are impossible to solve using the standard axioms of mathematics. But that's another big problem altogether. *Jacob Aron*

$2^{74,207,281}-1$

The force behind encryption

MULTIPLY 2 by itself just over 74 million times, then subtract 1. This is the largest known prime number – a number that can only be divided by 1 and itself – with more than 22 million digits. It isn't just any old kind of prime, either. It is a Mersenne prime, one equal to a power of 2, minus 1.

Other numbers in the Mersenne club include 3 and 31, but finding larger ones is no easy task. We have only discovered 49 of them. Despite knowing for thousands of years that there are infinitely many primes, we have no idea if there are infinitely many Mersenne primes.

Without prime numbers like this one, the world would be a very different place. To ensure that all sorts of online transactions are encrypted, so that only the intended recipient can unscramble them, we rely on primes.

The idea is that the receiver multiplies two big primes to create a new number called the public key. Anyone with this key can encrypt messages, but to turn them from gobbledegook to something meaningful requires knowledge of the original two primes.

Multiplying primes together is easy for computers, but if the answer is large enough, the only way to work out the primes that produced it is essentially to try out all the possibilities. That's practically impossible, making the whole process secure.

We don't really need to find a 50th Mersenne prime for the sake of encryption. But it'd be nice all the same. *Timothy Revell*

CREDIT CHECK

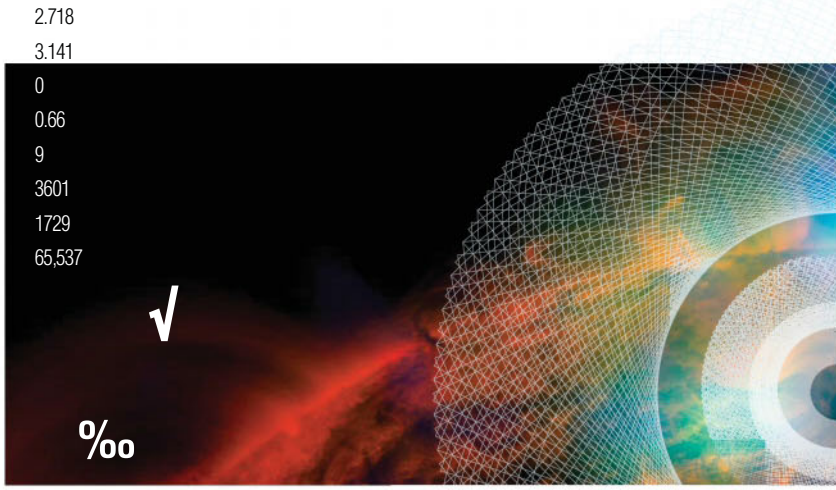
Ever wondered how a website knows you've typed your credit card number in wrongly before it's sent it to your bank for verification? It's probably thanks to a trick called the Luhn algorithm, the brainchild of the German-born American Hans Peter Luhn when he was working for IBM in 1954. A pioneer of mechanical data storage, Luhn was also a prolific inventor who held more than 80 patents, including one for ornamented, knitted stockings.

But the algorithm is his enduring achievement. The digits of most major credit card numbers are chosen so that, if you apply the Luhn algorithm to them, the result will be divisible by 10. Get any single digit wrong, and the number that comes out the other end won't end in a zero – and in the blink of an eye the computer says no. *Richard Webb*

To test your own credit card number see page 38 ›

CHECK YOUR CREDIT CARD NUMBER

1. Write down the 16-digit number backwards.
2. Add together all the odd digits – the ones in first, third, fifth position and so on.
3. Next, take all the digits in even positions and double them. If any of these are two-digit numbers, add the actual digits of those numbers together to get a one-digit number. Now add those numbers up.
4. Add together your answers from steps 2 and 3. The last digit of this number must be 0.



i

The imaginary number

THE rules of mathematics say that two positive numbers multiply to give a positive, and two negative numbers also multiply to give a positive. So what number could you multiply by itself to give -1? This is not a trick question – it's just that the answer is imaginary.

The square roots of negative numbers were first called "imaginary" by René Descartes in 1637. But it wasn't until the 18th century that they came to be represented as multiples of *i*, the square root of -1.

Imaginary numbers don't fit on the regular number line, so they are put on a second, independent line, with the two intersecting at zero. The lines can be treated as axes, making imaginary numbers handy for representing things that change in two dimensions. They are regularly used to describe wave functions in quantum mechanics and to define alternating current.

Conjuring an entirely different family of numbers from thin air might seem unjustifiable. But the truth is that "real" and "imaginary" numbers are both abstract concepts. We might be more familiar with 5 than 5*i*, but neither exists in the real world.

That gives mathematicians a certain creative licence. In 1843, the Irish mathematician William Hamilton invented numbers called quaternions, using additional solutions for the square root of -1 that he called *j* and *k*. These form the basis of additional number lines that are used to construct axes capable of encoding rotations in 3D. Computer game design is one area where they have proved useful.

If you follow the same mathematical logic, then there is no reason to stop there. The octonions add an extra four dimensions of imaginary numbers, and the rarely used sedenions give the option of extending the total to 15. Down here, it's a world of pure imagination. *Gilead Amit*

The Lyapunov exponent

The boundary of chaos

AND the weather on Tuesday will be exponential errors, followed by a loss in predictability. Because of Lyapunov exponents, it is impossible to accurately forecast the weather more than a few days ahead. Instead of predictability, there is chaos.

In the late 19th century, the Russian mathematician Aleksandr Lyapunov invented these numbers to describe how sensitive a system is to its starting point. Imagine, for example, throwing a ball across a field. Provided you know the angle and speed at launch, you can calculate where the ball will land to a good degree of accuracy without worrying about small effects like air resitance. If your measurements of the angle are a bit off, that doesn't matter either. This situation would have a Lyapunov exponent of 0, or perhaps a negative value.

Above that threshold of zero lies unpredictability. The weather is a case in point because tiny differences in starting conditions, such as in air pressure or temperature, grow exponentially over time to cause wildly different outcomes. If throwing a ball were like this, a launch angle of 30 degrees might arrive at catching height for your friend, while an angle of 30.00000001 degrees might land the ball on the moon. Mathematicians call this chaos.

Positive Lyapunov exponents make long-term weather forecasts impossible. As we can never measure wind speed, say, with total accuracy, an initial, barely noticeable error will grow so that in only a few days the forecast will be mostly error. In countries like the UK, where air currents are highly changeable, the Lyapunov exponent of the weather is much higher than in the tropics.

"We cannot predict the future. Any little uncertainty gets amplified exponentially by chaos," says Francesco Ginelli at the University of Aberdeen, UK. Whether it is predicting the weather, the stock markets or the next president, Lyapunov exponents tell us our efforts are futile. But experience tells us we're unlikely to stop trying. *Timothy Revell*

BENFORD'S LAW

What do absent aliens, dodgy dictators and financial fraudsters have in common? Benford's law can help hunt them down.

Benford's law states that lists of numbers related to some natural or human activities will contain a particular distribution of digits. If you take a list of the areas of river basins, say, or the figures in a firm's accounts, there will always be more numbers that start with 1 than any other. Numbers starting with 2 are the next most common, then 3 and so on. A number will start with a 9 only 4.6 per cent of the time.

The pattern was originally suggested by astronomer Simon Newcomb in the 1800s in a riveting analysis of how people use books of logarithm tables. In the 1930s, the engineer Frank Benford rediscovered the result.

Why on earth should Benford's law exist? Drill down to the root cause of most natural processes and they depend on random things, like the jostling of atoms. That produces bell-shaped curves, where most

The Laplace limit

Why we don't stray far from the sun

IN 1609 the great astronomer Johannes Kepler published a book called *Astronomia Nova*. This "new astronomy" delivered a bombshell: planets revolve around the sun in ellipses, not circles. But the equation at the heart of the revelations, Kepler's equation, had astronomer's heads spinning faster than the planets they were studying.

