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WEEKLY April 8-14, 2017

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...we've just been looking for it
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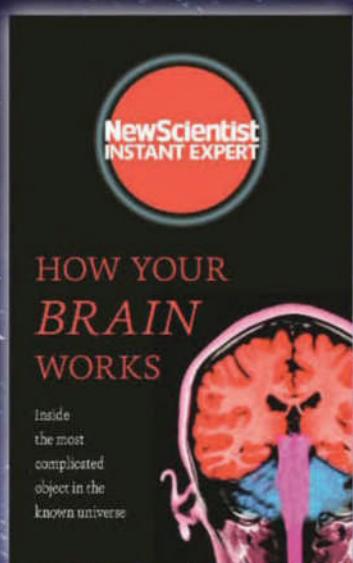


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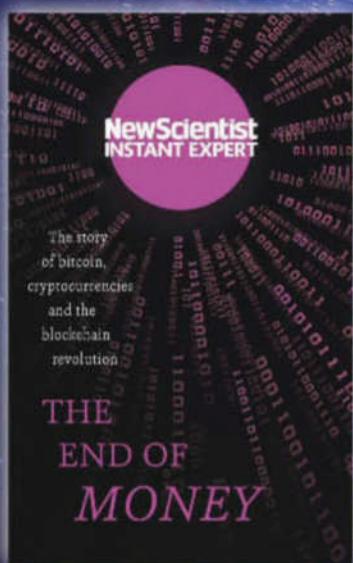


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APRIL 2017



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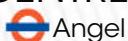
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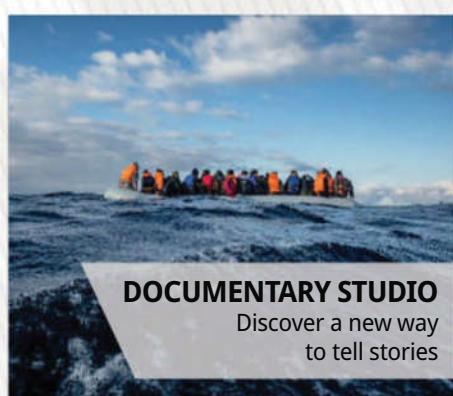
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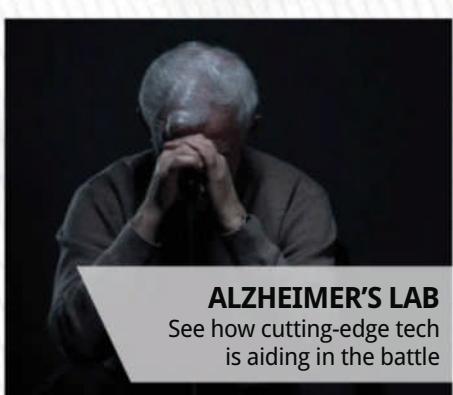
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GETTY

Same old story?

Fatigue is the friend of those who oppose action on climate

THE annual melt of Arctic ice is under way, and this year's may be the biggest ever. Its starting point is the most shrunken ice cap since satellite records began. By the middle of September the ice will have retreated to the shorelines of Greenland and Canada, leaving vast expanses of open water in the Arctic Ocean. It will not be many more years until the Arctic is ice-free in summer (see page 33).

This, of course, is not news. Nor is the fact that the US is about to renege on its climate change commitments, again.

One of the problems with reporting climate science and politics is fatigue. Everybody already knows the broad brushstrokes of the story and the news – if there is any – is rarely good. Prospects for change appear minimal.

But even for those with climate fatigue, the scale and speed of events in the Arctic still have the power to shock and dismay. Ditto the arrogance and recklessness of the Trump administration's climate policies (see page 22). The two are closely connected: without comprehensive, rapid global action, there is zero chance of preventing irreversible change in the Arctic that may bring catastrophe to the rest of the world.

Again, you have probably heard it all before. But the alternative is to stop talking about it, which plays directly into the hands of those who oppose action. Little suits them better than a bored and disengaged public.

While we are on the topic of not-news, have you heard the one about the antibiotic crisis? For years, if not decades, medics have been warning that overuse is driving up resistance, threatening to propel us back to a pre-penicillin age when common

"Little suits the climate change denialists better than a bored and disengaged public"

bacterial infections could be fatal.

Like alarms over climate change, those warnings often fell on deaf ears. Patients kept on demanding antibiotics and often failed to finish the course as instructed. Doctors kept on caving in to them despite knowing that antibiotics were unlikely to work.

Sound familiar? It is not hard to draw parallels between antibiotic resistance and climate change. Both are large, complex problems arising from technological progress. Both are distant threats that may or may not wreak havoc at some unspecified time in the

future. Both are a tragedy of the commons that requires collective sacrifice and both are open to freeloading. And both are unchanging, remorselessly negative stories that generally cause people to glaze over.

But on antibiotic resistance, there are signs that the penny is dropping. Great strides have been made in cutting back on the number of resistant infections, thanks largely to changing prescribing habits. Meanwhile, efforts to develop alternatives to antibiotics appear to be paying off, driven by a realisation that killing good bacteria as well as bad ones is not wise (see page 38).

But the parallels only go so far. The antibiotic problem has not been exacerbated by huge investment in the status quo. Unlike the fossil fuel industry, drug firms have not engaged in industrial-scale lobbying and the manufacture of denial.

That is a crucial difference between the two problems. But there is still a positive conclusion to be drawn. The goal of denial is not just to cast doubt on the scientific consensus, but also to bore the public. Fatigue is the friend of inaction. The antibiotic story shows that it can be overcome, as long as some people refuse to shut up about it. ■

Coca's role in killer slide

NEARLY 300 people are thought to have died when part of Mocoa, a town in Colombia, was swept away by a torrent of water, mud and debris on 1 April. The trigger for the landslide was a night of extreme rainfall, leading the president, Juan Manuel Santos, to blame climate change.

But while global warming may have intensified the rain, this seems to have been a disaster waiting to happen. Deforestation in the surrounding mountains, driven by cattle ranchers and by farmers growing coca, the source of cocaine, degraded the environment and helped create the conditions that led to the disaster, says Nazih Richani of Kean University, New Jersey.

"The interplay of those factors over the last three decades damaged

the soil, making it susceptible to flooding," Richani says.

The town's position in a steep-sided valley also made it vulnerable.

What's more, the town ignored specific warnings as far back as 2012 about the risk of a major landslide. "This vulnerability was known for at least a few years," says ecologist Liliana Dávalos of Stony Brook University, New York, whose work first revealed how the drug trade drives deforestation in Colombia.

A 2014 article on a local news website, for example, described how small landslips in the mountains around Mocoa had blocked river channels, leading to a build-up of water in nearby soil and fallen debris. It warned of "a tragedy of unimaginable proportions".



The landslide killed hundreds

900-year ice low

A MAJOR glacier in Alaska has retreated to its lowest point in 900 years.

Glaciers around the world are in retreat. But the Columbia glacier is one of the most dramatic and well-documented cases, as well as the largest contributor to sea level rise out of the 50 or so glaciers that descend to the sea in Alaska.

To put the current ebb in the context of the past millennium, Anders Carlson at Oregon State University and his colleagues bored down into the mud at the

bottom was 900 years ago (*Geology*, doi.org/b46k).

They then ran climate simulations to find out what triggered the rapid retreat of the glacier over the past 30 years. This revealed that summer air temperatures about 1°C higher than normal between 1910 and 1980 led to the glacier thinning until it became unstable in the 1980s. The team attributes this to human-caused climate change. "What was surprising was the tight coupling between surface temperature of the glacier and its response," says Carlson.

"It shows that a small temperature increase of less than 2°C is sufficient to destabilise a glacier," says Chris Rapley at University College London. International efforts to fight climate change are focused on limiting warming to 2°C.

It's unlikely that this is an isolated case. The authors say that at some sites around the world, retreating glaciers are exposing trees that are some 7000 years old, indicating that those glaciers are now smaller than they have been in many thousands of years.

"A small temperature increase of less than 2°C is sufficient to destabilise a glacier"

bottom of the bay that the glacier flows into, Prince William Sound, on the southern coast of Alaska. They then examined the layers of sediment deposited over the past 1600 years or so, and also looked at the age of tree trunks left on the surface by the retreating glacier. From this, they worked out that the last time the glacier was this

EPA science attack

THE US Environmental Protection Agency is facing a future in which it will struggle to make effective policies based on science.

Last week, the US House of Representatives passed the HONEST Act, which, if approved by the Senate, will prevent the EPA from basing any of its regulations on science that is not publicly accessible – not just journal articles themselves, but all the underlying data, models and computer code. "The HONEST Act

requires EPA to base new regulations on sound science that is publicly available, and not hidden from the American people," said the chair of the House science committee, Lamar Smith, a Texas Republican who sponsored the bill.

While this may sound like a laudable move towards increased transparency, it would actually hobble the agency's ability to develop good, science-based public health regulations, says Andrew Rosenberg at the Union of Concerned Scientists.

Launching again and again

EVEN Elon Musk was speechless – well, for a moment. On 30 March, in a first for space flight, SpaceX launched and successfully landed an orbital rocket that had already flown once before.

The Falcon 9 was carrying a communications satellite for firm SES, which got a discount for allowing its cargo to be transported on a used rocket. The booster for this mission first ferried a Dragon cargo capsule to orbit last April before

making the first successful landing on a drone ship. It then went through rigorous testing before getting its certification to fly again. A year later, the booster landed right in the centre of the same drone ship.

Musk said he was at a loss for words after the booster landed. He called it an "incredible milestone in the history of space", adding: "This is going to be a huge revolution in space flight." He wants to have a rocket relaunch within 24 hours.

60 SECONDS

Copyright quarrel

IT'S a fight for the future of the web. The World Wide Web Consortium (W3C), which sets standards for how the web works, has formally proposed adopting a controversial anti-piracy tool.

"Critics say that adopting the anti-piracy tool will stymie innovation and create security risks"

The Encrypted Media Extensions (EME) mechanism allows web browsers to deal with digital rights management (DRM) software. This means people can easily view copyrighted videos without installing separate plug-ins like Adobe Flash or encountering compatibility issues across browsers or devices.

But critics argue that standardising EME will stymie innovation and create security risks for users. As it is illegal to tamper with DRM systems in the US and European Union, security researchers also fear they will be unable to properly inspect browsers with EME for bugs. "This is really bad security," says Harry Halpin of the Inria research centre in Paris.

It's not unprecedented for a proposal to be so controversial, says Philippe Le Hégaret at W3C, but such divisions are rare. "It happens only once every 10 years or so," he says.

GLEN LOKITCH / SEA SHEPHERD GLOBAL



Hundreds of whales will be killed

Open whale season

THE harpoons are out. Norway's whaling fleet is setting sail this week, with a kill quota of 999 minke whales. The mammals will be caught for meat, and 90 per cent are likely to be pregnant females. And Japan's fleet has just returned to port with its cargo of 333 minkes, but will be heading out again soon to catch endangered sei whales in the north Pacific Ocean, claiming it is for scientific research.

"An expert report doesn't see any value in Japan's scientific whale hunting. It's utterly pointless"

This comes as yet another report condemns as unnecessary the killing of whales for scientific research. Issued by a panel of the International Whaling Commission – the body that introduced a moratorium on commercial whaling in 1996 – the report rejects the rationale behind Japan's proposal for killing whales in the north Pacific for scientific research. "The proposal does not adequately justify the need for lethal sampling," the report says. The panel recommends no whales should be killed until additional work is undertaken and reviewed.

Conservation groups say the panel's report adds to mounting

evidence that Japan's "scientific whaling" programme has no scientific justification.

"It's yet another example that when an independent panel looks at the science, they can't see any value in it," says Matt Collis, from the International Fund for Animal Welfare. "It's so utterly pointless."

Norway, meanwhile, continues whaling for commercial purposes.

Sexual health delay

IT HAS become harder to access sexual health services in the UK, finds a study of 220 of the country's 248 genitourinary medicine (GUM) clinics.

UK standards advise that 98 per cent of people should get seen within 48 hours of contacting a clinic. But in 2015, researchers pretending they had symptoms were able to get appointments within two days less than 91 per cent of the time. In 2014 it was possible 95 per cent of the time.

Researchers saying they had concerns but no symptoms got slots within 48 hours in less than 75 per cent of cases (*Sexually Transmitted Infections*, DOI: 10.1136/sextrans-2016-052882).

"The biggest worry is that patients will go undiagnosed and pass their infection on to other people," says Elizabeth Foley at the Royal South Hants Hospital in Southampton, UK.

SPACE X



Used rocket, one careful owner

Sea to rise by 3 metres

The worst-case scenario for sea-level rise just got even worse. If the latest numbers are correct, oceans could rise almost 3 metres by 2100. The new figure includes rapid loss of mass from the Antarctic ice sheet, and tops the 2013 IPCC estimate by 2 metres (*Environmental Research Letters*, doi.org/b46w)

The dope on sport

There were more than 1900 violations of anti-doping rules across 85 different sports in 2015, says the World Anti-Doping Agency. That's 14 per cent up on 2014. Of these, 280 infringements came to light via "evidence-based intelligence", rather than lab tests, reflecting the agency's push to expand its methods for discovering dopers.

Blink and it's gone

Around 90 per cent of the Red Planet's atmosphere was lost to space in just a few hundred million years. NASA's MAVEN orbiter measured the ratio of two argon isotopes to work out how much had disappeared (*Science*, doi.org/b46r).

Cancer progress

Death rates for most cancers are declining in the US, according to the *Annual Report to the Nation on the Status of Cancer*. Between 1999 and 2013, cancer incidence fell in men, but stabilised in women. Compared with the mid-1970s, five-year survival rates had increased significantly by 2012 for all types of cancer, except those of the cervix and uterus.

Turing Award

World Wide Web creator Tim Berners-Lee has been awarded the 2016 Turing Award, often described as a Nobel prize for computing. The Association for Computing Machinery credits Berners-Lee with inventing the web, the first web browser and "the fundamental protocols and algorithms allowing the web to scale".

Piercing the galaxy's heart

We're about to take the first images of our galaxy's central black hole, says **Leah Crane**

GET ready to peer into the unknown. This week, we will have our first chance to take a picture of the supermassive black hole at the centre of our galaxy. The image could teach us how black holes work and even how the largest and smallest forces governing the universe fit together.

The Event Horizon Telescope is switching on. It consists of eight radio observatories around the world, including telescopes

"Event horizons have been part of the mythology of science, but they will become real"

in Spain, the US and Antarctica (see map). And for just four or five nights between 5 and 14 April, if the weather is clear at all of the observatories, they will all turn on at once.

Each telescope will point at Sagittarius A*, the supermassive black hole at the centre of the Milky Way, and measure every radio wave coming from its direction. Linking together observatories spread across such a huge area and combining their observations to filter out extra light will effectively create a powerful "virtual telescope" almost the size of Earth.

These telescopes will together capture sharper and more detailed data than we've ever had from Sagittarius A*, which we still know very little about, as well as the larger black hole at the centre of nearby galaxy M87.

With the telescopes generating a total of 2 petabytes of data per night – enough to store the full

genomes of some 2 billion people – astronomers hope to take the first image of the event horizon around a black hole, and the bright matter hurtling around it.

"Event horizons have been part of the mythology of science, but they will become real, in a way," says Heino Falcke at Radboud University in the Netherlands, who is part of the international collaboration. "Seeing is believing."

The actual images may not be processed and ready for publishing until next year, but simulations mean that the team has a decent idea of what they should see.

Even light is bent in the intense gravity around a black hole. The side of the black hole rotating towards Earth should feature a bright crescent of light warped around its edge, while the side rotating away will be dimmer.

All together now

The Event Horizon Telescope needs eight radio observatories in six different locations around the world to work in sync



One of many eyes on the sky

Once they can study that "banana" of light for the first time, researchers hope they will be able to clear up some of the long-standing enigmas of black holes. One such puzzle is how some supermassive black holes, like the one in M87, generate the enormous jets of particles that shoot from their centres at near the speed of light and where all that energy comes from.

As other telescopes are added to the network in coming decades, observations of the black holes will become even more precise, and should provide fundamental insights into the workings of our universe.

One of the greatest mysteries in modern physics is how Einstein's theory of general relativity, which covers gravity and the behaviour of very large objects, meshes with quantum mechanics, whose realm is the very small.

Falcke hopes that observing the intense gravity at the edge of a black hole will help us figure out how the two main theories describing our universe fit together. "Something new will happen, and I think that new thing will happen at the event horizon."

"If you create an image at a resolution you've never had before, you might see things that you've never even thought of," says Stefan Gillessen at the Max Planck Institute for Physics in Munich, Germany. The Event Horizon Telescope's first run should prove that event horizons really exist. Future runs could help us understand the basics of our universe. ■

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Neural nets translate speech straight to text

GOOGLE's latest take on machine translation could make it easier for people to converse in different languages, by translating speech in one language directly into text in another.

Machine translation of speech normally works by first converting it into text, then translating that into text in another language. But any error in speech recognition will lead to an error in transcription and a mistake in the translation.

To cut out the middle step, researchers at Google Brain, the tech giant's deep learning research arm, have turned to neural networks. By skipping transcription, the approach could potentially allow for more accurate and quicker translations.

The team trained its system on hundreds of hours of Spanish audio with corresponding English text. It used several layers of neural networks – computer systems loosely modelled on the human brain – to match sections of the spoken Spanish with the written translation. To do this, it analysed the waveform of the Spanish audio to learn which parts seemed to correspond with which chunks of written English. When it was then asked to

translate, each neural layer used this knowledge to manipulate the audio waveform until it was turned into the corresponding section of written English (arxiv.org/abs/1703.08581).