The formula describes the relationship between the coordinates of an object in orbit and the time elapsed from an arbitrary starting point. Actually solving it to find that location is fiendishly tricky. But eventually, astronomers saw it pointed to a particular number.

It took 150 years to find a mathematical way to solve it. The laborious process involved long strings of mathematics known as series expansions. Then the French polymath Pierre-Simon Laplace showed that this method would not work if the orbit was too elliptical.

You can measure how far removed an ellipse is from a circle with a measure called eccentricity. A circle has an eccentricity of 0, and for values greater than that things become more skewed. Laplace found is that for orbits with an eccentricity of more than about 0.66 – now known as the Laplace limit – the method would not converge on a solution.

Eccentric bodies

This means that "in general, orbits are less stable if the eccentricity is higher," says Gongjie Li of Harvard University. Fortunately, Earth's orbital eccentricity is about 0.02. Bodies farther out often have higher eccentricities. Pluto's is 0.25.

This doesn't mean that orbits with an eccentricity of more than 0.66 are impossible. Halley's comet has an eccentricity of 0.9. But that's best thought of as a fly-by rather than an orbit, really. The comet's swinging loop brings it close to the sun, then catapults it into the coldest reaches of the solar system. Not a place we'd want to be. *Stuart Clark*

of the values are in the middle. But if several natural phenomena are at play – which is the case in a huge number of fields – then it turns out that Benford's law is what holds.

No surprise then, that you can use it in lots of neat ways, especially to catch out miscreants. In 2009, for example, a suspiciously large number of vote tallies for one candidate in the Iranian elections began with a 7, suggesting vote-rigging.

The US Internal Revenue Service has scored several major successes by using Benford's law to probe firms' books for financial chicanery. And in 2013, a new application arose that brought it right back to its astronomical origins. Thomas Hair at Florida Gulf Coast University showed that the masses of thousands of confirmed and candidate exoplanets conform to the pattern. OK, it doesn't tell us where to look for ET, but it gives us confidence that our ways of seeking exoplanets aren't delivering spurious results. *Michael Brooks*

Infinity

The concept that makes and breaks maths

A BILLION! A squillion! Infinity! Infinity plus one! Children of a certain age delight in outdoing each other with the biggest number. It's just a shame that we grow up into a humdrum world where nothing as exotic as infinity exists.

Or does it? Despite our innate discomfort with the idea, infinity is baked into the way we understand the world. Take Einstein's theory of gravity, general relativity. It predicts black holes where space-time is infinitely curved. Then there's calculus, a crucial technique used to describe processes of continual change that relies on the fact that space and time are infinitely divisible.

That's not to say physicists are comfortable with infinity. When equations in cosmology give us infinity, they go to great lengths to rewrite the theories.

But there's no avoiding it in another bedrock of science – set theory. The set, an abstract mathematical container, can help explain what a number is if defined rigorously enough. Our first attempt at that definition involved the empty set (see "Zero", page 34). It worked well enough until infinity got involved.

Try imagining the set of all whole numbers. How large is it? You can keep counting forever, so the answer seems to be "infinitely large". But then consider a head-scratcher posed by the German mathematician David Hilbert in 1924. He imagined a hotel with an infinite number of rooms, all occupied. Then an infinite busload of new guests turns up. Can the hotel cope?

Intuition says no, but infinity says yes. Move the guest in room 1 to room 2, the guest in room 2 into room 4 and so on; to put it another way, every guest in room n winds up in room $2n$. Now all of the odd-numbered rooms are free and your hotel, which was infinitely full, has infinite vacancies.

In other words, sets of whole numbers that have apparently different sizes can both, on close inspection, be infinite. Set theory has never managed to deal with such contradictions.

Even worse, some infinities are larger than others. Think of the set of all whole numbers – it is infinitely large. But now think of all the decimals between each of those whole numbers – it's infinitely larger again. How's that for a way to win a playground argument? *Stuart Clark*

I know what your dog is thinking

No other species is as close to us as our dogs, says **Gregory Berns**, which is why he opened a window into their minds

In an anatomy classroom in 1990, the gathered medical students were instructed to inject an anaesthetised dog with various drugs to study how they affected its heart rate and blood pressure. At the end of the lesson, they were told to euthanise the animal. Reluctantly, Gregory Berns shouldered that responsibility. Today, still haunted by the memory, Berns advocates treating animals in experiments as if they were humans – by acknowledging that they have feelings and experience the world as we do. He has functional MRI scans to make his case.

GREGORY BERNS

PROFILE
Gregory Berns is a professor of psychology at Emory University, Atlanta, Georgia, and directs its Center for Neuropolicy. He has run the MRI-based Dog Project since its inception in 2011, and is author of *What It's Like to Be a Dog* (Basic Books)

Berns with his MRI-trained dog, Callie
Left: A willing subject assumes the position

What made you put dogs in an MRI scanner?
Strangely enough, it started with the 2011 mission that killed Bin Laden. There was a dog on that mission. I thought, if dogs can be trained to jump out of helicopters and work in noisy environments, then we can train them to go in an MRI machine – which sounds like a jackhammer when you are inside it. I wanted to know what dogs were thinking. Is it just about food or do they have any emotions similar to ours? My favourite pet dog had died months earlier. Maybe subconsciously I had wondered if he'd experienced anything similar to the feelings of love that I had for him.

How difficult is it to teach a dog to play along?
It's actually not that difficult, but I'm saying that with hindsight, having trained almost 100 dogs to do it. First, we created MRI simulators, starting with bits of construction tubing on a table. We built the elements of the head coil that picks up the signals. Once we'd figured out how to make a chin rest that dogs could put their head on to ensure a consistent and stable position, the behaviour itself is easy for the dogs. It's just lying down and staying. Then it's a matter of gradually getting them used to the banging noise of the MRI.

What are your ethical guidelines?
They go beyond what's legally required. We don't give dogs any sedation or anaesthesia, or restrain them. If they don't want to be in the scanner, they can get up and leave. Sometimes they do. Self-determination is critical: animals in experiments are rarely given that right.

Why do you study dogs?
Neuroscience has concentrated on just a few species. We know a lot about ourselves, rats and mice, and something about monkeys. But in many ways, dogs are even closer to humans than monkeys, because they are the only other species that truly share our social environment. They can tell us things no other animal can: we are blazing a path in studying the evolution of cross-species sociality.

What do other scientists think about this work?
It's mixed, but a common criticism is, "you can always design behavioural experiments to learn about the internal state of a dog. You don't need brain imaging to tell you."

I don't agree. Dogs are not like rats or monkeys. In evolving from wolves, dogs' strategy has been to attach themselves to us, and that's very effective – just look at all the dogs in the world. So in any behavioural test, pet dogs especially look towards the human to solve the problem for them. That makes it very hard to design good behavioural tests for dogs as you are constantly battling their tendency to look to the human. And people cannot help it: if the dog can see you, it's all too easy to give subtle signals that the dog will pick up.

What have you seen with MRI scanning that you couldn't get with a behavioural experiment?
Functional MRI data tells us something about mental states that we can't get just by looking

Photographed for New Scientist by Raymond McCrae Jones

at outward behaviour. For example, we did an MRI study on 50 dogs in collaboration with a group that trains service dogs – at significant expense – for people with disabilities. The goal was to see if we could predict, based on brain activity alone, whether a dog would be useful for people with disabilities. We found we could.

What did you do to test the dogs?
After training the dogs to lie still in the scanner, we presented them with hand signals, either from their trainer or a stranger, indicating that a food treat was coming or not. The reaction in the brain showed that the animals were responding to the two humans differently. This was particularly evident with activity in the caudate nucleus, the structure in mammal brains that signals anticipation of something important, and the amygdala, which is linked to the level of emotional arousal or anxiety an animal is experiencing.

Dogs that responded strongly in the caudate nucleus regardless of who gave the hand signals were highly likely to have a successful placement. A strong response in the amygdala to the stranger correlated to the dog ultimately failing its service training.

How do you interpret these results in terms of possible mental states?
The dogs were simply lying down, so there was no behaviour to suggest differences in mental states. But the caudate activity suggested that dogs who attached a higher incentive value to the hand signals were the ones who eventually became good service dogs. Perhaps this is a measure of motivation. In contrast, higher amygdala activity in the dogs – perhaps from anxiety or excitement – indicated that they were experiencing arousal without showing it.

How could this approach be better than a behavioural one?
By focusing on internal states, we may be able to detect emotions before they lead to problem behaviours. We could reinforce "good" internal states with praise and play, and decrease "bad" states through calming approaches.

"If the dogs don't want to be in the MRI scanner, they can get up and leave"

In your book, you say philosopher Thomas Nagel's 1974 essay, "What is it like to be a bat?", cast a long shadow over neuroscience. Why?
That essay basically said it doesn't matter how much you study the brain, you'll never know what it's like inside another brain or mind.

He picked bats because they fly and because they echolocate, unlike humans. But that's no longer true. Now, people put on wingsuits and jump from cliffs. So they know what it's like to fly and can tell us about the experience. Even the echolocation argument is false, because people can echolocate: we can all tell the dimensions of a room, and whether it has hard or soft surfaces, just by how it sounds.

So what's your take-home message?
That pretty much all mammals have basically the same sensory experiences, albeit enhanced or degraded in different ways. Denying this allows scientists to do experiments on animals that we wouldn't do on a person, because we supposedly don't know what the animal is experiencing. But I think we do know: when we see similar structures and functions in the brains of other animals, they are very likely having similar subjective experiences. It's easier to ignore their plight if you sweep their sentience under the rug. ■

Interview by Anil Ananthaswamy

The return of climate science's preacher man

After 10 years fighting climate denialism, **Al Gore** thinks we're on the road to salvation. **Fred Pearce** sees his new film and meets the man

An Inconvenient Sequel: Truth to Power, in cinemas now

AL GORE is an optimist. That's official. After a quarter of a century of being seen as a climate doom-monger, he says we are on the way to fixing global warming. "The train has left the station," he said in London earlier this month.

And as he told *New Scientist*, "The world is now clearly in the early stages of a global sustainability revolution – on the magnitude of the industrial revolution, but with the speed of the digital revolution.

"I don't want to say new technology will solve this on its own, " he says. "It requires civil society to demand change, too. But we have the tools, and they are increasingly affordable."

Gore was promoting a film of his campaigning life, *An Inconvenient Sequel: Truth to Power*, which follows his decade on the road selling the science behind his 2006 Oscar-winning film, *An Inconvenient Truth*.

I didn't expect to be moved by it. But I was. By the man, the story he tells and by his long march as a travelling medicine-man-cum-preacher, out to witness climate change and heal the world.

His is a world tour like no other. The film's opening scenes take place in Greenland, where he walks over the ice, balancing precariously on the edge of a moulin, the spot where a river of glacier meltwater pours down a sinkhole to the bottom of the ice a kilometre below.

There, as Swiss glaciologist Konrad Steffen explains while holding Gore steady, the water will lubricate the glacier's slide to the sea. Gore is watching global warming being fast-tracked into sea level rise.

The pictures are mind-blowing. The politics is good too. Later, on his way to one of the training sessions he does on how to communicate the facts of climate change, he wades through flooded streets in Miami, Florida. He gets a certain pleasure out of going to the scene of the "hanging chads" (the not-quite-punched holes in ballot cards) that deprived him of the presidency in 2000, and musing on how the state's governor continues to deny that the rising tides are caused by climate change.

> **"The world is in the early stages of a sustainability revolution – at the speed of the digital revolution"**

Is the science good? Mostly, yes. He pushes the bounds by implying that most wild and weird weather can be blamed on climate change. But who wouldn't want to point out that one of his most ridiculed predictions of a decade ago – that storms and rising tides could soon flood the site of the 9/11 disaster in Manhattan – came true during Hurricane Sandy in 2012?

In one of the film's most compelling sections, he goes to the city of Tacloban in the Philippines, which was hit in 2013 by Typhoon Haiyan and more than 6000 people died. The city's mayor shows him frantic footage of his staff scrambling onto the roof of a municipal building as it filled with water.

While visiting the city, Gore holds one of his training sessions for the survivors. You would think that they had their own stories to tell and that they would be more compelling than Gore's graphics.

But Gore admits to camera: "I wanted to meet face-to-face the people who experienced this… I don't know any other way." Was he implicitly criticising George W. Bush's invisibility after Hurricane Katrina in New Orleans? Yes, probably. Had he demonstrated Haiyan was caused by climate change? Well, no.

Consistent message

The pain of being denied the presidency is still palpable in the film and in almost everything he says in interviews. For me, it makes the Gore roadshow as poignant as it is remarkable. Such constancy on the campaign trail is rare among politicians, even in pursuit of office. Such consistency of message is unheard of in the age of the tweet.

And the training sessions he gives seem to work. One of his early attendees – in 2007 in Nashville, he remembered for me – was a diplomat called Christiana Figueres, who later became the UN's chief climate negotiator. She was centre stage, arms aloft, as the Paris climate accord was gavelled through in 2015, while an avuncular Gore stood and applauded from the floor. It was a touching and understated moment.

But his journey has undeniably been lonely. He gets flak from the political right, who find it easier to mock him than to address his science. He gets flak from the left, because he believes that capitalism – through

PARAMOUNT PICTURES/ENTERTAINMENT PICTURES/ZUMAPRESS.COM

Al Gore runs training sessions to help communicate climate facts

entrepreneurial solar power companies, carbon taxes and the like – can fix things.

Is he the only one without another agenda? He thinks so. He rails on camera against the "dark money" funnelled into climate denialism: "Our democracy has been hacked… by big money." In an age when some public faces of climate science speak with the same venomous certainty as their adversaries, Gore looks for bipartisanship.

In fact, the only other politician to get more than a few seconds in the film is a Republican mayor from a Trump-voting small town in Texas, who was working to power his town completely from wind turbines and solar panels. He has now succeeded, Gore said triumphantly during our interview.

But for a man who has tasked himself with teaching others how to communicate about climate change, Gore sounds almost humble about his failure to convince his fellow Americans. "It's frustrating," he says. "For many years I have tried… I have felt it is a personal failure on my part."

He often seems bemused by the visceral hate that he engenders for telling people things they don't want to hear. I asked him about this. He said that he has spent time consulting "neuroscientists and behavioural psychologists", and has concluded that humans "have an innate need to feel things are basically fine".

How does he counter this? He doesn't quite answer, but wonders whether Americans who once felt secure that there was no problem from climate change will soon flip to feeling secure that the problem they once denied is being fixed. Maybe that explains his more optimistic tone these days. "Yes, we can," as someone once said.

"Gore has concluded that humans have an innate need to feel that things are basically fine"

The narrative arc of the film is from Gore's wilderness years – fighting the deniers and taking a long march to turn the tide – through to tasting victory in Paris. In the run-up to the conference, India is the barrier to a deal. That sets up the film's climax.

Paris deal broker

In perhaps the only jarring note in the film, a bit of cheap editing suggests that by fixing a final-hours deal to give India access to US solar-energy technology, Gore breaks the deadlock and saves the conference.