"It learns to find patterns of correspondence between the waveforms in the source language and the written text," says Dzmitry Bahdanau at the University of Montreal in Canada, who wasn't involved with the work.

The system could be useful for translating speech in languages that are spoken by very few people, says Sharon Goldwater at the University of Edinburgh, UK. International disaster relief teams, for instance, could use it to quickly put together a translation system to communicate with people they are trying to assist. When an earthquake hit Haiti in 2010, says Goldwater, there was no translation software available for Haitian Creole.

Goldwater's team is using a similar method to translate speech from Arapaho, a language spoken by only 1000 or so people

in the Native American tribe of the same name, and Ainu, a language spoken by a handful of people in Japan.

The system could also be used to translate languages that are rarely written down, since it doesn't require a written version of the source language – unlike conventional systems.

Until it is tested on a much larger data set, it's hard to tell how the new approach really compares with existing translation systems, says Goldwater. But she thinks it could set the standard for future machine translation.

Text translation service Google Translate already uses neural networks on its most popular language pairs to translate whole sentences at once. Intriguingly, this system appears to use an "interlingua" – a common representation of sentences that have the same meaning in different languages – to translate from one language to another. This means it could translate between a language pair it hasn't explicitly been trained on.

The Google Brain researchers suggest the new speech-to-text approach may also be able to produce a system that can translate multiple languages.

But while machine translation keeps improving, it's difficult to tell how neural networks are coming to their solutions, says Bahdanau. Matt Reynolds ■



I hear you

CO₂ levels to hit 50-million-year high by 2050

WE ARE pumping carbon dioxide into the atmosphere so fast that it could soar to its highest level for 50 million years by the middle of this century.

And if we carry on burning fossil fuels, by the 23rd century CO₂ levels will be as high as they were 400 million years ago. But this time the planet will be much warmer than it was back then, because the sun is

hotter now than it was at the time.

These conclusions come from the best estimate yet of how CO₂ levels changed over the past 420 million years. To produce it, Gavin Foster at the University of Southampton, UK, and his colleagues compiled data from more than 100 different studies.

Comparing their estimates of past CO₂ levels with standard scenarios for future emissions, they say the level will soon be as high as the average around 50 million years ago, at around 600 parts per million (*Nature Communications*, DOI: 10.1038/ncomms14845).

Human emissions are now reversing the long-term decline in CO₂ levels revealed by Foster's estimates for the past half a billion years. This decline has balanced out a gradual rise in the sun's warmth over the same period, says Foster, keeping our planet's temperature in the habitable zone – with a little help from plants. Land plants help break down volcanic rocks that then react with CO₂ and

"By the 23rd century, carbon dioxide levels will be as high as they were 400 million years ago"

remove it from the atmosphere.

But CO₂ is now rising too fast for its warming effect to be counteracted by this natural weathering. This has led some groups to investigate whether it is possible to speed up the process, to geoengineer our way out of global warming.

"Plant-driven weathering processes are too slow to save us from global warming, but they can be accelerated by applying crushed silicates to croplands to capture CO₂," says David Beerling at the University of Sheffield, who is leading a project to explore this idea. Michael Le Page ■

Great apes can read your mind

Sam Wong

OUR closest evolutionary relatives are quite the mind readers. And they can use that knowledge to help people figure things out when they are labouring under a misapprehension, according to the latest research.

The ability to attribute mental states to others, aka theory of mind, is sometimes considered unique to humans, but evidence is mounting that other animals have some capacity for it.

In a study last year, chimps, bonobos and orangutans watched videos of people behaving in different scenarios as cameras tracked their eye movements. The experiment found that the apes looked where an actor in the video would expect to see an object, rather than towards its true location, suggesting the animals were aware others could hold false beliefs.

But that experiment left open the possibility apes were simply predicting that the actor would go to the last place he'd seen the object, without understanding that he held a false belief. Now, David Buttelmann at the Max

Planck Institute for Evolutionary Anthropology in Leipzig, Germany, and colleagues tested 34 zoo chimpanzees, bonobos and orangutans, in search of more conclusive evidence.

In their test, person A places an object into one of two boxes, then either remains in the room or leaves. Person B removes it, places it in the other box and locks both boxes. Then A tries to open the box where they left the object. The apes know how to unlock the

boxes and can decide to open either one.

When A remained in the room, the apes were equally likely to unlock either box. But when A wasn't there for the switch, the apes unlocked the box containing the object in 77 per cent of trials. This shows apes can recognise when A is acting under a false belief, the researchers argue. The apes guess that the person is trying to find the object, and help them by opening the right box. Their performance in this test closely matches the behaviour of a 16-month-old baby.

In a second test, A gives the object to B, then leaves the room while B puts the object in one of the boxes. In this case, rather than

having a false belief, A doesn't actually know where the object is. The apes chose to unlock each box equally often, perhaps, the researchers say, because it was less clear what the person's intention was (*PLoS One*, DOI: 10.1371/journal.pone.0173793)

Because the apes behave differently in each of the two scenarios, it shows they have some mental representation of what the other person believes, says Buttelmann, rather than just thinking that person doesn't know where the object is.

The results show apes apply their understanding of others' beliefs when deciding how to behave in social interactions, he says. Many other studies have found that great apes understand other mental states such as goals, intentions and desires. "The fact that we now have two studies that show evidence of belief understanding in great apes, shows that we are not that different," says Buttelmann. "Whether this belief understanding is as fully fledged as it is in humans is a different question."

Alia Martin from Victoria University of Wellington, New Zealand, isn't convinced by the conclusions. "I'm excited to see researchers look for this amazing ability in apes, but we're going to need more research to settle the ape theory of mind debate." ■



I know what you're thinking

CGI humans help computers understand us

WE ARE hard for computers to figure out. Our actions are unpredictable enough that machine vision systems, such as those used in driverless cars, can't readily make sense of them.

Fake people - videos and images of computer-generated bodies walking, dancing and doing cartwheels - could help them learn what to look for.

"Recognising what's going on in

images is natural for humans. Getting computers to do the same requires a lot more effort," says Javier Romero at the Max Planck Institute for Intelligent Systems in Tübingen, Germany.

At the moment, the best computer vision algorithms are trained using thousands of images that have been painstakingly labelled to highlight key features. This is how they learn to distinguish an eye from an arm, say.

Ideally, every pixel in every frame of a video would be labelled. "But this would mean instead of creating thousands of annotations, people would have to label millions of things,

and that's just not possible," says Güll Varol at the École Normale Supérieure in Paris.

So Varol, Romero and their colleagues have made thousands of videos of "synthetic humans". They walk, they run, they crouch - and since the clips are computer-generated, every frame is automatically labelled with all the important information.

In total, the team generated more

"With synthetic images, you can create more unusual body shapes and actions to train vision algorithms"

than 65,000 clips and 6.5 million frames. Randomly selected body shapes and clothing were used for the figures, each one set in different poses (arxiv.org/abs/1701.01370).

"With synthetic images, you can create more unusual body shapes and actions," says Mykhaylo Andriluka at the Max Planck Institute for Informatics in Saarbrücken, Germany.

Computers with an enhanced grasp of our movements could also better predict them. A driverless car, for example, might be able to tell whether a person is walking close by or about to step into the road. Timothy Revell ■

Chaotic egg division causes fall in fertility

WOMEN are reminded only too frequently about biological clocks. Now we actually have a clearer idea of what makes fertility fall – chaotic mix-ups when egg cells divide.

One reason egg quality declines is a loss of cohesion between chromosomes during the final divisions of eggs as they mature. Because the chromosomes in older eggs stick together less well, eggs can end up with too many or too few chromosomes, usually making them infertile.

But Greg Fitzharris at the University of Montreal in Canada and his team have now identified another way in which cells can be left with the wrong number of chromosomes. They have found that eggs from older mice are more likely to behave chaotically during the first phase of dividing than those from young mice.

This is caused by microtubules, structures that normally corral chromosomes to opposite ends of a cell before it divides. But in half the cells taken from old mice, microtubules sent chromosomes in different directions, causing clumps in three or four spots. This made the resulting egg cells more likely to have the wrong number of chromosomes (*Current Biology*, doi.org/b46s).

Swapping the nuclei of young eggs with those from old eggs showed that it is the age of the egg cell, and not the chromosomes inside the nucleus, that seems to cause this problem. When given a young nucleus, older cells still had dysfunctional microtubules. But younger eggs hosting older nuclei didn't show chaotic division.

"It implies that there's something about that aged cytoplasm, the big volume of that cell, that's not able to direct the chromosome segregation machinery," says Francesca Duncan, at Northwestern University, Illinois.

Fitzharris says that understanding what's going on might one day equip us to make older eggs behave like younger ones. Chelsea Whyte ■



A window on cosmic history

Oldest-ever dust shines a light on early universe

THE early universe was filthy. That much can be gleaned from newly detected cosmic dust in a galaxy whose light reaches us from when the universe was only 600 million years old.

The finding is a game changer that might ultimately show how quickly the early galaxies evolved.

In the past 10 years, astronomers have learned that dust is forged during the aftermath of the supernova deaths of massive, short-lived stars. But many mysteries surround dust's origin. Astronomers, for example, don't know how dust can withstand the violent shock waves from supernovae and precisely how long it takes to form.

In light of that, Nicolas Laporte at University College London and his colleagues turned ALMA, the Atacama Large Millimeter/submillimeter Array, to peer out at the early universe. They studied a star-forming galaxy called A2744_YD4, whose light dates back to just 200 million years after the birth of the earliest stars.

With a little help from a foreground galaxy cluster called Abell 2744, which acted as a

gravitational lens and thus magnified the distant galaxy by a factor of two, Laporte's team discovered the distant dust. To boot, there's enough of it that it could fill the sun 6 million times over (arxiv.org/abs/1703.02039).

So much dust so early on provides a strict limit on the time it takes to form, which should help astronomers better understand some of the mysteries about the

“Examining dust may ultimately show how quickly the first galaxies evolved”

origins of dust. It also hints that the early universe might have looked familiar, with protoplanetary discs or even Earth-like planets circling those early stars, says Darach Watson at the University of Copenhagen in Denmark.

That's because dust is a crucial building block; it gives all molecules something to bind to, from molecular hydrogen within stars to the complex molecules inside planets and even you. "You need dust to do anything actually interesting in

the universe at all," says Watson.

The findings also suggest that tracing cosmic dust could be a useful probe for studying these early galaxies.

Astronomers usually study the universe's first galaxies by counting their numbers, measuring their luminosities and observing their colours, says co-author Richard Ellis at University College London. That's much less information than we can get from observations of nearby galaxies, of which we can take crystal-clear pictures and detect spectral lines – spikes or drops in light at specific wavelengths based on the chemical elements they contain.

But the detection of early dust is a big step forward in investigating the first galaxies – standing as a proxy for the presence of heavier elements, which also form from supernova explosions.

Next, astronomers want to peer back to a time in cosmic history when the emission from dust disappears. These first galaxies were so pristine that they contained only the hydrogen and helium left over from the big bang.

"That's what we're looking for," says Watson. "We're trying to push back far enough where we see the formation of the first galaxies." Shannon Hall ■

Prehistoric artists used exotic beasts

Alice Klein

STONE Age style was all about the latest animal necklaces and bracelets. Some of the first humans to cross the ocean from Asia to Australia fashioned jewellery from the bones, teeth and shells of the unfamiliar creatures they found on islands along the way.

The finding adds to evidence that early inhabitants of Australasia had symbolic practices that were just as rich as those of their European counterparts.

"We used to think that the spark of human brilliance and artistic genius came out of prehistoric Europe"

Modern humans first left Africa at least 60,000 years ago, with some travelling west towards Europe. Others spilled east, spreading to the southern edge of mainland Asia, before building boats and island-hopping to Australia about 50,000 years ago.

Along the way, they stumbled across a dizzying array of new and exotic plants and animals that differed from island to island. Growing evidence suggests they

quickly integrated these species into their symbolic lives. Last year, for example, archaeologists reported on 42,000-year-old jewellery beads made from the shells of *Nautilus pompilius* – a South Pacific mollusc – found in a cave on the island of Timor.

Now, a team led by Adam Brumm and Michelle Langley at Griffith University in Queensland, Australia, has dug up three ancient ornaments created from the bones and a tooth of native animals on the island of Sulawesi, north-west of Timor.

One is a pendant made from the finger bone of a bear cuscus (*Ailuropus ursinus*), a tree-dwelling marsupial. A hole drilled in the top suggests it was strung from a necklace or bracelet. The other two are beads made from the tooth of an odd-looking pig known as a babirusa or pig deer (of the genus *Babirousa*). The ornaments – between 22,000 and 30,000 years old – were found in an inland cave (*PNAS*, DOI: 10.1073/pnas.1619013114)

The cave was excavated because it is near some of the world's oldest rock art: a 35,000-year-old painting of a babirusa and a 40,000-year-old hand stencil reported in 2014.



Surprising finds on Sulawesi

Brumm believes future excavations on Sulawesi and other islands between Asia and Australia – known as the Wallacea region – are likely to yield further examples of prehistoric art and jewellery. "The area is woefully underexplored," he says. Although there are 2000 islands in Wallacea, only seven are being investigated for early human occupation, he says.

More research is needed to

work out the route humans took from Asia to Australia and how they altered their symbolic practices in each new habitat. A 46,000-year-old kangaroo bone nose ornament recently found in Australia has already confirmed that humans continued to adapt their jewellery-making skills to new fauna when they arrived from the islands.

"For a long time, people thought that the spark of human brilliance and artistic genius came out of prehistoric Europe," says Brumm. "But all these emerging findings show that there were complex, sophisticated, symbolic cultures flourishing on the other side of the world at the same time."

Peter Veth at the University of Western Australia agrees. "The idea that complex, figurative behaviours did not exist in Wallacea and Australia at this time is just not true," he says. "It's exciting that we're now filling in the gaps." ■

LATEST LINE IN NEANDERTHAL DECORATION

A BONE from a raven's wing carved with regularly spaced notches is the best evidence yet that Neanderthals, too, had an eye for aesthetics.

Francesco d'Errico at the University of Bordeaux, France, and colleagues examined a 38,000 to 43,000-year-old raven bone from a Neanderthal site in Crimea. Five of its seven carved notches are parallel, with a similar depth and shape, suggesting they were cut with the same tool. But

notches 2 and 6 are shallower and angled slightly obliquely. D'Errico thinks these two were most likely added later to fill in gaps in the original sequence and create a more regular pattern for aesthetic reasons.

His team found that notches 2 and 6 are needed for the sequence to be perceived as being evenly spaced. In addition, volunteers given stone tools like those the Neanderthals had and then asked to carve evenly spaced

notches, created similar patterns to those on the raven bone (*PLoS One*, doi.org/b45g). "When you compare it with modern human variability in producing the same type of notch on a bird bone, you see that there was a will by the Neanderthal to make them equidistant," D'Errico says.

He thinks the pattern may have been symbolic, perhaps as a mark of ownership, but such explanations remain speculative. Sam Wong



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Augmented reality minus the headset

Victoria Turk

YOU don't need special glasses to enjoy an augmented view of the world. A new device superimposes images over real-world objects without the need for a bulky head-mounted display.

Combining camera and computer, Lightform connects to a video projector to beam images and animations onto surrounding objects – a technique called projection mapping. It essentially turns any surface into a screen by using depth sensors to map the shape of objects, then tailoring its lighting effects to fit.

"The idea is to seamlessly merge the virtual world with the physical world, and to do it without wearing anything on your face," says Lightform CEO Brett Jones. Initial demos show a coffee shop's price list materialising on a blank slate, squiggly lines dancing across a store window display, and a cactus undulating with decorative pulses of light.

Until now, augmented reality (AR) has often been delivered via a wearable device: Microsoft's HoloLens uses a headset, and the

much-hyped Florida-based start-up Magic Leap is expected to follow suit later this year.

Eliminating headsets would mean many people can share in an AR experience at once, without special preparation. It also sidesteps problems involving the comfort, weight and power cables of wearable displays.

Lightform, based in San Francisco, has designed its system to work with existing projectors, the choice of which determines the scale of the experience.

"You could do your coffee mug using a tiny pico projector or you could do the side of a building using a really big projector," says Lightform's design director Phil Reyneri.

The device's camera periodically rescans the scene and recalibrates if things have moved, making the system suitable for long-term installations. An app gives control over the graphics.

The whole package will cost more than a depth sensor like Microsoft's Kinect but less than a mid-range laptop when it goes on sale later this year, says Jones.

The mapping is not quite real-time – it takes about a minute to do a scan – and you can't interact with the projected images, unlike with some systems that use haptic feedback or motion tracking to give users the illusion of touching what they see.

Using light to augment reality is exciting, says Natan Linder at the Massachusetts Institute of Technology. Adding projection mapping means you can "paint with light" and give objects virtual textures that fool the eyes.

Jared Ficklin, chief technologist at design firm Argo Design, imagines projected interfaces for controlling smart home devices alongside voice-recognition technology like Amazon's Alexa. They could beam a recipe on to a kitchen surface, for example.

But projected AR has its own drawbacks, Linder points out. Shadows can be a problem if anything gets between the projector and surface, and it does not work well in bright spaces.

If projected interfaces become integrated into the spaces we live and work in, they could usher in a new kind of ubiquitous computing, Linder says. But first they need to find really useful applications. ■



GETTY IMAGES

Immersed in a projection

Tiny fish drugs predators with unique venom

SOME little fish bite back. A tropical blenny uses prominent fangs on its lower jaws to inject venom that sends larger fish into a limp mess.