That was never quite true, Gore admitted to me. "There were many elements," he said. A big loan to India from the World Bank and phone calls from Obama both played their part. Not to mention good old-fashioned Indian brinkmanship.

In the event, this year President Trump rather kiboshed the triumph by reneging on the Paris deal. So now the film ends with Gore still on the road. "There have been lots of setbacks. Now we have another one," he says to camera.

But in person, he is more optimistic. Many things are moving in his direction: renewables are as cheap as coal; solar panels are spreading rapidly; electric cars are proving hugely popular. So "despite Trump", the US will meets its Paris targets, he believes.

At 69, Gore seems to pin his faith in original virtue. Just as the civil rights movement of his youth triumphed, just as gay rights "crossed a tipping point" years later, so it will happen with climate change.

He has a line at the end of the film about how, after all the "nos" have been said, there will be one final "yes" that will trump all. That didn't sound like science. But then, maybe climate science needs a few preachers. And optimists. ■

Fred Pearce is a consultant for *New Scientist*

Evolution, jazzed up

An imaginative book about improvisation gets a little overheated, finds **Steven Mithen**

The Evolution of Imagination by Stephen T. Asma, University of Chicago Press

NO ONE disputes the complex role of imagination in everything from science and art to daily life. Its origins, however, remain elusive.

The Evolution of Imagination, one of the latest attempts to grapple with it, focuses on improvisation, characterising this as spontaneous creativity and arguing it is the fundamental process behind the artistic and scientific imagination.

It's hard to disagree with philosopher Stephen Asma's view that imagination is good for us, individually and as a society. But should we really let it "off the leash" to run free in the uncertain future we face? Donald Trump's impromptu tweets suggest such behaviour is best avoided for the sake of world peace.

While Asma does cover politics towards the end of his book, his touchstone is jazz improvisation. Having played with some great musicians, Asma has fascinating insights into how improvisation works. He also weaves together ideas from Eastern and Western philosophy, neuroscience, anthropology, archaeology and everyday life, often drawing on his experiences of having lived in a variety of cultures.

On Eastern philosophy, I can only take Asma at his word. But in my own area of expertise – prehistoric archaeology and human evolution – I fear his imagination has run riot. My main worry is Asma's allegiance to the idea of the "triune brain": the notion that our brain evolved in distinct layers, beginning with an ancient, motivational "reptilian" brain to which evolution added an "emotional" brain (the limbic system) and then a "rational" brain (the neocortex).

As Lisa Feldman Barrett's *How Emotions Are Made* and other books make clear, neuroscientists have long rejected the idea that emotion and rationality can be easily separated in the brain, while accepting that evolution has involved reorganisation of core circuits, rather than simply the addition of new layers.

Asma believes that early humans (by which I think he means any prior to *Homo sapiens*, although the Neanderthals are left hanging) lived by their emotional brain alone. They relied on "hot cognition", their imaginations unconstrained by rationality, the "cold cognition" provided by the expanded neocortex of modern humans. Those early hotheads were unable to control their imaginations, leaving minds fixed in what we would see as a dream-like state.

If so, one wonders how *Homo erectus* and the rest could have searched for carcasses on the savannah, made symmetrical stone tools or built social alliances. Also, how much cortex does it take before cold cognition kicks in? Early humans had relatively large neocortices compared with other primates, as do living non-human primates compared with other animals. The idea that imagination evolved from the dream-like and uncontrolled to being domesticated by the rationality provided by an expanded neocortex is imaginative but lacking in credibility.

"Evolution has reorganised core circuits in the brain, rather than simply adding new layers"

Equally unsubstantiated is Asma's idea that spoken language might have evolved around the time of the first Upper Palaeolithic cave painting, serving to decouple hot from cold cognition. And the evidence simply doesn't support his assertion that children's artistic development recapitulates that of graphic art in the archaeological record.

Elsewhere, Asma's imagination seems to fail him. Drawing on his experience of safaris in Tanzania and Rwanda, he suggests that early life on the savannah would have been one of constant fear. My own imagination suggests those who grew up there most probably loved it and would have feared our urban environment.

Whether it deals with the role of imagination in education, politics or jazz, much of Asma's book is compelling. So while I profoundly disagree with his view of how the imagination evolved, I greatly appreciate how his imagination fuelled and helped shape my own, and I feel much better for that. ■

GUY LE QUERREC/MAGNUM PHOTOS

Unleashed: jazz greats Miles Davis and Joseph "Foley" McCreary

Steven Mithen is an archaeologist and the deputy vice chancellor at the University of Reading, UK

NEW SCIENTIST DISCOVERY

Baja whale-watching expedition

Witness the gathering of grey, blue, fin, sperm and humpback whales on an unforgettable 11-day sailing expedition around the Baja California Peninsula

DEPARTURE:

23 JANUARY 2018

11 days from $6265 per person

EXHILARATING WHALE WATCHING

Between December and April, grey whales migrate to the warm, calm waters of the Baja California Peninsula to calve and to nurture their young. Sail through this magical area to spot an abundance of marine life, including majestic grey whales, on small expedition vessel the Searcher.

LEARN ABOUT MARINE CONSERVATION

Enjoy the company of marine expert Jo Ruxton on board during the voyage. After a long career with conservation organisation WWF and the BBC Natural History Unit, Jo is currently leading the campaign to protect the world's oceans from plastic pollution. Quiz her on the science behind protecting oceanic ecosystems.

GET CLOSE TO BREATHTAKING MARINE WILDLIFE

From the decks of the Searcher, or in a smaller boat known as a panga, experience unparalleled whale watching from the waters. Be guided by the passion and knowledge of Art Taylor, owner and captain of the vessel, who has been navigating the peninsula for more than 30 years.

We've teamed up with Steppes Travel to offer readers a chance to get close to marine wildlife, with naturalists for company.

SPEAK TO OUR WILDLIFE TRAVEL EXPERTS TODAY

Visit **newscientist.com/Baja** or call toll free **1-844-675-3956**

SteppesTravel

Fellowships

FOR POSTDOCTORAL SCHOLARS AT

Woods Hole Oceanographic Institution

Scholarships are available to new or recent doctoral graduates in diverse areas of research. Applications will be accepted from doctoral recipients with research interests associated with the following:

Departments - Applicants who wish to conduct research on topics of general interest to one or more of the departments are encouraged to apply. Interdepartmental research is also encouraged. The Departments are:

- **Applied Ocean Physics & Engineering**
- **Biology**
- **Geology & Geophysics**
- **Marine Chemistry & Geochemistry**
- **Physical Oceanography**

A joint USGS/WHOI award will be given to a postdoc whose research is in an area of common interest between USGS and WHOI Scientific Staff. The individual will interact with both USGS and WHOI based advisors on their research.

Recipients of awards are selected competitively, with primary emphasis placed on research promise. Scholarships are awarded for 18-month appointments with a stipend of $58,500 per year, a modest research budget and eligibility for group health and dental insurance. Recipients are encouraged to pursue their own research interest in association with resident Scientific and Senior Technical Staff. Communication with potential WHOI advisors prior to submitting an application is encouraged. **Completed applications must be received by September 20, 2017** for the 2018/2019 appointments. Awards will be announced by December. Recipients of awards can initiate their study and research period at the Institution any time after January 1, 2018 and before December 1, 2018.

Further information about the Scholarships and application forms as well as links to the individual Departments and Institutes and their research themes may be obtained through the Academic Programs section of the WHOI web pages at:

www.whoi.edu/postdoctoral

An Equal Opportunity/Affirmative Action Employer

WOODS HOLE OCEANOGRAPHIC INSTITUTION 1930

HARVARD UNIVERSITY

The Department of Psychology anticipates making a tenure-track appointment at the assistant professor level to begin **July 1, 2018**.

We seek candidates with expertise in the application of computational models toward understanding human perception or cognition. Our interest is less in specific areas and methods than in innovation and excellence in the application of modeling techniques to experimental data from adult humans, children or animals. The appointment is expected to begin on **July 1, 2018**. Candidates at all levels are encouraged to apply.

Candidates must have a strong doctoral record and have completed their Ph.D. Candidates should have demonstrated a promise of excellence in both research and teaching. Teaching duties will include offerings at both undergraduate and graduate levels.

Please submit a cover letter, curriculum vitae, research and teaching statements, up to three representative reprints, and names and contact information of three to five references (three letters of recommendation are required, and the application is complete only when all three letters have been submitted) to

http://academicpositions.harvard.edu/postings/7663

Questions regarding this position can be addressed to **alvarez@wjh.harvard.edu**. The committee will consider completed applications starting immediately on a rolling basis through October 1. Interviews will be conducted in late September and continue in October.

Harvard University is an affirmative action/equal opportunity employer and all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, disability status, protected veteran status, or any other characteristic protected by law. We actively encourage applications from women and minority groups.

FDA U.S. FOOD & DRUG ADMINISTRATION

Regulatory Pharmaceutical Analysis Program OFFICE OF REGULATORY AFFAIRS (ORA)

The FDA's Office of Regulatory Affairs is seeking PhD-level scientists with experience in chemical analysis of complex pharmaceutical products to work at ORA's field laboratory located in Irvine, CA. Candidate must have a PhD in a mainstream technical field such as chemistry, biochemistry, and physics. The preferred candidate must have extensive experience in the mass spectrometry analysis/characterization of complex pharmaceuticals such as protein-based or nanotechnology drugs; and must be an expert in mass spectrometry, including method development, troubleshooting, and maintenance.

Candidate must be able to independently execute defined projects, develop new methods to meet agency needs, and serve as an expert in area of specialty. Candidate must possess excellent written and oral communication skills. Must be able to engage with other experts in industry, academia, other parts of FDA, other federal, state and local agencies; establish collaborations when necessary; and represent ORA in field of expertise. Only US Citizens and Permanent Residents are eligible to apply and candidate must be willing to relocate to Irvine, CA.

Salary range: $75,000 – $120,000 per year and will be commensurate with experience.

Interested persons can send curriculum vitae or resume with cover letter to: **ORSJOBSEARCH@FDA.HHS.GOV**

NATIONAL POSTDOC APPRECIATION WEEK
SEPTEMBER 18-22, 2017

Since 2009, the National Postdoctoral Association has sponsored National Postdoc Appreciation Week to recognize the significant contributions that postdoctoral scholars make to U.S. research and discovery.

PLAN **PUBLICIZE** **CONDUCT**

During this week-long celebration, organizations are encouraged to plan activities and special events that increase awareness of postdocs and recognize the contributions they make.

Submit your events to contact@nationalpostdoc.org
http://www.nationalpostdoc.org/?page=NPAW

National Postdoctoral Association

"Our mission is heavily intertwined with supporting the people behind the research," says **John E. Burris,** President of the Burroughs Wellcome Fund.

"We fund creative risk-takers who are driven by a desire to make contributions to society. **Our grants are a validation for innovative biomedical researchers** with remarkable new ideas, and we provide these grantees with the mentorship network, career guidance, and professional resources they need to prosper. We want our investment in a researcher to last more than just one project or award cycle—but for the lifetime of impact they will have on biomedical science."

BURROUGHS WELLCOME FUND

"We cultivate relationships and partnerships to help create a nurturing ecosystem for researchers. When you bring together eager and brilliant minds, anything is possible."

— John E. Burris, PhD, President

For more than 60 years, the Burroughs Wellcome Fund has advanced biomedical science by supporting research and other educational activities. We nourish research talents, skills, and fields in need of attention, filling gaps to advance the whole. We cultivate networks of scientists, educators, and worthy organizations—seeking the brightest and most promising in their fields to assist them towards unimagined possibilities.

When we make personal investments, we help nurture and advance the entire biomedical research enterprise—and, in turn, help confer good health and knowledge to all.

John E. Burris, Burroughs Wellcome Fund

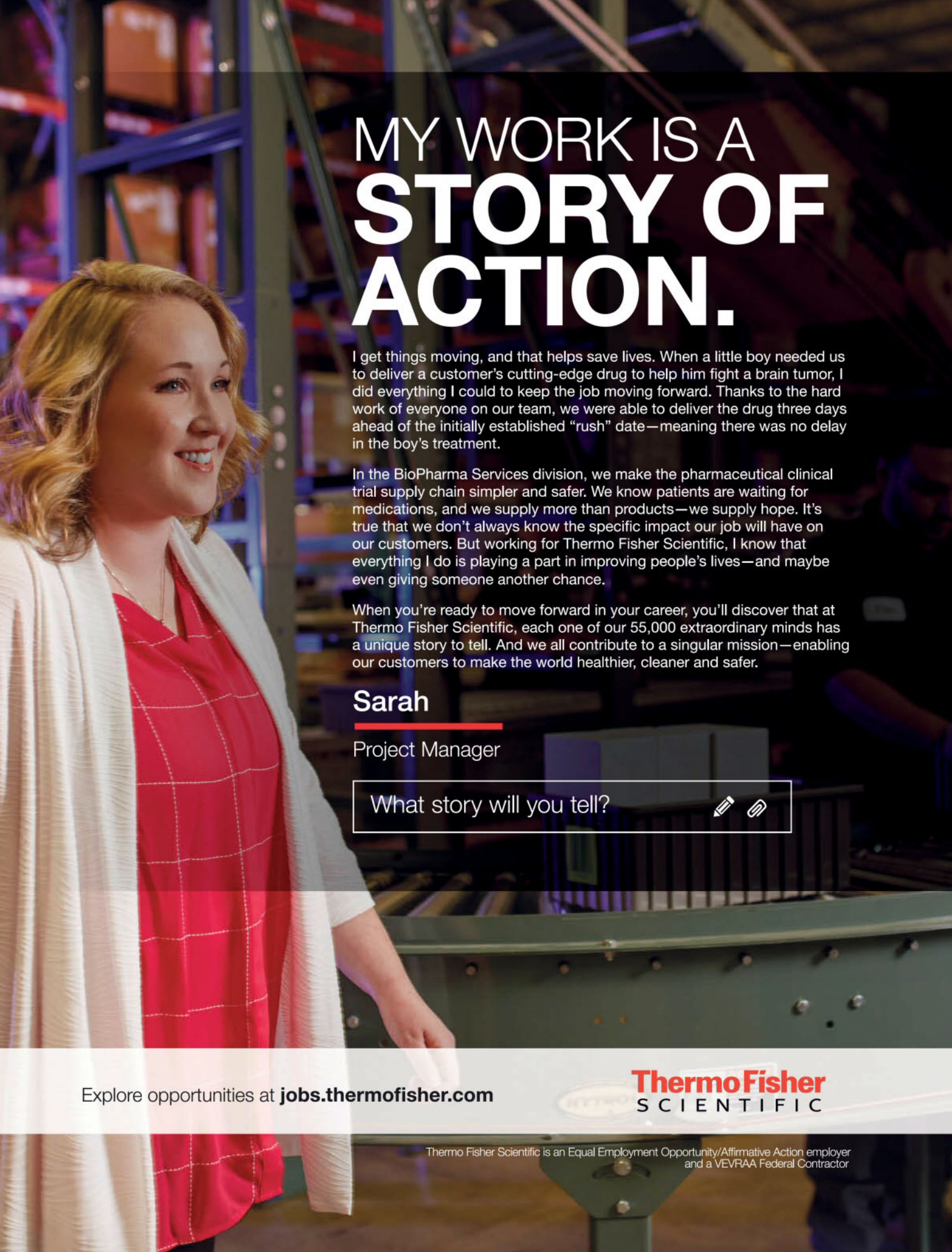
Upcoming Grants and Deadlines

Career Awards at the Scientific Interface (CASI)
$500,000 career awards targeting advanced postdoctoral researchers bringing biophysical, engineering, and computational approaches to solving biomedical questions.
Pre-Proposals due 06 September 2017
Full Proposals due 10 January 2018