When a predator engulfs a blenny, the tiny fish bites the predator's mouth. The bigger fish's blood pressure plummets, its coordination goes awry and its mouth gapes involuntarily, allowing the blenny to

swim out unscathed. "The predators shake and quiver, and open their jaws and gills really wide," says Nick Casewell of the Liverpool School of Tropical Medicine, UK. "They never eat blennies again, so whatever the effect is, it seems to be very unpleasant."

Casewell and his colleagues have tested the venom of 11 species from reefs in the western Pacific, including the striped poison-fang blenny (*Meiacanthus grammistes*). The venom has three main components. One is enkephalins – seen in some scorpions – which act on opioid receptors, suggesting they have a pain-relieving

effect. "What's really unusual are these opioid-like neuropeptides called enkephalins, which don't induce pain," Casewell says. "Most animals that produce venom use it to inflict pain, yet we found no evidence of that with the blenny."

The second, neuropeptide Y, has been found in cone snails and causes blood pressure to drop. Casewell thinks the enkephalins and

"When bitten, the predator's blood pressure plummets, its mouth gapes open the blenny swims out"

neuropeptide Y act together to cause a drop in blood pressure of as much as 37 per cent in 4 minutes. "If this happened in a human, you would feel faint, dizzy and quite sick," says Casewell. "We don't really know what sensations fish experience, but they clearly suffer such an adverse sensation that they avoid ever eating blennies again."

The third main ingredient is PLA2, a phospholipase – commonly made by snakes, lizards, bees and scorpions – that probably causes inflammation (*Current Biology*, doi.org/b447).

Andy Coghlan ■

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New eye in a new place

Tadpoles see with transplanted eyes

Jessica Hamzelou

BLIND tadpoles have learned to see again – using eyes implanted in their tails.

With help from a drug usually used to treat migraines, the eyes grew new connections to the tadpoles' nervous systems. The same approach may work in people, allowing the body to integrate organs grown in the lab.

"If a human had an eye implanted in their back, connected to their spinal cord, would the human be able to see out of that eye? My guess is probably yes," says Michael Levin at Tufts University in Medford, Massachusetts.

Many people in need of new organs spend years on transplant lists. Synthetic organs might solve this, and teams around the world have created replacement organs – bladders, for example – in the lab and tried implanting them in people. Groups are now working on more complex organs, such as eyes and hearts.

But to work, these particular organs would need to be connected to the central nervous

system, which controls the body and feeds information back to the brain. To see if the body might be able to adapt to a new eye, for instance, Levin's team turned to frogs. Although they are very different to people, frogs share similarities with us at the molecular level, says Levin.

The team removed eyes from three-day-old tadpoles, and attached one eye into each of

"This work suggests you could put an ear on the neck. It might look funny, but it could still work"

the tails of other tadpoles of the same age that were also blind. Some of these were then given a drug on the site of their new eye straight after the surgery. Called zolmitriptan, the drug activates a class of serotonin receptors that seem to trigger electrical activity in cells – something that Levin's team had previously discovered encourages the growth of neurons.

Of those that didn't receive the drug, only 5 per cent grew new neurons that reached their central

nervous systems – an essential step for being able to send visual information to the brain for processing. But this rose to 40 per cent in those given the drug (*npj Regenerative Medicine*, doi.org/b448).

What's more, the tadpoles could see with the eyes, despite them being connected to the spinal cord, not the brain. The team found the tadpoles could learn the difference between red and blue areas, for instance, and avoid coloured triangles as they moved on a screen beneath them.

That the tadpoles could see using eyes connected to their spinal cords is surprising, says Bernd Fritzsch at the University of Iowa, and good news for teams developing engineered organs like eyes and ears.

"We have no idea how we would connect a retina to the brain, and if you wanted to replace an ear, you would have to cut out a big piece of the skull," Fritzsch says. "This work suggests that this might not be necessary – that you could put the organ on the neck, for example, and connect it to the spinal cord. It might look funny, but it could still work."

But Fritzsch says the team needs to find out whether the drug works the same way in people, and whether its effects extend beyond young animals to adults. ■

Neurons linking breathing and stress found

A TYPE of brain cell that connects breathing rate to alertness has been found in mice. Killing these neurons made mice unusually calm, and these cells may explain why deep breathing makes us feel relaxed.

Kevin Yackle at the University of California, San Francisco, and his team have dubbed these brain cells "pranayama neurons" in reference to a yoga breathing exercise. They identified them using a database of gene activity in mouse brain cells, which showed that the pranayama neurons are a distinct type of neuron in the hindbrain.

There are only 350 of these cells in a mouse's brain, located in a region responsible for controlling breathing, and they are connected to a nearby area known to control alertness. When the team used genetic engineering and a special drug to kill the pranayama neurons in three mice, the animals took a greater number of slow breaths and spent less time exploring and sniffing (*Science*, doi.org/b449). They also did more grooming, becoming "super-chilled out", says Yackle.

The usual role of these neurons might be to ensure that when mice are more physically active – such as when they are exploring a new place – their sniffing and fast breathing trigger greater alertness, says Yackle. If the same mechanism is at work in people, slower breathing might make these neurons less active and so lower stress levels.

Many kinds of relaxation therapies, such as yoga and meditation, involve deliberately slowing our breathing. Doctors also recommend deep breathing to help combat anxiety or panic attacks. Miguel Farias of Coventry University, UK, hopes the findings will encourage more research into relaxation techniques. "Deep breathing is a very effective way of calming you down," he says. "It's a very strong and quick effect." Clare Wilson ■

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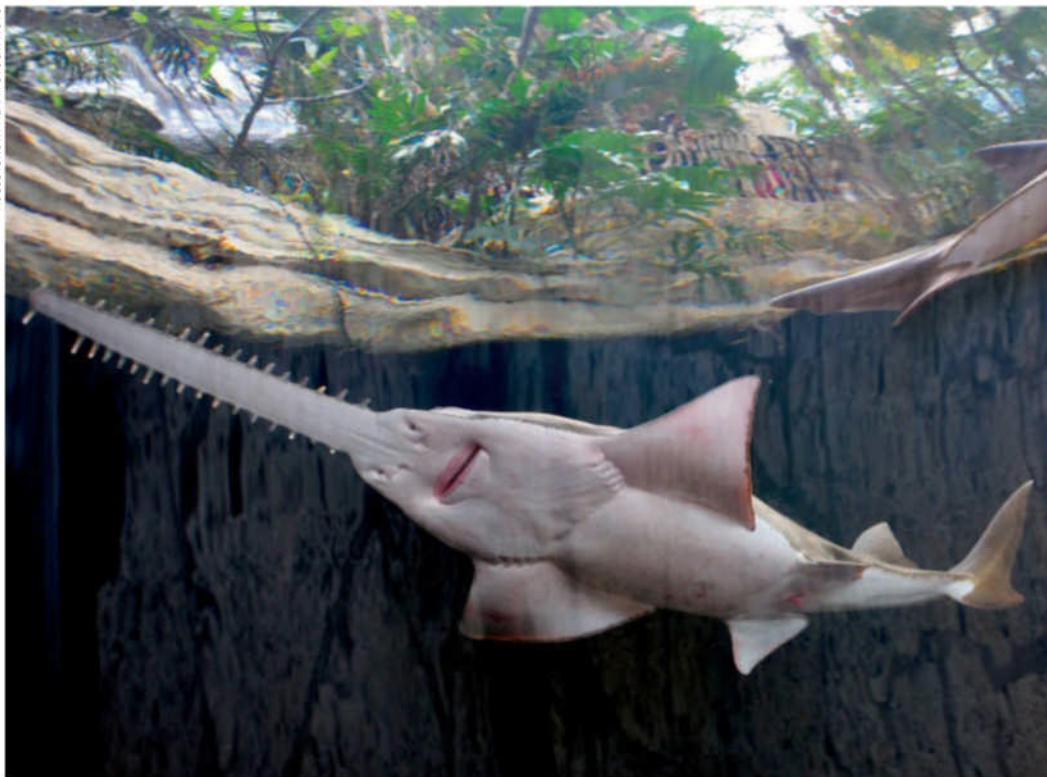
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Stealthy sawfish is more inconspicuous than it looks

YOU would think it would be hard to miss, but the formidable snout of the sawfish has evolved to be undetectable to prey as it swishes through water.

So says Sam Evans, an engineer at the University of Newcastle, Australia, and colleagues. Evans was inspired when he watched a TV programme about the sawfish and realised its snout – called a rostrum – looked similar to the wind turbine blades he usually studies. To find out whether the rostrum had similar properties, his team CT-scanned three sawfish species and made 3D computer models. They used videos of the rostrum's natural

movement to ensure the program mimicked it accurately. “These are tools we use every day for engineering problems, but now the technology is able to cross boundaries into biology,” says team member Phil Clausen.

We knew that sawfish use rostra as weapons to bludgeon prey, sometimes impaling fish on the razor-sharp teeth. But Evans and his team found that the snouts also cut through water without creating vibrations – just like wind turbine blades through air (*Journal of Fish Biology*, doi.org/b43g).

This is crucial to hunting because prey fish rely on vibrations in the water to determine whether potential predators are swimming nearby. It is especially true in areas with low visibility like the muddy coastal waters and estuaries of Western Australia, where sawfish thrive.

Dark web not all that dark, it turns out

IF YOU thought your anonymity was assured on the dark web, think again.

Close links between the dark web and the regular “surface” web could pose privacy issues for users. An investigation of 1.5 million pages on the dark web network Tor found that more than 20 per cent imported resources like pictures, documents and Javascript files from surface

websites such as Google. Owners of these resources can track when they are loaded, potentially letting them monitor traffic to dark web services.

Privacy researchers also found tracking scripts, designed to analyse users' browsing behaviour, on 27 per cent of the hidden pages. Nearly a third originated in the surface web.

That's a problem, says Iskander

Sanchez-Rola at the University of Deusto, Spain: anyone using the same script as a dark web service could track a user's activity and potentially identify them when they visit less private sites. The team presented their work at the World Wide Web Conference in Perth, Australia, this week.

Those using Tor proxies – services on the surface web that act as gateways to the dark web, like the popular Tor2Web – are most at risk, says Sanchez-Rola.

Space-time ripples slow down star spin

THE rapid spin of a neutron star is slowing in bursts – and it may be because of gravitational waves.

Neutron star J1023+0038 flits between a state in which it emits mostly radio waves and one where it mainly gives off X-rays, when its spin slows more quickly.

Brynmor Haskell at the Polish Academy of Sciences and his colleague now suggest that gravitational waves could be behind the unusual slowing. In the X-ray phase, they say, the star steals material from a smaller companion star that orbits it. The material sticks to J1023's surface to build up a bump. This pushes the atoms beneath deeper into the star, where higher pressure fuses them into heavier elements.

This could make the star's gravitational field asymmetrical, and cause it to radiate gravitational waves that carry away energy, slowing its spin more (arxiv.org/abs/1703.08374).

Apps conspire to steal your data

THOUSANDS of Android apps are colluding to obtain information such as your contact list or location data, without permission.

Once Android apps are downloaded, they can function by talking with each other without notifying you. But some exploit this to gain access to data they shouldn't be able to touch.

Among the 100,206 most popular apps in the Google Play store, Gang Wang of Virginia Tech and colleagues found 23,495 pairs in cahoots. But each pair contained one of just 54 apps that instigated the collusion. Those most likely to be up to mischief included emoji and ringtone apps.

The researchers presented their work at a security conference in Abu Dhabi this week.

Giant octopuses live on... jellyfish

AN ELUSIVE deep-sea giant has been filmed with its prey for the first time - and it's surprisingly low-calorie for a giant. The octopus, *Haliphron atlanticus*, was filmed on top of a medusa jellyfish, devouring its innards with its beak, with the medusa's sticky tentacles still hanging out of its mouth. The researchers think the octopus might even be using the jellyfish tentacles to ensnare more prey.

Little is known about this octopus, which can grow to be 4 metres long and weigh 75 kilograms. Steven Haddock from the Monterey Bay Aquarium Research Institute in California and his colleagues have only seen it in the wild three times in as many decades before filming three of them using remotely operated vehicles.

The team also analysed the stomachs of five museum specimens, mainly finding the remains of gelatinous zooplankton and jellyfish. The open ocean is teeming with such creatures, so the octopuses make use of what's available. But most other octopuses eat more substantial prey such as fish and crustaceans, so it is a surprise to see this species grow so large on jellyfish (*Scientific Reports*, doi.org/b43h). Haddock says this illustrates the complexity of the ocean food web and the overlooked role of gelatinous food.



Europe's first ever cavefish discovered in south Germany

A CAVE diver in Germany has discovered Europe's first cavefish. The pale-coloured loach is thought to have begun to diverge from surface fish as glaciers from the last ice age receded some 16,000 to 20,000 years ago, linking surface and cave waters.

"Our first genetic studies, plus knowledge of the geological history of the region, suggest the cave loach population is amazingly young, certainly not older than 20,000 years," says Jasminka Behrmann-Godel at the University of Konstanz in

Germany, who led the team that analysed the fish.

"Despite this short time span, the fish show trademark adaptations to cave life compared with loaches from surface locations nearby, including a pale body colouration, much smaller eyes, plus larger nostrils and barbels," she says. Larger barbels, whisker-like feelers, may improve tactile sensing in the dark (*Current Biology*, DOI: 10.1016/j.cub.2017.02.048).

It shows fish can adapt quickly to these subterranean habitats,

and just a few thousand years might be enough, says Behrmann-Godel. "Cavefish could exist virtually everywhere in principle, and there's no good reason to expect long evolution times for them to adapt to caves," she says.

Simply dubbed "cave loach" or "barbatula" for now, the fish was discovered in 2015 by Joachim Kreiselmaier, an amateur cave diver, in a water-filled cave labyrinth called the Danube-Aach System in southern Germany. "To reach the area with the fish takes an hour [of diving]," he says.

Planet and asteroid play chicken

THERE'S an asteroid in Jupiter's orbit around the sun that's going in the opposite direction – and it may have been doing so for more than a million years.

Object 2015 BZ509 was discovered in 2015 and is the only asteroid we know of that shares a planet's orbital space while moving in the opposite direction. Paul Wiegert at the University of Western Ontario in Canada and his colleagues have now examined it to see why it doesn't crash head-on into Jupiter.

The asteroid passes the planet twice per orbit: once when it slips between Jupiter and the sun, and once on the planet's far side. Each pass provides a small gravitational tug, which keeps BZ509's path just to one side of Jupiter's so they don't collide.

The team has calculated that this precarious-sounding orbit is actually fairly stable and safe for the asteroid. It has been following this retrograde path for at least 1 million years and ought to remain on it for a million more.

We still don't know what put it on its backwards path in the first place, however. "It's very peculiar," says Mattia Galiazzo at the University of Vienna, Austria.



JAMES DAVIDS / ALAMY STOCK PHOTO

ALS linked to occupational exposures

WORKPLACE exposure to electromagnetic fields is associated with a higher risk of developing amyotrophic lateral sclerosis (ALS).

Several studies have found a higher risk of ALS in electrical workers. One theory is that electrical shocks are to blame, or extremely low frequency magnetic fields.

Now a study of more than 58,000 men and 6500 women suggests the second idea may be correct. Roel Vermeulen at Utrecht University in the Netherlands and his team found that people whose jobs exposed them to high levels of very low

frequency magnetic fields were twice as likely to develop ALS as people who have never had this kind of occupational exposure (*Occupational & Environmental Medicine*, doi.org/b43j). Jobs with relatively high exposures include welders, sewing-machine operators and aircraft pilots, says Vermeulen.

"The effect of extremely low frequency magnetic fields on ALS development is not clear," says Christian Holscher at Lancaster University, UK. He says the finding should be interpreted with caution as it may be a false positive.



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The price of emission

Donald Trump's rollback of climate legislation is a chance for the world to unite against the US with carbon tariffs, says **Michael Le Page**

LAST week, US president Donald Trump signed an executive order that aims to reverse the climate regulations introduced by the Obama administration. It could effectively cancel plans to restrict carbon dioxide emissions, such as those from coal-fired power plants. Years of legal battles lie ahead, but the message could not be clearer: the US is turning its back on efforts to curtail global warming.

The nightmare scenario that Trump's inauguration posed for the nearly 200 countries signed up to the Paris climate agreement has now become reality. The world's second-biggest emitter

of greenhouse gases has given up on even trying to meet its target under the agreement.

Now what matters is how the world responds. If other countries stand by and let the US brazenly flout its commitments, the entire agreement could slowly unravel as its credibility evaporates. But what can the other nations do when the agreement includes no enforcement measures?

There is an alternative approach, and many think it could lead to faster emissions cuts. It is introducing a global price on carbon, and slapping carbon tariffs on goods from any country that refuses to join in.

Such a global carbon price has historically been dismissed as politically infeasible. But that was before Trump's flagrant climate rollback. Suddenly, an intriguing possibility has arisen: could the outrageous behaviour of the US unite nations to take action on climate that will be effective?

An ever-rising price on carbon has long been the most agreed-on way to speed the transition to zero-carbon economies. But it is easier said than done.

"Trump might just outrage the world so much that he makes the politically infeasible feasible"

Although some countries have unilaterally introduced carbon pricing, they have done so only in a very limited way or with a very low price, or both – greatly reducing the effectiveness of the policy. Why so toothless? Countries fear that if companies have to pay high penalties for their carbon emissions, their industries will go bust or move production elsewhere to avoid the higher costs.

Take the European Union. In theory, it has carbon pricing in the form of its carbon trading system. Companies in carbon-intensive industries – for example, electricity, steel and

cement – must buy permits to emit CO₂ (see chart, right). However, to keep these companies competitive with their non-EU counterparts, the EU dishes out free permits, for instance, to the cement industry. Even when not given freely, the EU permits are so cheap they have failed to drive emissions reductions.