Physician-Scientist Institutional Award (PSIA)
$30,000 planning grants and $2.5 million full awards to launch recruitment and training programs that increase the number of medical doctors in biomedical research careers.
Pre-Proposals due 28 September 2017
Full Proposals due 03 April 2018

Career Awards for Medical Scientists (CAMS)
Highly competitive $700,000 career awards to encourage physician-scientists entering postdoctoral or fellowship training towards faculty service in basic biomedical, disease-oriented, or translational research.
Applications due 03 October 2017

Visit www.bwfund.org for grant information | Follow us on Twitter @BWFUND for grant updates
Burroughs Wellcome Fund, 21 T. W. Alexander Drive, Research Triangle Park, North Carolina 27709



MY WORK IS A STORY OF ACTION.

I get things moving, and that helps save lives. When a little boy needed us to deliver a customer's cutting-edge drug to help him fight a brain tumor, I did everything I could to keep the job moving forward. Thanks to the hard work of everyone on our team, we were able to deliver the drug three days ahead of the initially established "rush" date—meaning there was no delay in the boy's treatment.

In the BioPharma Services division, we make the pharmaceutical clinical trial supply chain simpler and safer. We know patients are waiting for medications, and we supply more than products—we supply hope. It's true that we don't always know the specific impact our job will have on our customers. But working for Thermo Fisher Scientific, I know that everything I do is playing a part in improving people's lives—and maybe even giving someone another chance.

When you're ready to move forward in your career, you'll discover that at Thermo Fisher Scientific, each one of our 55,000 extraordinary minds has a unique story to tell. And we all contribute to a singular mission—enabling our customers to make the world healthier, cleaner and safer.

Sarah

Project Manager

What story will you tell?

Explore opportunities at **jobs.thermofisher.com**

ThermoFisher SCIENTIFIC

Thermo Fisher Scientific is an Equal Employment Opportunity/Affirmative Action employer and a VEVRAA Federal Contractor

letters@newscientist.com @newscientist newscientist

EDITOR'S PICK

Awe can be a tool for manipulation as well as connectedness

From David Lewis-Williams, Johannesburg, South Africa
Jo Marchant describes people who have experienced awe as being more ethical, more generous and feeling more connected (29 July, p 32). Awe is another word for, or take on, the oceanic feeling of being one with the universe that has long been recognised as neurologically created in the brain. Unfortunately, it has become entangled with religion, as Marchant notes. It is now part of the false notion that religion is an intrinsic part of being human.

Awe is neither indisputably a good thing, nor is it an essential part of life. On the contrary, awe reduces people's cognitive independence and makes them vulnerable.

It is often interpreted and manipulated in culturally specific circumstances. We may find the decorated caves of the Upper Palaeolithic awesome. If the people who first saw them were awestruck – as I suspect some were – we must realise that they interpreted that sensation in terms of their own beliefs and, importantly, social relations.

Always, we must ask: who benefits from the awe created by, say, the architecture of a cathedral?

To omit the social context and manipulation of mental states is to miss a significant point.

From Jon Atack, Nottingham, UK
Thanks for an excellent article on awe. The Open Minds Foundation, which I helped to found, works to educate people about human predators and their methods of seduction and recruitment. Your article focuses on the potential benefits of awe, but the induction of awe – or a peak experience – is often an aspect of cult recruitment. Leni Riefenstahl's films *Triumph of the Will* and *Olympia* exemplify the deliberate use of awe to bind followers to a group's beliefs. In colonial Africa, the British used firework displays.

Time to look again for a Barnard's star exoplanet

From Richard Swifte, Darmstadt, Germany
Didier Queloz gets credit as the first discoverer of an exoplanet (8 July, p 40). But when I was an astronomy student around 1970, it was widely accepted that Barnard's star was orbited by a large planet. This faint star is just 6 light years from our sun and its "proper motion" – the angular velocity as seen from Earth – is the largest known.

In the 1960s, the astronomer Peter van de Kamp claimed, after analysing a long series of photographic plates, to have detected fluctuations in the proper motion. He calculated that these were due to at least one large planet. During the 1970s, however, doubt was cast on this claim, as other astronomers using

"I was promised moral depravity. Which way to the moral depravity?"

Lorelei Armstrong is disappointed that atheism seems not to lead to moral depravity, despite measured prejudices (19 August, p 22)

more accurate techniques failed to replicate the results. So the mantle of being first to discover an exoplanet has passed from van de Kamp to Queloz.

With the current sensitive space and ground-based telescopes, it would be interesting to know if Barnard's star might have smaller planets orbiting it after all. I don't know whether it has been a candidate for such observations.

Do we have to retrain this neural network again?

From Brian Curtis, London, UK

Liesbeth Venema discusses the hope that neural networks using memristor technology may be the answer to artificial intelligence (5 August, p 33). They learn from experience, not from a downloaded program.

The learned experience of a neural network that is simulated on conventional hardware can be copied and backed up. Would the same be true for this new variety? If not, every new AI would have to learn from scratch. This would be very frustrating if one had a neural network computer for many years and had to replace it.

From Frank Aquino, Perth, Western Australia

Venema's account of memristors that mimic the features of the human synapse is brilliant. It suggests I might see a real, learning, working artificial brain within my lifetime.

I do wonder about the role of the pleasure of knowing you're right in promoting useful learning. We know a chair is a chair because somewhere deep in our emotional brain we get a little hit of something – such as the neurotransmitter dopamine – that reinforces our self-belief that we know what we're seeing or experiencing is correct. Is there an equivalent of "pleasure" to reinforce learning in a machine?

I sense this kind of caring about "rightness" would open the way to embed Asimov's first law of robotics (no harm to humans). Attempting to violate it would bring shutdown.

Trust robots no more than their makers

From Valerie Knight, Brighton, East Sussex, UK

Ron Arkin asks whether we should give robots autonomy, including the right to kill (8 July, p 32). But all robots are designed and programmed by fallible, emotion-laden, irrational and, in some cases, deluded and arrogant humans. Some scientists seem to think they are more rational and objective than the rest of us when, from historical experience so far, they have no claim to be.

Come to think of it, from experience, I wouldn't trust most men to judge what is right or wrong on the world's behalf.

We can sit out a war of robot against robot

From Steve Swift, Medstead, Hampshire, UK

Reading chess grand master Garry Kasparov's thoughts on artificial intelligence, I suddenly realised that we don't have to fear the prospect of superintelligent machines deciding to do without us (3 June, p 42). If they are disposed to get rid of the competition, then they will go to war with each other, and eliminate themselves. In battle, you always destroy the most potent threat first. ›

How software enforces hardware waste

From David Myers, Commugny, Switzerland
Matt Reynolds deplores the waste caused by suppliers wanting their products to be replaced not repaired (29 July, p 20). I agree, but there is another problem.

Manufacturers rarely provide updates to a smartphone's operating system and new applications are written for the latest version. Four years ago, I bought the top-of-the-line Android smartphone. It works, but won't run various new apps, including one from my bank.

Legislation is required to oblige manufacturers to supply system updates for a reasonable length of time. After all, a smartphone is a tool, not a fashion accessory.