How to break the stalemate?
Carbon tariffs, also known as border adjustment taxes, are one answer. The idea is that countries that impose carbon pricing on their own industries would also impose border taxes on goods imported from countries that do not. This would allow countries to raise carbon prices to a meaningful level without putting their own industries at a disadvantage.

Better still, if enough powerful countries banded together to institute carbon tariffs, it would create a compelling incentive for other countries to join in too. That's because if your exporters are forced to pay a carbon tax, better to collect that money yourself rather than see it go to another country (see "How to put a price on carbon", below).

A global carbon price is the approach that many prominent researchers and economists, including Axel Ockenfels at the University of Cologne in Germany, have been calling for. They argue that it will produce much faster falls in emissions than simply setting targets, which is the current approach. For example, under the Paris agreement, each country comes up with its own target for cutting emissions – and there are no penalties for failing to meet them.

Last year, the prospect of using carbon tariffs to force countries to adopt carbon pricing faded after the apparent success of Paris. After signing the agreement, countries could not then turn around and threaten to impose carbon tariffs on others, says Glen Peters at the Center for International Climate Research in Norway. "The general feeling is

that it would create so much bad will, when Paris created good will."

Now the situation has changed. Trump has just demonstrated how ineffectual the Paris approach is. The key problem, as his executive order reveals, is that the Paris agreement does not deter selfish behaviour: nations leaving it to others to tackle climate change while benefiting from their efforts.

"The Trump case confirms that climate change is a problem of international free-riding," says Ockenfels. "And carbon pricing could be an effective way of preventing free-riding."

So carbon tariffs are now back on the agenda. After Trump's election, former French president Nicolas Sarkozy openly called for the imposition of carbon tariffs on US goods. Mexico, whose relations with the US have been strained by the new administration, has also said it is considering it.

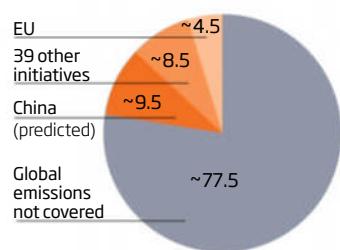
And in February, Europe's steel-makers joined the calls for a tariff, claiming that they are losing out to competitors in other countries because of the EU carbon trading system.

EU leaders have been more circumspect. In public, they have said they have no plans for tariffs – but conspicuously have not ruled anything out.

Even before last week's climate U-turn in the US, there was much discussion behind the scenes about how to deal with the US

Getting away with it

Just under a quarter of the world's CO₂ emissions from fossil fuels and cement production should soon have a price on them, but it is too low to lead to cuts



situation, says Oldag Caspar of trade and environment group Germanwatch, based in Bonn. "EU-China talks are already starting on this."

This could lead to new agreements between China and the EU, Caspar says – possibly including one on carbon tariffs.

China's stance could be crucial. In the past, it has been the proposed target of the tariffs, and has fiercely opposed them. But now its situation has changed. China has been making huge efforts to cut pollution, and it also has plans to introduce a carbon trading system similar to that of the EU. For the first time, China may be starting to see some upsides to tariffs as well as downsides.

So could the EU and China join together to impose them on the US? This is the surprising scenario that Christoph Böhringer at the University of Oldenburg in

Germany has been analysing using an economic model. His as-yet-unpublished work suggests more countries would need to join in to force the US to change course.

If tariffs are imposed only by the EU and China, the short-term costs to the US will be relatively small, Böhringer concludes. China, by contrast, would lose much if the US claimed carbon tariffs violate trade rules and retaliated by slapping punitive tariffs on goods from China – in other words, if there was a trade war.

In principle, there shouldn't be. If carbon tariffs are designed to be fair, they should be allowed under World Trade Organization rules, says Sam Lowe of environmental organisation Friends of the Earth. But no one can say for sure. "So much has

Climate change is a problem of international free-riding – one that carbon pricing could solve"

been written on this question," Lowe says. "We will only find out if it gets challenged."

For many economists, the risk of trade wars is the strongest argument against carbon tariffs. However, world leaders will need to weigh this risk against the immense and growing costs of climate change. There is an opportunity here for countries that are serious about tackling climate change to bypass the ineffectual Paris agreement and club together to impose a global carbon price.

Here again, Trump might make the decision easier. He has been threatening to slap big tariffs on goods from China to boost US industries, an action that could spark a trade war. If it happens, imposing carbon tariffs on US goods would be one of the ways China and others could respond while maintaining the moral high ground. We live in interesting times. ■

HOW TO PUT A PRICE ON CARBON

If someone vandalised your house, you'd be outraged if they got away scot-free. The idea of a carbon price is to make polluters pay for the damage their emissions will do to people's homes and livelihoods, as a result of climate-change related floods, storms and sea level rise (see page 33).

One approach is to tax goods and services on the basis of how much carbon dioxide is emitted during their

production – a carbon tax. The other is to impose a limit on how much CO₂ can be emitted by large industries, and then sell permits to pollute – cap and trade, or carbon trading.

We already know that a high-enough carbon price discourages fossil fuel use, encourages energy efficiency and makes renewables more competitive. To be really effective, the carbon price just needs to rise rapidly.

The heat is on

Pumping chemicals into the stratosphere to cool Earth is a scary idea, but we may have to do it anyway, says **Jamais Cascio**

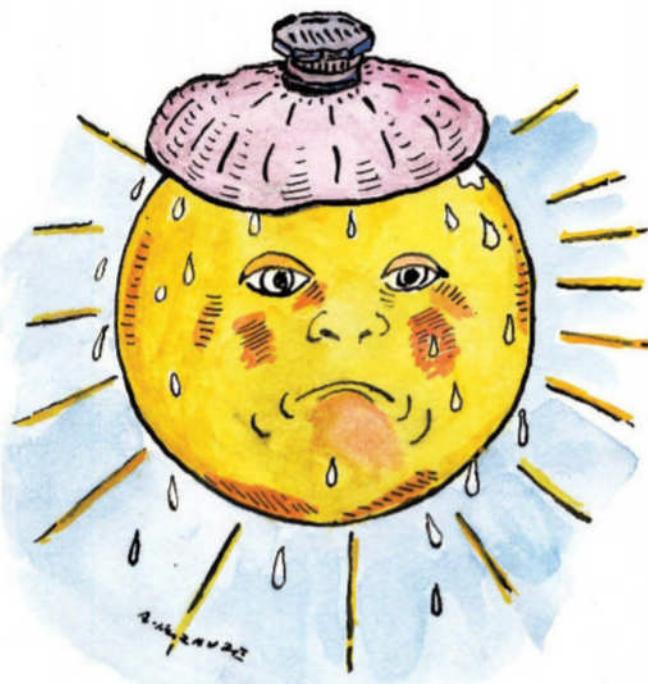
FEW people working on ways to geoengineer the atmosphere to cool Earth think it's anything but a scary idea. Unfortunately, it's one we may soon have to embrace.

Solar radiation management (SRM) adds particles to the upper atmosphere to reflect a small fraction of incoming sunlight, potentially slowing, halting or reversing global warming.

Researchers at Harvard University are about to launch a project in the sky above Arizona to see if it works for real. The test will be too small to alter global temperatures, but it still amounts to the biggest trial of the method.

Those studying geoengineering emphasise that this technique, although potentially quick and relatively cheap, would not offer a permanent fix. It would be a climate tourniquet to temporarily stem rising temperatures.

SRM alone would do nothing to



halt the rise in atmospheric carbon dioxide and acidification of the oceans. It also risks droughts and political conflicts over control and liability.

But we may eventually have to use it. Why? Because planetwide efforts to reduce greenhouse gas emissions have been sluggish, all but wiping out hope of avoiding a 1.5°C rise. Averting a 2°C rise also looks doubtful. And there is broad agreement that warming above 3°C risks "apocalyptic" impacts.

This brings a key complication to the fore: the lag between action and effect. Due to geophysical factors, such as CO₂ persisting in the atmosphere for decades, even a rapid reduction in carbon emissions won't immediately end temperature rises. The longer we wait to really get going, the greater the chance we will see more than 3°C of warming, even after major action across the globe.

Avoidable illness?

Is most cancer just bad luck or does lifestyle still matter, asks **Darren Saunders**

COMPETING narratives of chance and lifestyle often frame debate about cancer's causes. Studies are frequently misinterpreted as showing that cancer is either largely bad luck or almost entirely preventable. Who's right?

To answer that, we need to gauge the relative contributions of three routes to the DNA

changes that characterise cancer: inheritance, random errors when cells replicate, and environmental exposures such as smoking.

The latest attempt to do this comes from US researchers (doi.org/10/b43q), who aimed to resolve conflicting evidence by using genome-wide sequencing and population-wide disease data

from 69 countries.

It is a follow-up to their 2015 study, which suggested that variations in cancer incidence in different tissues were linked most closely to the number of stem cell divisions, and hence random DNA replication errors, in those tissues. Unfortunately it was ripe for misinterpretation, usually that "most cancer is just bad luck". Some researchers questioned the study and insisted external factors still dominate.

"So which of the competing narratives about cancer's cause - chance or lifestyle - is right?"

Hence the follow-up, showing that the link between stem cell divisions and cancer holds across nations with very different environmental conditions.

This time, the authors used a model that could distinguish between internal and external drivers of mutation in a more complete way. This goes some way to resolving apparent conflict between biological mechanisms and population-level estimates of the role of environmental factors. For example, the authors cite the fact that nearly 90 per cent of the most common form of lung cancer is preventable, even if they find random stem cell copying

At the planetary level, this would mean that our best efforts may not be enough to keep temperatures at a liveable level. So drastic changes to billions of people's lifestyles and dozens of countries' economies will have delivered little apparent benefit. Imagine the fallout when we eliminate carbon emissions, but temperatures keep rising and climate disruption worsens.

Thus the importance of the Harvard test. Simulations indicate that SRM could hold down temperatures, while studies of events such as volcanic eruptions also support the idea, but there is no hands-on experience with the technique outside labs.

We need to know how it could work and, more importantly, how it could fail before we face the possibility of having to use it. Field trials may well prove critical to our civilisation's ability to deal with global climate disruption.

Even the co-lead of the Harvard experiment, atmospheric scientist Frank Keutsch, calls the prospect of full-scale deployment "terrifying". He's right, but it might be the only way to avoid an even worse outcome. ■

Jamais Cascio is a distinguished fellow at the Institute for the Future in California

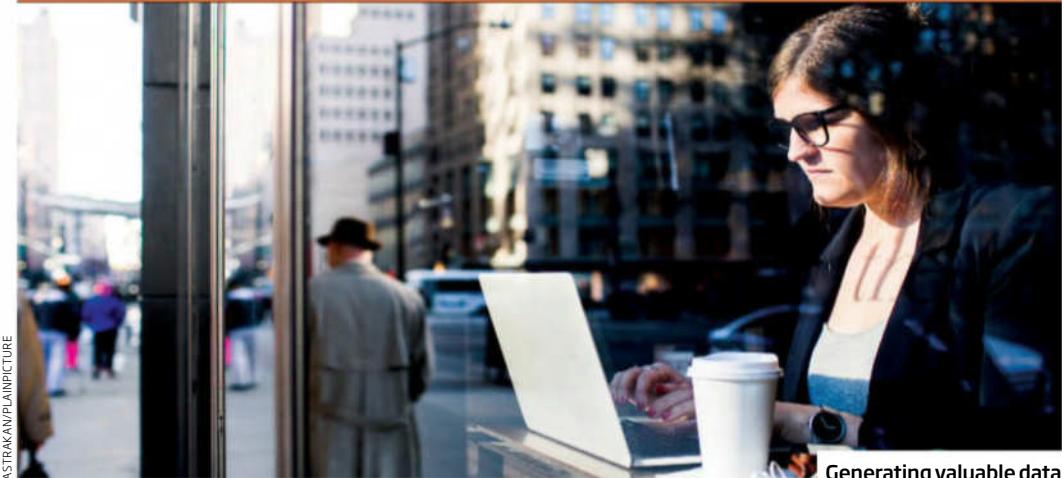
errors account for 35 per cent of DNA changes in this tissue.

So which of the competing narratives about cancer's cause is right? Unsurprisingly, the answer lies somewhere in the middle.

Two key messages emerge. First, it is impossible to say with certainty what caused a particular tumour, so trying to translate population-wide data to individual cases is not wise. Second, we can reduce cancer risk by modifying lifestyle, but chance does play a significant role. ■

Darren Saunders is a cancer biologist at the University of New South Wales, Australia

INSIGHT Privacy



ASTRAKHAN/PLAINPICTURE

Generating valuable data

Your entire internet history is now for sale

Sally Adee

ONLINE in the US? Everything you do is for sale. On 28 March, US Congress finalised the process of scrapping laws passed in the late days of the Obama administration, which would have required internet service providers (ISPs) from the end of 2017 to ask permission before selling the data they collect about their customers to third parties. This isn't just another small erosion of our dwindling privacy on the internet: it's more fundamental, and worrying, than that.

The repeal eliminates any requirement by the Federal Communications Commission (FCC) – which oversees internet regulations in the US – that ISPs get consent from their customers before collecting and selling sensitive data: not just your web browsing history, but also geolocation data, financial information – such as who you bank with – and metadata.

It may sound like ISPs are just getting the same deal as tech firms like Facebook and Google. But Facebook and Google are optional, ISPs are not. "If all ISPs collect and sell your data, it is impossible to use the internet without

giving up your privacy," says Jeanette Hofmann, director of the Alexander von Humboldt Institute for Internet and Society, Berlin.

And as ISPs aren't required to say what data they share about you, you will never know exactly what they are gathering or where that data goes.

So who can they sell it to? The Obama ruling explicitly mentioned advertisers, but not because ISPs are restricted to selling your data to them. It's just that advertisers are currently the highest bidders, and it might be damaging to an ISP's reputation if it got out that they were selling

"If all ISPs collect and sell your data, it is impossible to use the internet without giving up your privacy"

individual customers' data to, say, a pharmaceutical company.

But the absence of a rule means that if an ISP puts something into their privacy policy, they can sell the data to whoever they wish. "We've seen data brokers sell lists of 'gullible seniors', or rape victims or AIDS patients," says Jeremy Gillula at the Electronic Frontier

Foundation, a digital rights campaign group. "It's a lot more than advertising."

It might also become more likely that ISPs analyse your email account in detail to look for useful information to sell.

For now, not much will change after the repeal, since the scrapped law wasn't due to go into force until the end of 2017.

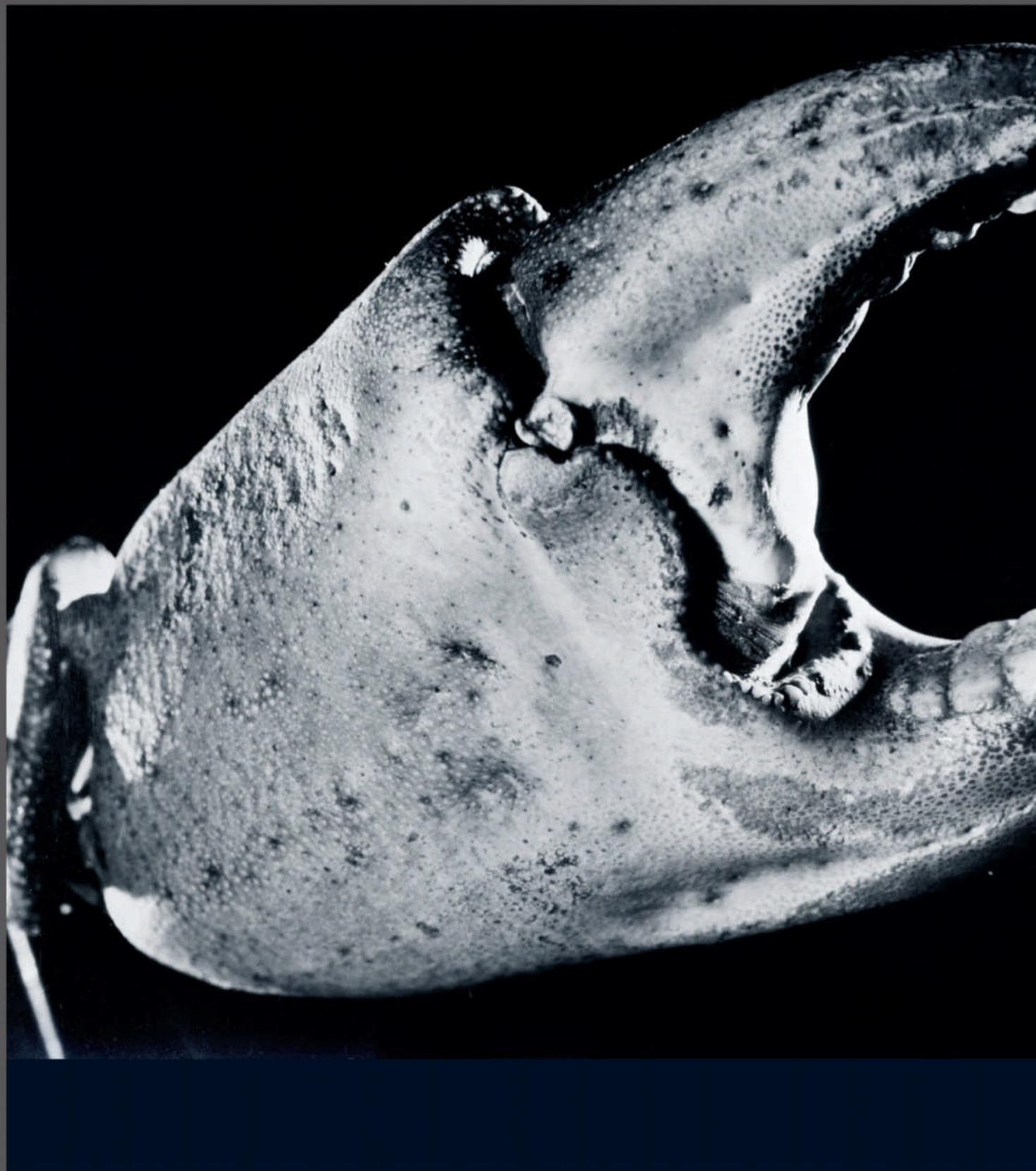
But what worries many is the precedent it sets. In comparison with European Union directives like the right to explanation and the right to be forgotten, it's hard not to see this as relegation of Americans to digital second-class citizenship, says John Havens, who runs the IEEE Ethics Initiative in New York City.