Send rubbish back where it came from, please

From Peter Ryan, Ayr, UK
Bob Holmes mentions "extended producer responsibility" for waste (22 July, p 39). The conclusion of this is returning packaging to the producer – for example using reverse vending machines. These would read barcodes on packaging and give the consumer points or money. If a producer has to pay to deal with returned packaging, it makes economic sense to design it to be easily recyclable.

From Peter Urben, Kenilworth, Warwickshire, UK
You say that about 10 per cent of glass disposed of in the US goes to energy recovery. This old scientist can't see how you can recover energy from glass.

The editor writes:
■ The waste incineration figures include glass that goes through to landfill in the ash. It is also worth noting that the recycling figures include food that is composted.

Do not say that chemical bonds are energy-rich

From Tony Sollars, Holmer Green, Buckinghamshire, UK
David Hambling says: "In molecular nitrogen, two atoms are connected by a triple bond that releases a load of energy when broken" (29 July, p 36). But you need to put in energy to break bonds. This is why nitrogen is such a stable and inert molecule.

I spent my whole teaching career telling chemistry students this. Energy is released on forming new bonds. One should not say that bonds are energy-rich. Rather, the products of a reaction have yet stronger bonds.

Being precise about common ancestry

From Richard Price, Chipping Sodbury, Gloucestershire, UK
You say that people in Lebanon today still share 90 per cent of their DNA with that found in ancient Canaanite skeletons (5 August, p 7). Since we share a higher proportion of our DNA with chimpanzees, this seems far too low. Would it be accurate to say that modern Lebanese derive 90 per cent of their human ancestry from Canaanites?

The editor writes:
■ It would. Humans are roughly 98 per cent identical with chimps, and 99.9 per cent to one another. The 0.1 per cent differences between pairs of humans allow us to identify the genetic ancestry of any segment of the genome.

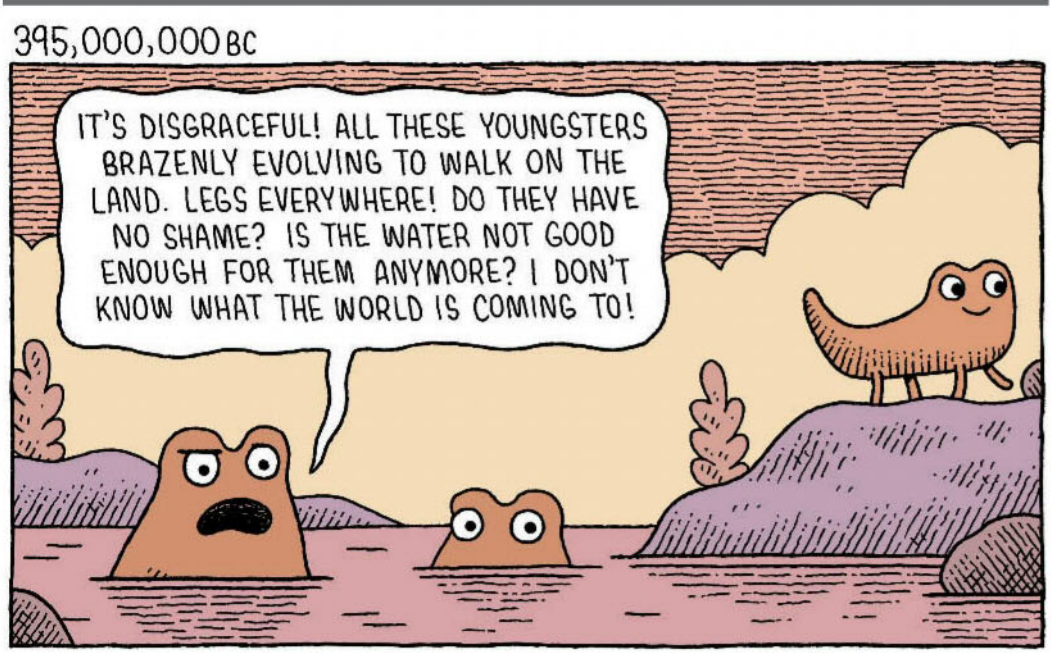
What caused Fukushima reactor failures

From Bryan Norris, Rainworth, Nottinghamshire, UK
You say that a tsunami damaged emergency generators that would have provided power to keep the nuclear reactors at Fukushima in Japan cool (29 July, p 4). But the earthquake that caused the tsunami also caused the cooling systems to fail. Japan hasn't fully reactivated its reactors because it is an earthquake-prone country.

Would fetuses follow faces in artificial wombs?

From Pamela Ramtohul, London, UK
Fetuses are more likely to follow a pattern of dots that resembles a face (17 June, p 12). With the creation of artificial wombs in progress, I wonder whether a fetus grown in one will do the same. You quote researcher Marco Del Giudice proposing that some infant skills develop before birth. How might this differ in fetuses grown in artificial wombs? A fetus hears the sound of its mother's heartbeat. Will one in an artificial womb learn to recognise the sounds of machinery instead?

TOM GAULD



For the record

■ **Deadly serious: nine per cent of people admitted to a UK hospital with a heart that has stopped are discharged alive (12 August, p 37).**

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

Include your full postal address and telephone number, and a reference (issue, page number, title) to articles. We reserve the right to edit letters. New Scientist Ltd reserves the right to use any submissions sent to the letters column of *New Scientist* magazine, in any other format.

RUSSELL COBB

A recipe for disaster

Averse to fish? Terrified of tomatoes? No problem. The internet is still your oyster with this recipe-fixing algorithm

"Online, I'm bombarded with #foodporn, but my allergies mean the tasty recipes are often deadly unless I make some substitutions," says Rosemary Nutall. "Can you find a way to auto-swap ingredients so I'm free to express my inner Jamie Oliver?"

After watching my vegan friend google "how to replace an egg" for the 40th time, I realised there had to be a way to adapt all those internet recipes on the fly to suit people with special diets or food allergies. Handy, then, that tinkering with web browsers requires nothing more than a little know-how.

So I hammered out some JavaScript code, and a couple of crashes later, I had a souped-up browser that used a plug-in to swap out words.

I figured this would be the icing on the cake for my friend's birthday, or at least the recipe for it. So I modelled the plug-in around vegan food swaps – like substituting beef with tofu and cheese with, er, "nutritional yeast". Yum.

A quick skim through BBC Food showed the plug-in worked like a charm.

You can't gift-wrap an email attachment, but a USB memory stick will do the trick, so I embedded my code into one shaped like a carrot and went out to post it.

It was only when I returned home that I noticed things had taken a strange turn. I was accused of having a tofu with someone on Facebook and that my fine words would marge no parsnips.

And my media library was peppered with anomalies: who was Kevin Facon, star of *Footloose*, and why did I own an album by a tribute act called Quorn Loaf?

My boyfriend had taken to addressing me as "agave" in emails. The penny dropped when I saw photos from my recently married friend's agavemoon.

As for those troublesome eggs, imagine wearing a pair of lagarings, playing an arpapplesauceio, or buying a bootlaquafabaed DVD.

My friend assures me that I'm the very soya milk of human kindness, but I do wonder if she might prefer a paper recipe book in future.

Hannah Joshua ■

For more Makes visit **bit.ly/ns-make**

PAUL MCDEVITT

HAIL to our new cockroach overlords, and to those subscribers eking it out in fortified bunkers. That you received this magazine at all is a testament to the fortitude of your local postal service – why not thank them with some solid fuel cubes or jewellery fashioned from old soup cans?

Feedback is writing to you from the halcyon days leading up to the total solar eclipse in North America on 21 August, an event that Christian numerologist David Meade tells us will precipitate the end of the world. Specifically, the solar eclipse will encourage the telescope-shy planet Nibiru to appear in the sky, shortly before appearing much closer as it crashes into Earth.