The new ruling also bars the FCC from adopting any similar rules to govern ISP collection and behaviour in the future.

There are some small measures you can take to protect your data. Different ISPs let you opt out of different data collection: you can call each ISP and ask them what the opt in and opt out policy is, and to whom they sell data. One way to minimise what they see is to visit sites which use https.

Another possibility may arise. In 2013, AT&T began to charge about \$29 extra per month to customers who didn't want their traffic analysed using deep packet inspection. So take heart, Americans. You don't have to be second-class citizens – if you've got the cash. ■

APERTURE



Scarily good in claws-up

THESE fearsome pincers are no B-movie prop. Long before David Attenborough brought the natural world to UK television screens, Jean Painlevé was sharing his own passion for marine life with French audiences through films and photographs.

After studying biology at the Sorbonne, Painlevé set up a studio on the coast of Brittany in 1925, where he used microscopes to capture close-ups of crabs, octopuses and sea urchins that belie their true size. Admired by many on the Paris avant-garde art scene, Painlevé showed that the natural world was a source of images and tales just as bizarre and shocking as anything Dada and surrealism could offer.

Painlevé was also a pioneer of underwater photography, encasing his camera in a rudimentary waterproof box (pictured below) to make films such as *L'Hippocampe (The Seahorse)*. He didn't shy away from using anthropomorphism and humour to help his audience relate to the lives of animals, describing, for example, the labour pains of the male seahorse, the courtship rituals of the octopus and the vanity of a crab. He also championed the use of film in scientific research.

By the time he died in 1989, Painlevé had made more than 200 films in a career spanning half a century. His work is the subject of an exhibition at the Ikon Gallery in Birmingham, UK, until 4 June.

Sam Wong



Images

Crab Claw (1928) and Painlevé with camera (1935) © Archives Jean Painlevé, Paris

Ikon Gallery, Birmingham, ikon-gallery.org

Speaking in ripples

Unseen influences may explain the mysteries of quantum reality, says Anil Ananthaswamy

IN OCTOBER 1951, physicist David Bohm left the US for Brazil. Branded a communist sympathiser, he had been arrested for refusing to testify to the US Congress. Acquitted, he was still stripped of his Princeton professorship. His departure began an exile that would last until his death, as a naturalised British citizen, four decades later.

The theory Bohm was nurturing as he left his native shores has spent even longer in the cold. In part, that's down to politics. But his ideas also seemed scientifically beyond the pale. Bohm proposed there was a hidden reality to quantum theory, meaning its crazy predictions of a world that doesn't exist until you choose to look at it are just that: crazy.

That went against the established grain, and still does. But more than six decades on, Bohm is getting a fresh hearing, as new experiments are hinting that he might have been on to something. If so, some aspects of reality would become easier to fathom, while others would be harder to stomach. Forget standard quantum weirdness – the world Bohm revealed is a more profoundly and mysteriously interconnected place than we ever imagined.

It wasn't always distasteful to suggest that reality is, well, real. Before quantum physics, our understanding was governed by classical theories in which reality exists

regardless of observers. Newton's laws of motion, for example, say we live in a clockwork, deterministic world that behaves in well-defined, predictable ways independently from what we are doing.

The thin end of the wedge came in 1905, when Albert Einstein said that the photoelectric effect, in which certain metals give out electrons when illuminated, can only be explained if light is made up of quantum particles – photons, as they came to be called.

The thing was, light was known to be a wave. In the early 1800s, Thomas Young had done a version of the now classic double-slit experiment, in which light is shone at two parallel slits. The interference pattern formed on a screen beyond is what we would expect if waves of light were spreading outwards from both slits – behaviour that seems impossible if it is made of single particles.

So which is it then – particle or wave? Both, as versions of Young's experiment have since confirmed. These involve light so dim that only one photon at a time passes through the double slit. Each photon lands on the screen at some seemingly random spot. Over time, however, these positions turn out not to be random; rather, the accumulated spots form an interference pattern, as if each photon were going





through both slits and interfering with itself.

Try to detect the photons' path through one or the other slit, however, and the interference pattern disappears. Not only is light's nature fundamentally ambiguous, but its guise seems determined by what we choose to measure. And as a young French physicist named Louis de Broglie proposed in 1924, it's not just light. Experiments soon confirmed all the quantum particles that make up material reality have this dual nature, too.

Finding that reality's true character is slippery is still a big step away from saying it doesn't exist when we aren't looking. Yet this is exactly what orthodox quantum mechanics says. In this picture, often called the Copenhagen interpretation after the Danish city where it took shape, a quantum object is represented by a mathematical wave function that allows us to make probabilistic predictions of what we will find when we measure things. Only on measurement does this wave function "collapse" to reveal

"Reality's nature is slippery, but that's a big step from saying it doesn't exist"

something localised in space and time. In the words of Werner Heisenberg, a pioneer of the Copenhagen interpretation, "the idea of an objective real world whose smallest parts exist objectively in the same sense as stones or trees exist, independently of whether or not we observe them... is impossible". That remains the dominant view to this day.

Yet it's not the only possible interpretation (see "The many guises of quantum theory", page 31). De Broglie suggested another: that particles are real and have equally real waves associated with them. In this picture, when a particle goes through one of the double slits, its "pilot" wave goes through both, interferes with itself, and then guides the particle to a location on the screen.

De Broglie presented his ideas at the 1927 Solvay Conference in Brussels, a legendary gathering of the early quantum greats. But he had not developed the theory mathematically, and it received a lukewarm reception. He quietly dropped the idea, becoming an adherent of the Copenhagen interpretation.

David Bohm was unaware of de Broglie's work when, in the early 1950s, he developed a mathematically solid theory in which a wave with properties identical to that of the wave function guides particles around. "This

SAM CHIVERS

wave is a pilot wave," says physicist Sheldon Goldstein of Rutgers University in New Jersey. "It choreographs the motion of the particles."

Bohm's theory made exactly the same predictions as standard quantum theory. But the fact that you could only predict outcomes of experiments probabilistically was because you lacked knowledge about the particles' initial state, not because nature doesn't exist when you're not looking. Bohm's ideas made de Broglie revisit and revise his own pilot-wave theory. He developed a two-wave theory in which every particle rides a pilot wave, which in turn interacts with another wave that behaves like a wave function.

Spooky influences

Both of these pictures also explained another central feature of the quantum world – the way "entangled" quantum objects seem to influence each other's states instantaneously at a distance. Standard Copenhagen quantum mechanics provides no explanation for this non-locality, or "spooky action", as Einstein dismissively referred to it. In the alternative picture, though, if particles are entangled, a common pilot wave guides them, and any change in the position or momentum of one particle instantly changes the pilot wave, thus influencing all the other particles. "The fact that Bohmian mechanics is non-local is not a defect of the theory," says Roderich Tumulka, Goldstein's colleague at Rutgers. "It is a feature that a true theory has to have."

In another world, Bohm's work might have been seen as a breakthrough. But by the time the idea was published in 1952, he was already in exile. "A lot of the reception of Bohm's theory is tied up with that," says David Albert,

a philosopher of physics at Columbia University in New York City. It didn't help that Einstein, then in his twilight years and a vocal critic of quantum theory, dismissed it too. In a letter to Max Born, another quantum pioneer, he wrote: "Bohm believes (as de Broglie did, by the way, 25 years ago) that he is able to interpret the quantum theory in deterministic terms... That seems too cheap to me." Bohmian mechanics entered the twilight zone of scientific theories – not quite dead, but not really a live concern either.

And there it has largely stayed, bar the odd finding that, if anything, hindered its revival. In 1992, for example, a thought experiment by physicist Marlan Scully of Texas A&M University and his colleagues showed that the theory made it possible for a particle to be measured passing through one slit in a double-slit experiment, but then land on the screen at a position that implied it had passed through the other. "Tensely: Bohm trajectories are not realistic, they are surrealistic," they wrote.

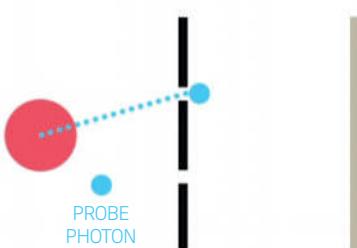
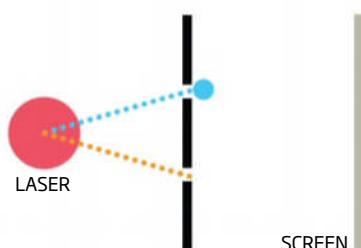
Really surreal

Quantum double-slit experiments tell us that nothing is quite as it seems

Measurements at the slits detect single photons passing through one slit or the other: **light is made of particles**

Allow the photons to reach the screen and an interference pattern develops over time: **light is a wave**, and it passes through both slits

Now introduce an entangled "probe" photon that tells us which slit its partner photon passed through. Measure at the slits again, and the states of the two photons must agree



The many guises of quantum theory

Why does reality only seem to coalesce into a definite state when you make a measurement? The answer depends on your preferred view of the quantum world

Copenhagen interpretation

The “shut up and calculate” view: the quantum world does not exist in any meaningful sense without measurements.

Many worlds interpretation

Make a measurement and the universe splits, taking you into the parallel world where you got the result you did.

Objective collapse

Spread-out quantum states are collapsing into definite states all the time. Your clodhopping measurement just helps things on their way.

Quantum Bayesianism

Quantum uncertainty is not intrinsic to reality – it has to do with your own lack of knowledge about whatever you are attempting to measure.

Information

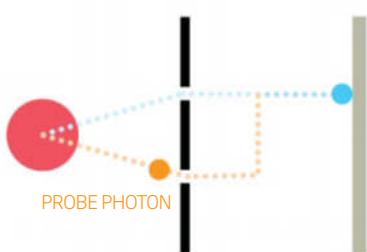
When you measure something, you extract some physical form of information from it, forcing it into a high-definition state.

Bohmian mechanics

Reality is guided by pilot waves; measurement just discovers what reality is up to, in the same way as classical physics (see main story).

It was a series of unlikely experiments involving oil droplets that started to change some minds. In 2005, Yves Couder and Emmanuel Fort at Denis Diderot University in Paris stumbled upon a physical analogue of pilot waves. They discovered that if they let a millimetre-sized droplet of silicone oil fall on to a bath of the same oil that was vibrating up and down, the droplet would bounce indefinitely on the surface. And not just that: when it bounced the first time, it created a wave that it encountered on the next bounce,

Take measurements at the screen, however, and half the time they disagree: the state of the probe suggests the travelling photon went through one slit, but its position on the screen implies it passed through the other – a seemingly surreal trajectory



which gave the droplet a horizontal as well as a vertical kick. The bouncing droplet started wandering across the oil bath, guided by the very wave that it had created and helped sustain with each bounce.

The interesting thing was what happened when this wave-particle system encountered a barrier, a fraction of a millimetre below the surface, with two gaps in it: a double slit. The walking droplet went over one or the other slit, while its pilot wave went over both, and the wave pattern that emerged on the other side guided the droplet on. The researchers collected 75 such trajectories, and their analysis suggested the formation of an interference pattern on the far side of the slits. Despite there only ever being one particle-like droplet in the apparatus at any time, its pilot wave was causing it to acquire seemingly wave-like behaviour. If you couldn't see the wave, the pattern built up over time would make you think the droplets had gone through both slits (*Physical Review Letters*, vol 97, p 154101).

It was clearly only an analogy, and attempts by other teams to repeat the work suggest that the supposed interference pattern might have been the product of air currents, as well as inadequate statistics. More recently, John Bush and his colleagues at the Massachusetts Institute of Technology have performed a

more rigorous version of the experiment, with proper shielding from air currents. They found, once again, that the bouncing droplet creates a pilot wave that guides it on – and they discovered a second wave pattern. Created by the interaction of the droplet with the edge of the circular bath, this pattern in the droplet's position emerges over time and has properties that mimic the wave function. This is just as in de Broglie's more complex version of pilot-wave theory (*Journal of Fluid Mechanics*, DOI: 10.1017/jfm.2016.537).

The bouncing droplet experiments have allowed Couder's and Bush's teams to observe behaviour usually seen only in quantum systems. For example, the statistics of the droplet's seemingly chaotic movements bear an uncanny resemblance to those of an electron moving inside a corral of atoms. “Now we have a macroscopic realisation of the physical picture suggested by de Broglie, and it exhibits many of the allegedly inscrutable features of quantum mechanics,” says Bush. “That’s a hell of a coincidence.”

Maybe – but there was still the problem of those contradictory, surrealist particle paths the alternative theory seems to allow. Last year, a refined version of the double-slit experiment conducted by Aephraim Steinberg of the University of Toronto, Canada, and his colleagues suggested that might not be quite such a problem after all. Brace yourself, because this is where things get really weird.

First, the researchers created pairs of photons with entangled polarisations. One photon of each pair was sent through the double slit, which was designed so that if the photon was vertically polarised it would go through slit A, and if horizontally polarised through slit B. The second photon served as a probe: thanks to the entanglement, measuring its polarisation was akin to knowing the polarisation of the photon passing through the slits, and thus which slit it must have gone through (see “Really surreal”, below left).

This set-up gave the team two bites at the same cherry: they were able to determine the travelling photon's position as it went through the apparatus, and could also measure the polarisation state of the associated probe photon. They did this with tens of thousands of photon pairs, and found that, on average, at the moment a photon passed through slit A, the probe photon would be vertically polarised, as expected. But at the screen, things were a lot more ambiguous. When a travelling photon was measured at a position on the screen corresponding to

having passed through slit A, half the time the polarisation of the probe photon was horizontal – suggesting that the travelling photon had passed through slit B. These were seemingly surreal trajectories, unmasked (*Science Advances*, vol 2, p e1501466).

Reality regained

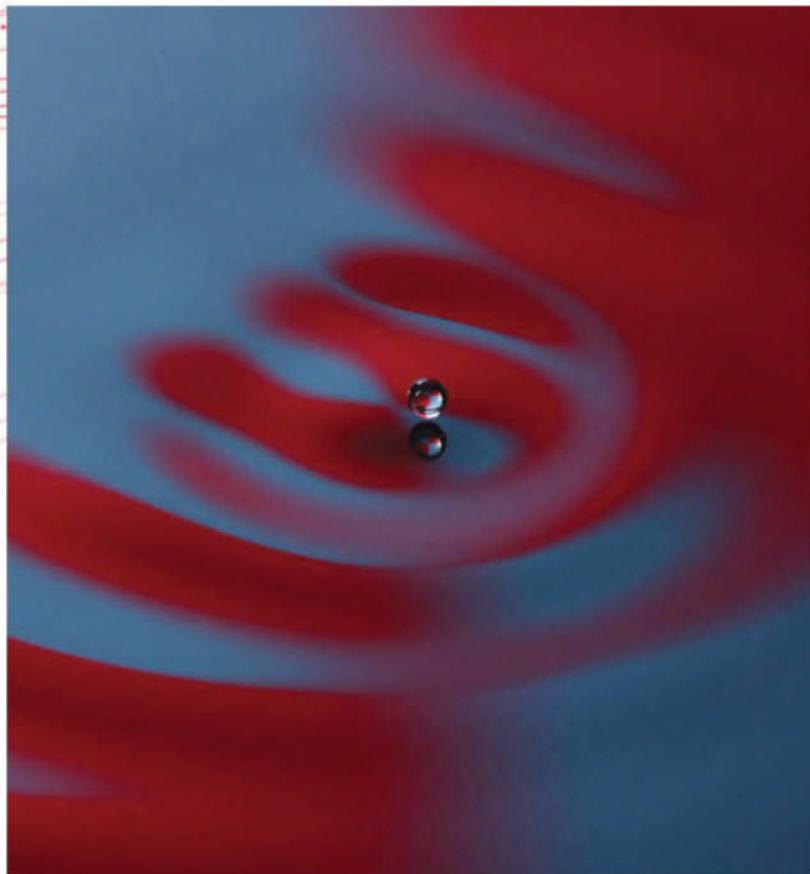
What's happening? In a word, non-locality. The experiment shows that the moving photon is constantly changing the polarisation of the probe photon. Look at the probe photon at the moment the moving photon goes through a slit, and there is no contradiction. But look at it the moment the moving photon hits the screen and, half of the time, its polarisation state has changed. This sort of non-locality is admissible in standard quantum theory, but it is baked into Bohm's version. The experiment is by no means a proof of Bohm's theory, but it shows that its prediction of surreal trajectories cannot be used to debunk it.

So Bohmian mechanics can and should remain a contender, says Albert. "Any realist picture is preferable to any anti-realist picture," he says.

But winning hearts and minds will still be a struggle. For a start, Bohmian mechanics is formulated to replicate the predictions of standard quantum mechanics: experimentally, it's almost impossible to tell them apart. Also, the theory is mathematically fleshed out only for particles travelling far slower than the speed of light. Quantum mechanics, in contrast, has been extended to embrace relativistic particles travelling close to the speed of light, and so forms the basis of quantum field theory and the standard model of particle physics. "Clean, worked-out Bohmian versions of those things do not exist," says Goldstein.

For David Kaiser, a physicist and historian of science at MIT, that may be the theory's Achilles heel. "My aesthetic concern is that it feels, in the original description at least, horribly non-relativistic, anti-relativistic," he says.

Goldstein and his colleagues have been trying since the mid-1990s to marry Bohm's ideas with Einstein's special relativity. The hardest part is to accommodate the instantaneous interactions of Bohmian mechanics. That's at odds with relativity's limit on how fast influences can spread – namely, the speed of light. What's more, relativity does not distinguish points in space as being in any one present. Goldstein and his colleagues have tried to get around this,



IMAGES COURTESY OF DANIEL HARRIS AND JOHN BUSH, MIT

BRAIN DEATH

Quantum mechanics gives a bizarre twist to that old trope about a monkey at a typewriter with infinite time. Ditch the monkey, and consider quantum fluctuations in an everlasting universe. They could at some point spontaneously form anything, even a brain. If one such "Boltzmann brain" exists, it's likely that many others do. In fact, if we live in such a universe, it's likely that our brains are this kind.

That sounds nonsensical. "If a theory predicts that the majority of observers are Boltzmann brains, that's bad for the theory," says Roderich Tumulka at Rutgers University.

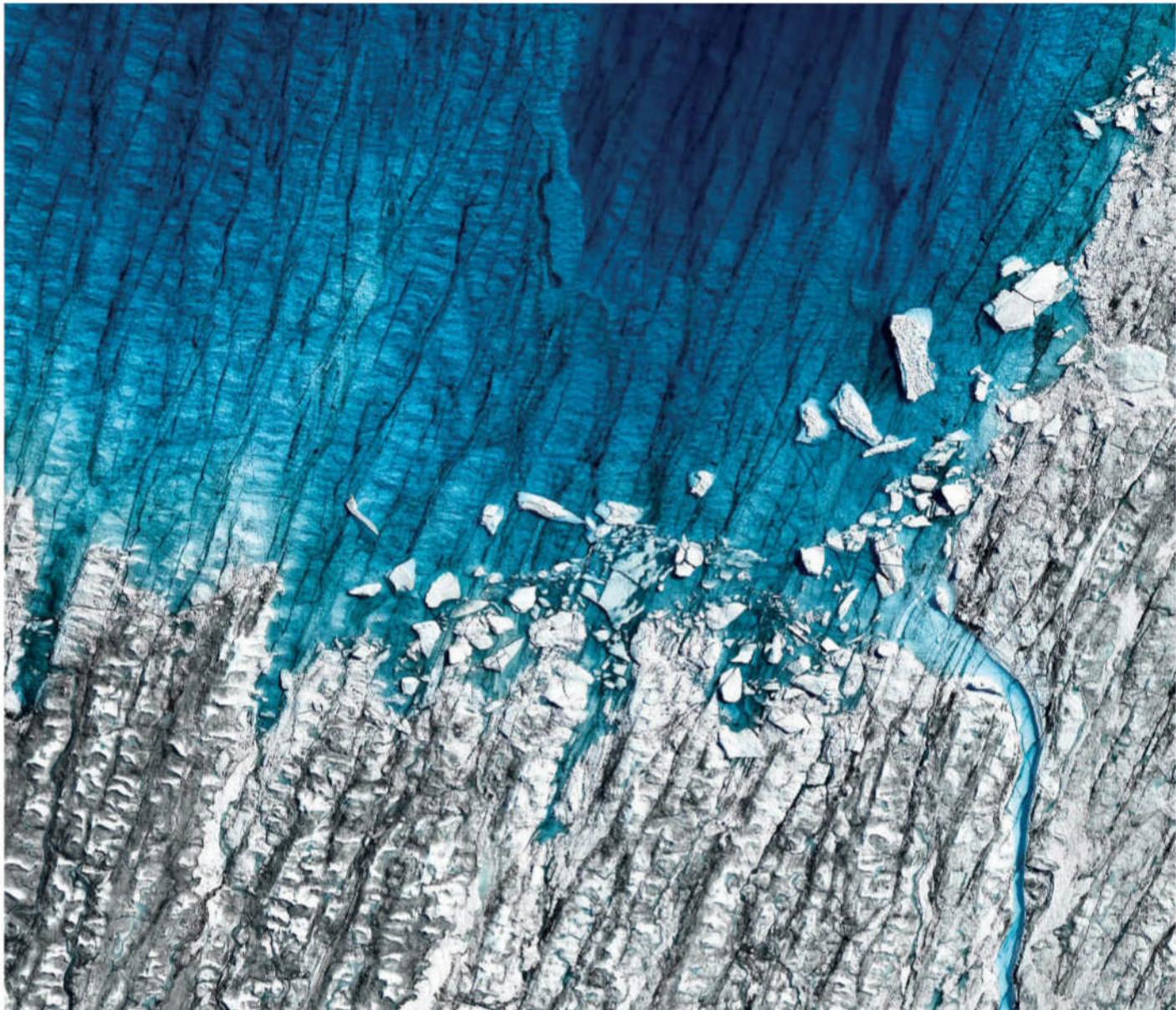
Standard quantum mechanics says that an infinitely enduring universe exists in a "superposition" of all possible states, including those with Boltzmann brains. But in Bohmian mechanics (see main story) such a universe evolves towards a static state. The probability of that state being one with Boltzmann brains is minuscule, and even if it is, nothing is changing so the brain can't be functional. "It's much more likely that there are no Boltzmann brains, and then it stays that way," says Tumulka.

showing that a Bohmian wave function can create structures or "foliations" in space-time, and that events on any one foliation are simultaneous, leading to non-locality. It's the most sophisticated approach yet – but also very much still a work in progress.

When Goldstein started learning standard quantum mechanics in the 1960s, he was seduced by its mystery and spookiness, he says – only to realise gradually that Bohm's ideas made more sense. Besides, he says, Bohm's ideas have their own sense of mystery: the way in which every entangled particle influences every other particle in the universe, and the fact that the wave function is a new kind of entity. "You have still got romance," he says. "It's in the right place now. Not misplaced."

In the end, though, it's not about winning over minds, but being open to the Bohmian picture, says Steinberg. "The best thing experiments like ours can do is to remind people that the interpretation exists," he says. "People aren't aware of it, and we want to bring more attention to it." Bush feels similarly about his walking-droplet experiments. "That's why I'm a believer in this venture, even if its sole result is to get young people to question their views on quantum mechanics," he says. ■

Anil Ananthaswamy is a consultant for *New Scientist*



*THAW #10 BY TIMOLIEBER / WWW.TIMOLIEBER.COM

A year on thin ice

The Arctic's four seasons have been radically transformed, finds Fred Pearce

CHANGE is afoot at the top of our world. Spring has sprung, marking a crucial moment in the Arctic's annual cycle. Each year, the ice sheet reaches its maximum extent in March, then begins to shrink as temperature warm up.

But this year, something is different. The floating sea ice, which at its peak normally extends as far as the eye can see and feels as solid underfoot as a continental shelf, is rotten. For the third year in a row, its maximum March extent is at a record low,

following a winter of heatwaves. February temperatures were above freezing.

These are the symptoms of a new Arctic that is being created – perhaps the most profound change to the look of our planet for millions of years, with consequences for the rest of the planet. In all likelihood the Arctic Ocean will soon be ice-free in the summer, surrounded by snow-free lands. “We are in a new Arctic regime,” says marine biologist Antje Boetius.

Follow us as we take you through a year on thin ice.



Winter

In the world's most northern settlement, an international research town in Svalbard called Ny-Ålesund, the sun sets in the last week of October and doesn't rise again until mid-February. The polar night ushers in freezing temperatures that are essential for the region's annual cycle (see diagram, right). As the mercury plummets, ice starts to grow out over the ocean's dark waters, covering it in a floating ice shelf. Winter has come.

Historically, the ice could grow to be 5 metres thick in places where it survived the summer and thickened with each passing winter. But that is changing. Antje Boetius, at the Max Planck Institute for Marine Microbiology in Bremen, Germany, experienced the new conditions first-hand during an expedition last October. "Areas that showed up on satellites with 100 per cent ice cover often had at best very broken ice. Even when there was ice, it was so thin we could often see through it," she says. "This rotten ice is causing misleading measurements," says David Barber at the University of Manitoba in Winnipeg, Canada. Satellites can't picture the planet's surface in high enough resolution to show the broken-up ice, which means that many of the usual statistics about ice cover underestimate what's going on.

Conditions didn't improve as the winter settled in. A heatwave in November and December brought temperatures that were as high as -7°C in some parts of the Arctic, 15°C warmer than the average over the past three decades. The repercussions were remarkable.

Satellite data collected by the US National Snow and Ice Data Center show that the growth of sea ice slowed down to a crawl at times. Twice – in late November and December – the ice cap actually shrank.

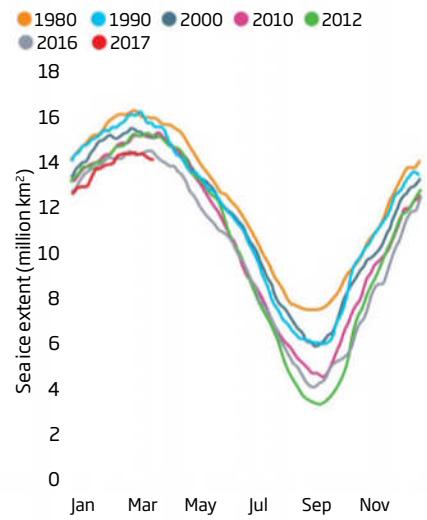
The consequences of the warm winter are likely to be long-lasting. Thin, broken-up ice is far less likely to survive the summer melt and form sustainable multi-year ice. Three decades ago, 45 per cent of ice during the winter maximum was multi-year ice. In March 2016 it was just 22 per cent and this winter is on track to be equally extreme, although the numbers aren't in yet.

Current climate models don't come close to predicting the scale of ice loss we're seeing in the region, says Julienne Stroeve at University College London. "We're basically about 30 years ahead of where the models say we should be." Why this is the case is a hot topic. One possibility is that the loss of ice brought about by global warming is being amplified by natural variabilities – decadal weather cycles that have nothing to do with climate change and fossil fuels. Another is that something isn't quite right in the models. Boetius points out that they don't properly mimic things like local weather changes due to global warming, and the physical effects of winds and waves that break up ice.

What is clear are the extreme conditions on the ground. The ice cap reached its maximum extent on 7 March this year. At 14.42 million square kilometres, it was the smallest it has been in 38 years of satellite records.

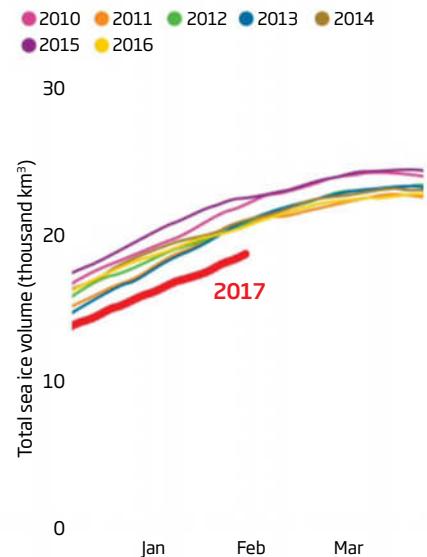
SEASONAL CYCLE

The Arctic sea ice grows and shrinks with the passage of the seasons. But the total area covered by ice is getting smaller year after year, because of global warming



SOURCE: NATIONAL SNOW AND ICE DATA CENTER (PIOMAS)

The thickness of the ice is also shrinking. Heatwaves late in 2016 mean the volume of the Arctic ice sheet is now much lower than any other winter on record



SOURCE: PSC CAP (PUMBU) (PIOMAS)

FACT FILE: HIGHER SEAS

- *Glaciers on land are flowing into the oceans faster because of climate change, pushing sea levels up worldwide*
- *Annual ice loss from the islands of the Canadian archipelago has increased 10-fold in 10 years*
- *Greenland's glaciers release 250 cubic kilometres of water a year, contributing 40 per cent of annual sea level rise*
- *If all the ice on Greenland melted, global sea levels would be 7 metres higher*

Spring

The annual return of sunlight to the Arctic triggers a cascade of events. The rays warm the air and start to melt the snow. Gaps between the sheets of floating ice get wider and the surface of the ocean warms up.

Beneath the ice, a unique food chain is set in motion: as light begins to filter through, photosynthetic algae start to grow in tiny crevices in the ice, feeding tiny crustaceans that in turn feed small fish. At the surface, polar bears emerge from hibernation to seek out seals, while whales move about in the widening cracks between the ice.

The return of light also highlights an important way in which the new Arctic is affecting regions further south: we are losing a vital mirror that helped keep the planet cool. White snow and ice typically reflect 85 per cent of solar radiation back out into space, whereas dark ocean only reflects 10 per cent. As the ice and snow disappear, the ocean's reflectivity is being almost entirely destroyed.

To calculate how much extra solar heat is being absorbed in the Arctic as the white surfaces turn dark, Ian Eisenman and colleagues at the Scripps Institution of Oceanography in San Diego, California, turned to satellite radiation data. They found that an extra 6.4 watts is being absorbed today for every square metre of the Arctic, compared with 1979.

For a sense of scale, the team compared this with the warming effect of carbon dioxide over the same period. They found that the loss of sea ice has delivered a warming boost to the entire planet equivalent to 25 per cent of the effect of rising CO₂ levels. This is the main reason why the Arctic has on average been warming more than twice as fast as the planet as a whole over the past half-century.

"You can't ignore that," says Eisenman. "The sea ice is an important player in the global climate change that we have observed in the past 30-odd years." Climate models do include the loss of Arctic reflectivity – also known as albedo – in their calculations of future warming but, he says, the change measured is twice as large as what models predict.

It's not just sea ice that is disappearing. Snow and ice are vanishing on land, too, and bare tundra reflects just 20 per cent of the sun's rays. This is also having a large effect, warns Peter Wadhams, an ocean physicist at the University of Cambridge. "The snowline retreat in midsummer is now 6 million square kilometres, compared to the 4 million square kilometres loss of sea ice," he says, adding that the warming effect of darker land masses could be as big as that from lost sea ice. The calculations are rough, but the message seems clear: the Arctic is amplifying global warming on a large scale.

FACT FILE: OCEAN GRAB

- Russia planted its flag on the ocean floor at the North Pole in 2007, kick-starting a dispute over who owns the Arctic
- The carve-up is likely to be done by the Arctic Council, an intergovernmental club of all eight Arctic nations
- The US Geological Survey estimates that 30 per cent of the world's undiscovered natural gas could be in the region
- Ice-free Arctic waters could also halve the journey time for cargo from China to Europe

FRAGILE ICE

The average thickness of the ice sheet has dropped considerably. This is a concern because thicker ice can survive the regular summer melt, but thinner ice cannot



1975

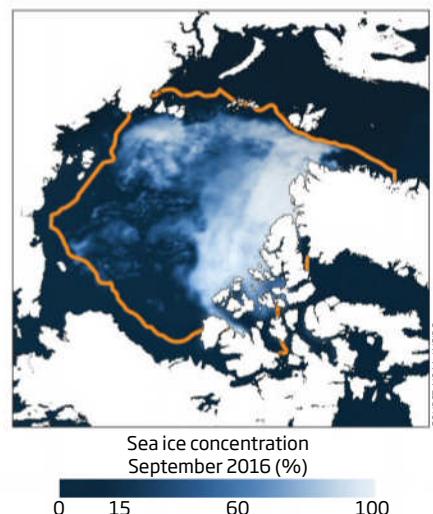


2012

SOURCE: 10.5194/ac-9-269-2015

September 2016 was tied with 2007 for the second-lowest summer ice extent on record. The oldest, thickest ice, which used to stretch over much of the Arctic Ocean, is now mostly packed up against Canada and Greenland

— Historical sea ice extent for September (median for 1981–2010)



Summer

Arctic summers are greener and more lively these days. Average June snow cover has declined by 58 per cent since 1979, exposing more tundra for longer. Howard Epstein of the University of Virginia in Charlottesville has measured a 20 per cent increase in plants on the tundra since 1982. Woody shrubs are spreading at the expense of more distinctive local species such as the lichen that are an important food source for reindeer.

Coastlines are also being transformed. Waves are pounding shorelines that ice once protected. According to Irina Overeem at the University of Colorado, erosion rates along the coast of the Beaufort Sea have more than doubled in half a century to an average of 14 metres a year.

In some ways, the greening of the tundra is good news. It is extracting CO₂ from the atmosphere, which helps to counteract global warming. But many predict this helpful feedback could soon be overwhelmed by the release of CO₂ and methane from melting permafrost on land and ocean sediments. The frozen Arctic traps an estimated 1500 billion tonnes of organic carbon, twice the amount of CO₂ in the atmosphere. Under controversial doomsday scenarios, large quantities could be belched into the atmosphere, pushing global temperatures up by a further 1°C or more.

Meanwhile, we are only just discovering the richness of life in the Arctic. Last year, Boetius led an expedition to Karasik Seamount, a submerged summit in a mid-ocean ridge just 400 kilometres from the North Pole, to document the world's northernmost known coral. The Arctic Ocean is a vast and largely unexplored space, and Boetius was stunned by the diversity she saw: "Huge white starfish, blue snails, red crabs and brown clams,

between huge globular sponges that are up to a metre across and hundreds of years old."