Feedback has requested time off to clear out the loft, something we promised ourselves we would get round to before the world ended. However, our editor points out that as Meade's armageddon only starts with the eclipse, and cites 23 September as the truly last day on Earth, we still have several more columns to file.

CELESTIAL events are ripe fodder for conspiracy theorists and other fans of fruitloopery. So too is the High Frequency Active Auroral Research Program (HAARP) in Alaska, variously touted as an alien telephone, weather modification project, or doomsday device.

Those seeking front-row seats to the end of the world might be wise to plump for HAARP, going by the online reviews. "Staff was nice and food was OK," says one happy doom-watcher, while another thinks that it is a "wonderful place for a date", which goes to show that romance isn't dead, even if all of us are.

PREVIOUSLY Alan Davies asked whether the J. P. Joule pub in Manchester ought to be pronounced to rhyme with jewel or jowl, prompting several of you to write in, warming to the topic (29 July).

"Late last century, our revered and venerable lecturer in first-year physics in Tasmania told us that joule was pronounced jowl, and tugged at his own sagging cheek to make the point," says Kevon Kenna.

Likewise, Philip Arundel writes that in the 1960s, "our headmaster at Cambridge taught thermodynamics and always pronounced joule to rhyme with jowl." Philip says that his tutor was from the north of England "and connected joule to the brewery in Manchester".

"PERHAPS it is time that we brought the discussion of that public house and James Prescott Joule under control," says John Cartmell. "To begin with, the pub is not in Manchester as you claimed, but in Sale, where Joule lived. While his neighbours probably called him 'jewel', his experiments were conducted in his father's brewery in Salford, and goodness knows how the workers there pronounced his name."

A FINAL word to tie the diverging threads back together comes from David Beauchamp. "In connection with your continuing pub crawl, a branch of Joule's family brewing business (John Joule & Sons) has a long connection with my hometown of Stone, in north Staffordshire."

David says that the town is littered with references to "Joule's Stone Ales": the brewery offices and canal-side warehouses are still standing, and residents do indeed pronounce the name as jowls.

"However, I teach physics locally, and always point out the connection to students, and they are happy to accept that although they know the name of the brewery as 'jowls', the physical unit is pronounced 'jewel'."

AND the taps are still flowing in our quest to find pubs named after other scientists. "I expected to find at least some reference to the engineer Isambard Brunel in Plymouth, considering the proximity to the Royal Albert Bridge over the Tamar," says Nuria Bonet. "It appears that a pub called Brunel did exist, but was destroyed during the second world war."

NURIA would have had better luck further up the main line, says Barry Cash, where for a long time travellers at Bristol Temple Meads station could quench their thirst at the Isambard Brunel.

Perhaps in reference to the engineer's idyllic but perilously located seafront railway stretching from nearby Exeter to Newton Abbot, "they changed the name to 'The Reckless Engineer'," says Barry, "which I thought was a bit unfair".

Barry reports that the pub is currently undergoing refurbishment, and is due to reopen as "The Sidings", perhaps another oblique reference, this time to the abandoned plan to electrify the line to London, "meaning that Brunel and his original station are both being sidelined".

PREVIOUSLY Alan Henness reported that the only way to know what was in a remedy was to look at the label (12 August). "This makes me wonder if any fraud would be committed by simply selling identical contents – sugar pills, say – and labelling the bottles as requested by the customer," says John Cartmell. "It would make it cheaper to stock such items, with the retailer printing off a specific label only at the point of sale." Progress!

"Did you know? 0.12m^3 = 3 showers or 209 pints or 698 cups of tea," Severn Trent tells Perry Bebbington. "I didn't know that," says Perry, nor what he's expected to do with this information.

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

Nudge factor

My 8-year-old son is very worried about Earth being destroyed by the sun when it becomes a red giant billions of years from now. I have tried to comfort him by suggesting we could shift Earth's orbit by hurling asteroids towards the planet on trajectories that will gradually move it away from the sun. Is this feasible?

■ Maybe your best hope is that your son forgets he asked the question, because humans may well be extinct by the time the sun swells into a red giant. Although some mammalian species have been known to last as long as 10 million years, their average length of existence is about 1 million years.

But setting this aside, using "gravity assists" would be a plausible strategy to help shift Earth. Rockets on asteroids or comets could push those objects along trajectories that would pull the planet into a higher orbit. Yet given that Earth might need to increase the distance of its orbit by 15 per cent to avoid spiralling into the red giant that our sun will become, many tens of thousands of these assists would be required. That would increase the possibility of an asteroid impact and a mass extinction, if not the end of life on Earth.

An alternative is to construct a "gravity tug". This could take the form of a solar sail attached to a huge mass. Sunlight would push away the solar sail, with Earth then gravitationally tugged by the mass.

However, either solution would simply replace one problem with another, because as the sun evolved into a red giant and then a white dwarf, the habitable zone would first expand but then contract. Perhaps our efforts would be better invested in developing the technology to move to a different planet.

Mike Follows
Sutton Coldfield, West Midlands, UK

■ Sorry, it's not feasible. Most asteroids orbit between Mars and Jupiter, and it would require huge changes in their velocity or momentum to get them on an orbit that would make them hit Earth. And if the sun became a red giant, Earth would have to be moved a long way beyond the orbit of Mars to get it far enough away from the sun's heat. The angular momentum imparted to Earth would need to be much greater than that of all the asteroids in the solar system put together, which have a total mass about a two-thousandth that of Earth.

Eric Kvaalen
Les Essarts-le-Roi, France

■ It depends what you mean by feasible. From the laws of conservation of momentum and energy, if you hit Earth with enough asteroids at the correct angle, then yes, in theory you could shift its orbit further out. However, the logistical challenge of achieving that goal would be impossible with current technologies. You would have to send rockets to many millions of asteroids, with enough fuel to alter those asteroids' orbits such that they would eventually impact on Earth from the correct side. It might be better to spend all those resources to colonise a planet further out.

A second problem to consider is the effect of all these asteroid impacts on Earth. It is estimated that the dinosaurs were driven extinct by the impact of a single asteroid roughly 10 kilometres in diameter about 65 million years ago, yet the mass of that asteroid was only a tiny fraction of the mass of Earth and made negligible difference to its orbit. Imagine what might happen to life on Earth if it were bombarded with enough asteroid impacts to actually shift our orbit.

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

This week's questions

ROUND THE BEND
Look carefully at this photo of a rainbow over Dinas Head near Fishguard in Wales (above) and you will notice that as it nears land it looks like there is a sharp bend in its arc. What caused this?

Eric Grandfield
Almondsbury, Bristol, UK

A DEGREE OF UNCERTAINTY
Life on Earth depends on liquid water and the temperature at which it freezes or boils. How much would the values of 0°C and 100°C need to change to make life here unsustainable, or hugely different?

Henry Rzepa
Via email, no address supplied

The writers of answers that are published in the magazine will receive a cheque for £25 (or US$ equivalent). Answers should be concise. We reserve the right to edit items for clarity and style. Please include a daytime telephone number and an email address if you have one. New Scientist retains total editorial control over the published content.

New Scientist Ltd reserves all rights to reuse all question and answer material that has been submitted by readers in any medium or in any format and at any time in the future.

Send questions and answers to The Last Word, New Scientist, 110 High Holborn, London WC1V 6EU, UK, by email to lastword@newscientist.com or visit www.newscientist.com/topic/lastword (please include a postal address in order to receive payment for answers). Unanswered questions can also be found at this URL.

Remarkable people doing work that matters

Leading in technology means investing in talent. We recruit remarkable people who create innovative solutions for our customers.

www.baesystems.com

BAE SYSTEMS
INSPIRED WORK