Her fear is that all this may be lost before it is even found – an ice-free Arctic will be a very different environment favouring a very different style of life. Recent years have seen mass congregations of walruses on the Alaskan and Siberian coasts of the Chukchi Sea, taking a breather on land because the sea ice from which they normally hunt had disappeared. The new behaviour has resulted in overcrowding, stampedes that are deadly to young calves, and food shortages.

It's not just behaviours that have changed. Melt the snow, warm the water, remove the ice that once kept the waters dark, and we can expect a biological cornucopia. According to the US National Oceanic and Atmospheric Administration, last year the Barents Sea north of Scandinavia had 19 per cent more biomass than the average for 2003 to 2015. That could be the start of a predicted 70 per cent increase in the Arctic Ocean's biomass production. At the base of the ocean's food chain, phytoplankton have increased by 20 per cent since 1998 thanks to more open water.

On top of this, Atlantic species are moving north, lured by more food and warmer waters. Some call this the "Atlantification" of the Arctic. In her latest expedition, Boetius found haddock at 85° north, just 100 kilometres from the North Pole. The fish are primarily a North Atlantic species and don't normally stray further north than Svalbard. Others have shown that both Atlantic and Pacific cod have also moved in. The concern is that an influx of newcomers could crowd out and even kill off the natives. Arriviste orcas, for instance, are hunting native narwhals in the archipelagos of northern Canada.

FACT FILE: RUBBISH

- *Arctic Ocean litter has increased 20-fold in 10 years*
- *A 2014 survey recorded 6333 pieces of litter per square kilometre off the Fram Strait east of Greenland*

HOT POLE

Arctic temperatures have risen more and faster than anywhere else on Earth

+2°C

AIR

*Air temperatures were 2°C warmer in 2016 than the norm**

+5°C

OCEAN SURFACE

*In August 2016, the surface waters were 5°C warmer than the norm**

+15°C

2016 HEATWAVE

*In November, air temperatures were 15°C above the norm**

*compared with the average for 1981-2010

Autumn

September marks a second turning point in the Arctic's annual cycle – known as the ice minimum – and one day soon it will be monumental. This is the point in the year when the shrinking stalls for a few days before winter starts up again and the cycle repeats. With 4.14 million square kilometres of ice, last September's minimum was tied with 2007's as the second smallest on record.

The downward trend is reliable, and according to the most pessimistic climate researchers, an ice-free September is just years away. Wadhams is in this camp, having said last year that he expects the first ice-free summer to be in 2017 or 2018. It's worth noting that what scientists have agreed to call "ice-free" in fact makes allowances for 1 million square kilometres of ice, most of which will be packed up against the region's convoluted coastlines and inside the Canadian archipelago, where the ice is thickest.

Wadhams is definitely at the extreme end of predictions. In practice, several factors – including natural variations in the weather from year to year – make it difficult to pinpoint the first ice-free summer with that degree of precision. A study published last year estimated that any forecasts must have an error bar of roughly 25 years. With that in mind, the first ice-free summer could be

between 15 and 36 years away if greenhouse gas emissions remain high, estimate Alexandra Jahn at the University of Colorado and colleagues. This could be delayed by a decade or so if we were to reduce emissions.

Can anything be done to save the Arctic's ice? Stroeve reckons only the 2015 Paris Agreement's aspirational target of halting global warming at 1.5°C would deliver a realistic chance of this. Some fear the region may soon pass a threshold beyond which the warming effect caused by the loss of reflective ice is sufficient on its own to melt most of what's left. That would be irreversible, and could unleash runaway global warming that would continue whatever we did to emissions. Eisenman calculates that this is unlikely before all the summer ice is gone, but perfectly possible thereafter.

We always knew a warmer world would be different, with deserts spreading north, super El Niños, conflagrations in the rainforests and more intense hurricanes bubbling up above the hot oceans. Many saw the melting Arctic as a largely passive victim of that climate change. No longer. Feedbacks from an ice sheet that has vanished faster than anticipated mean a new Arctic is alive and kicking. ■

Fred Pearce is a consultant for *New Scientist*

SEA ICE & YOU



3m²

of sea ice disappear for every...

1 tonne

of CO₂ emitted



A typical US car emits

1 tonne

of CO₂ per 4000 km



1 tonne

of CO₂ is emitted for each seat on a return flight from London to San Francisco



The average American emits

16 tonnes

of CO₂ each year



The average European emits

7 tonnes

of CO₂ each year



Globally, we emit

35 billion tonnes

of CO₂ each year

At these rates, the Arctic summer ice sheet will be gone by

2046

ARCTIC ICE, YOUR WEATHER

What happens in the Arctic doesn't stay in the Arctic. Studies show that the shrinking ice cap is effectively helping to warm the rest of the planet (see Spring, page 34). It may also be changing your local weather. Jennifer Francis at Rutgers University in New Jersey has pointed out that rapid warming in the north is reducing the difference between Arctic and mid-latitude air temperatures. That difference drives the northern jet stream, which moves weather systems around the hemisphere. So

changes in the Arctic may explain a 10 per cent decline in its speed since 1980, she says.

The slower jet stream has begun to meander more. Instead of pushing weather systems along, it traps them in one place, creating longer summer droughts and winter cold spells. The frequency of such stalled weather systems in summer has doubled since 2000, says Dim Coumou of the Potsdam Institute for Climate Impact Research in Germany. He blames this for the heatwave and forest fires in

Russia in 2010, the drought in North America in 2012 and Europe's killer heatwave in 2003. Francis suggests it could also explain persistent cold spells in east Asia.

Some researchers say weird weather can never be attributed to a single cause in this way. Francis agrees it may be a long time before we can be sure she is right. But if the new Arctic causes the jet stream to slow permanently, Europeans and North Americans could be in for a bumpy ride of climate extremes.



Living with the enemy

There's another big problem with antibiotics: indiscriminately killing bugs is making us sick. It may be time to call a truce, says Drew Smith

YOU are home to 10,000 species of bacteria. The vast majority, more than 99 per cent, cause you no harm. Indeed, many actually help by providing you with nutrients, tuning your immune system, balancing your metabolism and warding off mood disorders. You depend on these bugs.

Yet as anyone who's had an upset stomach after taking antibiotics can attest, when we target the dangerous minority of disease-causing species, we often wind up killing off the good ones too. Now, after generations of doctors prescribing antibiotics for every sniffle, we know that the collateral damage goes well beyond the occasional tummy ache.

Indiscriminately wiping out bacteria may be contributing to rising levels of asthma, allergies, obesity and many more conditions. These effects, together with the growing threat from antibiotic resistance, have some researchers advocating a sea change in the battle against the bugs: after 70 years of fighting to wipe them out, it may be time for a truce. If we can disarm harmful bacteria without killing them, we may be able to reduce antibiotic resistance, take the strain off these overworked drugs and leave our helpful inhabitants be. Doing so may even mean resurrecting some forgotten strategies from the past. If the 20th century was defined by our ability to kill off deadly bugs, then the 21st will be known as the era in which we learned to get along.

In the latter part of the 19th century, strong evidence that germs cause disease kicked off more than a century of war against bacteria. We expunged them from our water, food and homes with disinfectants; roused our immune systems against them with vaccines and wiped them out with penicillin and other chemical weapons. Human deaths caused by

infectious diseases fell by more than 90 per cent, contributing to a broader transformation of society. We take for granted our long lives and freedom from plague and infection, but this is unprecedented in human history.

This freedom comes with a cost. Ridding ourselves of all of these bugs has contributed to a rise in disorders of the immune system, metabolism and even the mind (See "Are antibiotics making us sick?", page 40). Taking a dose of antibiotics is like throwing a stink bomb into a subway. The criminals clear out, but so do the citizens. The rats and cockroaches remain, unfazed by the stench.

The survivors can become resistant to our weapons. Every year, 23,000 people in the US alone die from antibiotic-resistant infections. Proclamations of an impending superbug apocalypse are overblown – these bugs primarily attack older people and those who are already ill – but it is clear that overusing antibiotics drives up resistance, and we are running worryingly low on replacements.

If we were to treat infections without killing bacteria, they wouldn't need to evolve resistance to our antibiotics. Not only could this strategy, known as anti-virulence therapy, provide alternative drugs to fight infection, it could help to restore the potency of antibiotics for when we do need them. "If we don't always go to them for every infection, we can preserve their use for much longer," says Brad Spellberg, an infectious disease specialist at the University of Southern California.

So how can we do it? The idea is to stop bacteria behaving badly. Before they can cause an infection, bad bugs first need to stick in places where they aren't wanted. If they can't grab hold, they can't invade.

This strategy has already shown promise for treating urinary tract infections, which are particularly common in women. Most UTIs are caused by *Escherichia coli*, which use their hair-like pili to bind to carbohydrates on cell surfaces. But now researchers have found that if you give people carbohydrates similar to those naturally found on cells, they act as decoys. *E. coli* bind to the decoys, and never get a grip on the cell surfaces. As a result, the bacteria get flushed out when people urinate.

In a small trial of women with recurrent UTIs, just 15 per cent of those given the simple carbohydrate D-mannose got a UTI within six months, compared to 20 per cent of those treated with antibiotics and 61 per cent of the women given a placebo. In another trial, women who drank a solution of D-mannose didn't get another UTI for more than six months, on average, compared with 52 days for those given antibiotics.

Daniele Porru and colleagues at the San Matteo Foundation in Pavia, Italy, who ran the trial, also found that antibiotics became more potent for the women treated with D-mannose instead. Because antibiotic-resistant bacteria are generally less fit than susceptible strains, in the absence of antibiotics, regular bugs beat out resistant ones for resources, and come to outnumber them. That means when you do need antibiotics, they are more likely to work as most of the bacteria are the vulnerable kind. When the researchers tested samples of the bacteria, that's just what they found. "We noted an increased sensitivity to antibiotics, and very few side effects," says Porru.

1 in 3 Number of unnecessary prescriptions for antibiotics

SOURCE: US Centers for Disease Control



25,000

**People in the European Union
who die from antibiotic resistant
infections each year**

Source: World Health Organization

ARE ANTIBIOTICS MAKING US SICK?

Antibiotics are among the safest drugs. Indeed, doctors even prescribe them for viral infections, knowing they are useless, on the grounds that “it can’t hurt”.

Except that it can. And not just because it leads bacteria to develop resistance to the drugs. Antibiotic-associated diarrhoea and allergic reactions commonly send people to hospital. And antibiotic use is almost always the cause of diarrhoea associated with *Clostridium difficile*, which kills nearly 30,000 Americans every year (see main feature).

But people who study the microbiome suggest the toll may be far higher. One study in Denmark, for example, revealed that people who redeemed five or more antibiotic prescriptions over the course of a 15-year period were much more likely to develop type 2 diabetes compared with those who took antibiotics once or less during this time.

Beyond diabetes, changes in the balance of bacteria in our guts are now associated with obesity, inflammatory and autoimmune disorders and even depression.

Antibiotic use, especially in childhood, has been found to be a risk factor for all of these.

In some sense, links to obesity shouldn’t be news. Antibiotics have been used to fatten livestock since the 1940s. The first study showing a similar effect in people dates to 1955. But the mechanism was a mystery and there was little interest in follow-up. Germs were our enemy, antibiotics got rid of germs, so antibiotics were good, right?

Until the last decade, few imagined that gut bacteria might be needed for the development of our immune, metabolic and nervous systems. But it’s becoming clearer as links between the use of antibiotics and an increased risk of diabetes, psychosis, anxiety, depression and obesity steadily grow.

There is a lot that we still don’t know about the balance of bacteria in our bodies, but we now know enough to understand that constantly disrupting it is imprudent, even dangerous. Even if the rise of antibiotic resistance did not drive a need for alternative therapies, the need to preserve our health does.

More advanced blockers are in the works too. Scott Hultgren and Jim Janetka at Washington University in St Louis have developed synthetic mannose derivatives that may be more effective and linger longer within the body, meaning you need less to make a difference. Studies in mice show that a single dose can prevent *E. coli* infections for at least three days, and begin to clear existing infections within 6 hours. And by blocking *E. coli* instead of blasting them with antibiotics, the bacteria didn’t need to evolve resistance to drugs, and beneficial bacteria living in the urinary tract were left unharmed. The potential impact is big: in the US alone, more than 25 million antibiotic prescriptions are written for UTIs each year, and up to half of the people who take them will have a recurrence. Hultgren thinks using blockers is just the kind of approach that will “launch an antibiotic-sparing therapeutic revolution”.

If you can’t stop bacteria from sticking, the next line of defence is a long-forgotten treatment. The idea is to neutralise the toxins

that bacteria produce to break open cells and gobble up nutrients. It is a strategy first used in the 1880s by German bacteriologist Emil von Behring (right) and his Japanese colleague Kita Sato Shibasaburo. The pair injected sublethal doses of diphtheria and tetanus toxins into animals, harvested the toxin-neutralising antibodies they produced, and then used these to treat patients. This strategy eventually halved the death rate from diphtheria and tetanus, and earned von Behring the very first Nobel prize in medicine. But when antibiotics came along, anti-toxin therapy was largely abandoned.

“A lot of treatments were forgotten because antibiotics were so successful – and the loss of these is now reflected in the lack of treatment choices,” says Laura Piddock, a microbiologist at the University of Birmingham, UK. With the rise of antibiotic resistance, anti-toxin treatments are getting a fresh look.

One area in which anti-toxins have huge potential is in treating diarrhoea. Each year nearly 30,000 people in the US die from diarrhoea caused by *Clostridium difficile* (pictured, left) an infection often acquired after antibiotic treatment during hospital stays. The solution is usually even more antibiotics, but for a quarter of patients, the infection comes back. In a recent trial, when people were also given a drug that neutralises *C. difficile* toxins, it nearly halved the recurrence rate.

The trouble is, this kind of therapy doesn’t necessarily reduce risk of death from this infection down the line. Richard Proctor, an emeritus professor of microbiology at the University of Wisconsin in Madison, is nevertheless confident that next generation anti-toxin drugs will cover more strains of bacteria and be more effective. “The concept is correct,” Proctor says.

There is reason to hope: a lab-grown antibody to toxins produced by the common bacterium *Staphylococcus aureus* – known as MRSA in its antibiotic-resistant forms – can prevent death and disease in infected mice. It is now being tested to prevent pneumonia caused by *S. aureus* in people on ventilators.

Another approach is to play with the relationship between dangerous bugs and our immune systems. This is tricky though. We have evolved together with bacteria in a game

99 per cent
The proportion of bacteria in or on our bodies that do us no harm

Source: US National Institutes of Health

Nobel pursuit: Emil von Behring's (centre right) 140-year-old approach to defeating bacteria is being revisited



GETTY IMAGES

could prevent many types of bacteria from producing a whole menu of toxins. And studies in mice show that the strategy works. The trouble is, if the ploy were too effective, it could backfire; bugs that are resistant to these quorum-sensing scramblers could be more likely to survive and cause harm. Such drugs "could inadvertently select new strains of superbugs" that pump out high levels of toxins continually, says Proctor.

It is still years away from human trials, but there may be a less risky way to achieve the same thing. It turns out that some of the harmless bacteria that live on us also get a say in whether bad bugs go on the attack. One theory suggests that their presence deters harmful bacteria from invading because they don't want to share their plunder with strangers. *Corynebacterium*, a common skin inhabitant, releases compounds that suppress *S. aureus* infections in mice. Not only do they throttle production of *S. aureus* toxins, they turn up the expression of genes associated with a non-infectious lifestyle. They don't just disarm *S. aureus*, they convert it to a pacifist.

The golden age of antibiotics is over. We will never again develop safe, cheap, effective new ones as fast as bugs develop resistance to them. But old habits will be hard to break. Antibiotics have saved millions of lives. Even in our current age of resistance, most first-line treatments work most of the time. That means these new strategies have to clear a very high bar before doctors take them seriously. "We will almost have to get to the post-antibiotic era before that happens," says Proctor.

None of these strategies is a silver bullet. But they may provide alternatives, help make existing antibiotics more effective, and crucially, leave us less susceptible to disease. That is where their real value lies. "We have to reconsider antibiotic use in a wider context," says Piddock. "We don't want to disrupt the microbiome and inflict collateral damage."

If we don't reassess our use of antibiotics, we may have traded freedom from bacterial plagues for death by a host of other ailments. Obesity, fatty liver disease, diabetes, arthritis, inflammatory bowel disease, multiple sclerosis, asthma, anxiety and depression have all been linked to use and overuse of antibiotics. Without the ability to fight off infections, modern life would be impossible, but we also need to preserve the microbial communities so crucial to our health and well-being. It's time we learned to get along. ■

of cat and mouse that is millions of years old. The bacteria hide; our immune cells evolve to seek out and destroy them; bacteria evolve new ways of hiding. *S. aureus*, for instance, can cloak itself in human proteins, rendering it invisible to an immune system trained to ignore the body's own cells.

There is research into stripping away such disguises, but the more promising strategy is perhaps surprising: hide the bacteria on purpose. The most devastating consequences of infection – particularly septic shock, which kills more people in US hospitals than cancer – are not caused by the infection itself, but an overstimulated immune system on a rampage.

See no evil

One component of the cell walls of many harmful bacteria is a molecule called endotoxin. Its presence sets off an alarm triggering our immune systems to react. But despite its menacing name, endotoxin itself does no damage to our cells. Indeed, mice without the necessary gene to detect it are less likely to die from infection (though they are more likely to get infections in the first place). In studies, multi-drug resistant *Acinetobacter* kills all infected mice by driving them into septic shock. But when infected mice are given the experimental drug LpxC-1, which blocks the production of endotoxin, the death rate plummets. Because bacteria signal their presence in many other ways that prompt a less severe response than endotoxin, mouse immune systems eventually fight off the infections, but without setting off the alarms that send the animals into shock. Human trials may begin in the next few years.

Another strategy for thwarting harmful bacteria rather than wiping them out is to break up their social networks. For many kinds of bacteria the decision to switch from peaceful grazers to aggressive predators is a communal

one. The process is set in motion by so-called quorum sensing genes, which only kick into action when there are enough relatives around. If the signals from these genes can be scrambled, the bacteria won't attack.

This approach is appealing because it works on a more global scale, says Vanessa Sperandio, a microbiologist at the University of Texas Southwestern Medical Center. In principle, a single quorum-sensing inhibitor

EDIT BAD BUGS' DNA?

One strategy to disarm harmful bugs without wiping them out would be to disable the genes that make them attack. With the great strides taken in gene editing recently, why aren't more people trying it?

The trouble is, bacteria often carry many such virulence genes, and in a variety of combinations. "Targeting a single gene or factor can be a trap," says Brad Spellberg, an infectious disease specialist at the University of Southern California. Unless the gene is a linchpin for all factors bacteria can use to drive infection, "knocking it out is ineffective or even harmful".

The basic problem is the incredible diversity of the microbial world. Two strains of the common gut bacterium *E. coli* may share only 40 per cent of their genes. In other words, these bugs may be no more closely related than a dog is to a dogwood tree. All humans, by contrast, are more than 99.5 per cent genetically identical. Targeting a specific gene in bacteria is unlikely to take out more than a subset of the offending bugs, and they will quickly be replaced by mutants and variants missed by precision gene editing technologies.

Drew Smith is a molecular biologist and writer in Boulder, Colorado

How you see it, how you don't

When psychiatrist Hermann Rorschach used inkblots to open a window into his patients' minds 100 years ago, he also opened a can of worms, finds **Damion Searls**

NUREMBERG, 1945. Hitler, Himmler and Goebbels were dead, but two dozen other leading Nazis were awaiting trial for crimes against humanity. The prize catch was the creator of the Gestapo and the death camps, Hitler's number two: Hermann Göring.

While they waited, prison psychologist Gustave Gilbert administered psychological tests, keen to solve the mystery of the "Nazi mind". Most of the prisoners responded like show-off schoolboys, eager to beat their peers. They did well on IQ tests, but to assess their personality there was another technique to try, and the prison psychiatrist, Douglas Kelley, had written a book on it. He and Gilbert gave 19 Nuremberg prisoners the Rorschach test.

Hermann Rorschach, a psychiatrist working alone in a remote Swiss asylum, had invented the inkblot method in 1917 and published it in 1921. Rorschach was a follower of Freud, though never doctrinaire or dogmatic: he once joked to a colleague, "In Vienna, they're going to be explaining the rotation of the Earth psychoanalytically before long." He had also studied with Carl Jung in Zurich, where Jung had developed the first empirical test of the unconscious mind: word association.

Rorschach was a lifelong artist. In school he was known for his drawing skill and, aptly, his nickname was "Klex", the German word for inkblot. He was visual, whereas Freud was a word person. Psychoanalysis was built around the talking cure, slips of the tongue, what we say and don't say, but Rorschach thought how we see was more revealing than what we see.

After extensive revisions, Rorschach decided on 10 inkblots to make up the test. The same 10 are still used today, 100 years on. They are not random smears: they have structure, visual qualities beyond mere ambiguity. For instance, they are challenging

to integrate into a whole, so that while some of us can pull together a big picture, others get hung up on details. And do you see movement and life, or only cold, inanimate forms? There's one blot that almost everyone says looks like a bat or moth; do you say likewise?

Rorschach gave scores based on the frequency of what he termed "whole", "detail" and "movement" responses, among others. You could calculate ratios with those scores, and track patterns. The test results were derived from these measures. Rorschach originally called his inkblots a perception experiment, not a test; it simply explored how people process visual information. Only later did he realise that different kinds of people tend to see the blots differently.

Nazi personality

In the decades after his early death in 1922, aged 37, of appendicitis, Rorschach's test languished in Switzerland and Germany. But practitioners in the US helped it surge to prominence. That's why in 1945, Kelley and Gilbert, both Americans, saw a golden opportunity to try it on prominent Nazis.

Ultimately, though, the Rorschach test wasn't considered a success at Nuremberg because it didn't identify a "Nazi personality". Although it found some common elements, such as a certain lack of introspection, the Nazis showed essentially the same range of variation, from the psychotic to the very well adjusted, as any other group. This result was unacceptable to both psychologists and the general public – surely only monsters could do what the Nazis had done – and so the findings were disregarded for decades.

Meanwhile, in the mid-century heyday of Freudian psychoanalysis, the Rorschach test

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became the leading "X-ray of the unconscious". It was used in the most ham-fisted ways imaginable, and was expected not just to reveal mental illness or personality, but to practically read minds. Too many death-related responses to an inkblot dubbed the suicide card and you became a candidate for electroshock therapy.

Had he lived, Rorschach would have been appalled that an inkblot test could result in such drastic treatment. Shortly before his

"Used in the most ham-fisted ways, the test was expected to practically read minds"





Hermann Rorschach
(above) and card 2
of his 10 inkblots.
What do you see?

death, he wrote to a colleague eager to use the test to evaluate academic potential: "When I imagine some young person, who has maybe dreamed of going to university from an early age, being prevented from doing so as a result of failing at the experiment, I naturally feel a bit like I can't breathe."

Rorschach anticipated many objections to his test, in particular the potential conflict between its numerical results and a doctor's subjective insight into their patient. This "dilemma... comes up unfortunately quite often in the test," he noted. But Rorschach took the side of scientific objectivity: "All my work has shown that crude systematisation

is better than arbitrary interpretation."

Yet many psychiatrists preferred their own interpretations, and so the Freudian incarnation of the Rorschach test captured the world's imagination, spreading into film noir, advertising and popular culture. This version eventually, justifiably, met with widespread criticism. In the late 60s, it began to fall out of favour, along with Freud. In the UK and elsewhere, it has never recovered. But in the US, the test was reinvented in the 1970s with a renewed emphasis on numerical results.

From the beginning, the test was meant to be a science, not an art. A priority for Rorschach was that it could be scored

objectively. Although he initially logged responses as "+" or "-" for being good or poor descriptions of the card, he collected a large data set as quickly as he could and shifted to scoring answers as Popular or Uncommon, independent of his own subjective judgement.

The mountains of data collected and analysed since the test was invented allowed statistical norms

to be established. After psychologist John Exner devised a "Comprehensive System" for scoring in 1974, the test gave a more complex readout than ever before, with all sorts of measurable numerical thresholds.

These in turn could be mapped to diagnoses in the US psychiatrist's handbook, the *Diagnostic and Statistical Manual of Mental Disorders*, or other accepted assessments.

Whether such mapping is reliable has been controversial for decades, and is the subject of a great deal of research. Is the Rorschach test, even in its modern incarnation, just an excuse for a psychiatrist to draw whatever conclusions they want? According to a giant meta-analysis published in 2013 in *Psychological Bulletin*, the answer is no. In the light of that study, even some of the test's most vocal critics agreed that its ability to detect and differentiate between psychotic thought disorders now had scientific support. And those of Exner's scores that were found not to meet scientific standards of validity and reliability were removed from the system, leaving the rest on a firm footing.

The inkblots have been used in so many ways in the 100 years since Rorschach sent them out into the world that they can seem as hard to pin down as human nature itself. And, as with any tool, there is scope for misuse. Gilbert failed to heed what the inkblots told him in Nuremberg, and continued to believe that there was a "Nazi personality": in 1963, he published an article with the lurid title "The mentality of SS murderous robots". Yet Kelley, the more expert Rorschacher, had found nothing particularly out of the ordinary – simply the banality of evil.

No test can get around the complexity of how different people see the world, and that complexity will always generate controversies. One can only wonder what Rorschach himself would have made of it all. ■

Damion Searls is a writer and translator based in New York City. His new book is *The Inkblots: Hermann Rorschach, his iconic test, and the power of seeing* (Simon and Schuster)

Talking with hands

Did our free-roaming minds help turn gesture into language? **Alun Anderson** explores

The Truth About Language: What it is and where it came from by Michael Corballis, University of Chicago Press

THE TRUTH ABOUT LANGUAGE
WHAT IT IS AND WHERE IT CAME FROM
MICHAEL C. CORBALLIS

HUMAN language has long appeared miraculous. It has enabled us to accumulate knowledge, build cultures and conquer the

planet, making us a creature seemingly apart from the rest of the animal world.

During the 19th century, Alfred Russel Wallace doubted whether natural selection could explain such a unique power. In our century, Noam Chomsky, the Massachusetts Institute of Technology academic who has dominated linguistics for 60 years, has supported a hypothesis that language and thought arose suddenly within the past 100,000 years.

In *The Truth About Language*, Michael Corballis rejects all such “miraculist” explanations. He lays out a plausible route by which spoken language might have evolved, not from the calls of our primate ancestors, but through stages in which a language of gesture and mime dominated.

Corballis, now an emeritus professor at the University of Auckland, New Zealand, has spent a lifetime studying language and his book is a delight; it is confident, wise and witty.

The idea of rooting language in gesture is not new. Its key exponents are two more Michaels: Michael Tomasello, a co-director of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, and Michael Arbib,

ERIK LESSING/MAGNUM PHOTOS



a computer science professor at the University of Southern California in Los Angeles.

They have a good reason to consider that human speech didn't evolve directly from primate vocalisations. Ape calls are spontaneous, involuntary expressions of emotion, made even when there is no one to hear. Hand movements are different. They are voluntary and can be finely controlled. It's easy to shape fingers to represent objects or wiggle them to mimic movement.

Each of the Michaels has their own story, with Corballis's new

“Our ‘mind wandering’ may be built on an ancient ability to map movements and plan journeys”

account unique in stressing “mind wandering”, the subject of one of his earlier books, and storytelling as important parts of the long journey to language.

When we have nothing much to do, our minds travel through past experiences, future plans and imaginary possibilities. The process of mind wandering, or daydreaming, is more remarkable than it seems. It shows our capacity to recall particular episodes from the past and project them freely into possible situations in the future, even though we are not using words, but thinking in images.

Corballis quotes approvingly the White Queen in Lewis Carroll's *Through the Looking-Glass*: “It's a poor sort of memory that only

Tricky question: just how could mime morph into speech?

works backward.” We have the good sort that allows us to travel forwards, too. Without that, we would live in an “eternal now” and language couldn't have evolved.

Where did mind wandering come from? Corballis explores the evidence that other animals share some of this power of thought. Birds that cache food may remember where they hid it and also its “use by” date so they won't go to find it after it has gone off. Chimps and bonobos that have been shown King Kong-style movies demonstrate by where they look on screen that they anticipate what will happen next when they watch the films again.

Crucially, recordings of the rat hippocampus – the part of the brain that lays down memories – show how the brain constructs maps of movement in space and time. Our mind wandering may be built on an ancient ability to map movements and plan journeys.

Acting it out

Telling stories allows us to share those wanderings with others. Corballis quotes another researcher's fictional account of our early ancestors returning from a hunt with a kill and acting out the day's events, then miming plans for tomorrow. It is easy to picture and to see how the power of such stories could drive future cooperative activity.

Corballis agrees with Aristotle that fiction is more important than history because it deals with possibility. If the gestures of mime become standardised and abstract – which happens naturally in modern sign languages – communication would grow ever more fluent. This is a move towards language.

All this is just a part of the vista Corballis wants us to see. There is much more, including the ability of languages to refer to things that are not present, theory of mind and the emergence of grammar to make language more efficient. The trickiest section, however, is at the end when we reach the final step, as sound goes from an accompaniment of mime to a replacement, turning into speech.

At this point, I have doubts and must admit, as Corballis does on his final page, that he too might be writing a just-so story, despite the breadth of his evidence. Still, I much prefer a speculative account of how language might have evolved to an invocation of miracles. And, right or wrong, Corballis will make you see your own mind differently. ■

Alun Anderson is a consultant for *New Scientist*

Calling for help

A film telling the stories of desperately sick Chinese workers shows the shocking price of modern electronics, finds **Victoria Turk**

Complicit by Heather White and Lynn Zhang, Human Rights Watch Film Festival, London

YI YETING's bones hurt. It feels, he says, like ants are eating him from the inside out. Yi has leukaemia, caused by exposure to the carcinogen benzene, while working in a factory. He has already been to hospital 28 times for chemotherapy when we see him there, putting on a brave face as his wife and son visit.

Yi's story is one of many in *Complicit*, a documentary by Heather White and Lynn Zhang that premiered recently at the Human Rights Watch Film Festival in London. The film gives a voice to workers exposed to toxic chemicals making smartphones and other electronics in Shenzhen and Guangzhou.

Xiao Ya is another victim. One of hundreds of millions of China's migrant workers, she left her rural home as a teenager to seek a better life in Guangzhou and

Poisoned lives: work in the big city turns sour for many migrants

began to work on a smartphone production line, spending 15 hours a day in a poorly ventilated space polishing phone screens. She was poisoned by n-hexane, a solvent used as a cleaning agent that can cause nerve damage and paralysis. None of the workers knew about the dangers until they got sick.

The film-makers found sick workers just by walking into

"Shang Jiaojiao was poisoned by n-hexane. She left home to avoid being a burden. Now she is one"

hospitals near the factories. Others were directed to them by Yi, who campaigns against the use of benzene and n-hexane and helps workers get compensation.

This is not easy since sick workers must have an official diagnosis of occupational disease. One worker says when he sought a diagnosis, company officials accompanied him to the health authorities, carrying a bag of money. One crucial scene shows a woman revealing a rare piece of

paperwork: a document from the health authorities that states she has an occupational disease caused by exposure to benzene.

Sickness and struggle take their toll. For many young workers seeking a better life in the city, leaving is not an option. Like Xiao Ya, Shang Jiaojiao was poisoned by n-hexane. Even when she was in hospital unable to walk, she wouldn't tell her mother. She left home, she sobs, to avoid being a burden. Now she is one.

Those who fight back face brutality. Protesters are arrested, activists' offices raided, Yi's group has had to move several times.

"The most vulnerable are... targets of the crackdown the government is waging," says White.

There has been some positive action. Samsung announced an \$85 million fund for workers with occupational illnesses including leukaemia and lymphoma. And in 2014 Apple banned benzene and n-hexane in final assembly manufacturing processes.

But *Complicit* shows this is not enough. When you have global subcontracting and outsourcing, says White, it is easy for brands to look the other way and they have no legal liability for workforces. But Western consumers can use their voice, she says, to bolster campaigners' efforts and force big brands to take responsibility.

At the end of the film, Xiao Ya is out of hospital and has gone home. Yi has left his job for health reasons, after still more chemo. His dedication acts as a call to arms. The film-makers remind us of an Apple advertising slogan: "The people who are crazy enough to think... they can change the world, are the ones who do." ■



FROM COMPPLICIT

Who is Dominique Lambert?

How official tools represent us can distort our very identity. A tantalising exhibition dissects the troubling connections, finds **Laura Spinney**

Identité, FraenkelLAB, San Francisco, to 13 May

WHAT is the essence of you? What is it about you that makes you, well, you? These are no mere academic questions for armchair philosophers, but practical ones with real consequences.

Take a police artist sketching a suspect from an eyewitness description, or a profiler writing up the behavioural idiosyncrasies of a particular “perp”. These representations become tools in criminal investigations that often lead to arrests. If they fail to capture the essence of the person being sought, the wrong person may be arrested.

French artist Stéphanie Solinas is fascinated by the elusive nature of identity, and her exhibition at the FraenkelLAB in San Francisco is called *Identité*, in a nod to her nationality. In one project, *Sans Titre* (*M. Bertillon*), for example, she takes an 1893 mugshot of Alphonse Bertillon, the French police officer who, years before fingerprinting became popular, invented a way of identifying criminals based on photography and anatomical measurements.

Solinas ran the mugshot through facial analysis software to produce a 3D paper mask, cut it into pieces and invited people to assemble them to reconstruct Bertillon’s face.

In another project, *Traits*, she photographed young men face-on and in profile, the way police forces worldwide record suspects. She drew on the resulting images with a permanent marker, to highlight the facial characteristics by which a person is commonly identified – transforming the



Identity crisis: 12 attempts to define Dominique Lambert

images into near caricatures in the process. Both *Sans Titre* and *Traits* show how we distort identity simply by trying to define it, but the project that does this to best effect is *Dominique Lambert*.

In France, Dominique is the most popular first name shared by men and women, and the 27th most popular first name overall, while Lambert is the 27th most common surname. When Solinas launched the project, the French phone book contained 191 Dominique Lamberts. She wrote to all 191, inviting them to take part in an artistic experiment that meant completing a personality test and a questionnaire. This involved completing a list of statements such as, “If I were a

colour, I would be...”. Of the 65 people who responded, 20 complied with her other request to send a passport photo. This became her sample group.

Solinas set up the Advisory Committee for the Description of Dominique Lambert, with a

If representations of a suspect fail to capture their essence, the wrong person may be arrested

psychologist, a statistician, a police inspector, a lawyer and a corporate identity consultant. The five had to collaborate on a written physical description of each of the 20 Dominique Lamberts, based on their questionnaire answers.

One reads, “He is a 45-year-old man, stocky, with the beginnings

of a receding hairline and a high forehead. He wears round glasses high on the bridge of his nose, and a well-trimmed moustache.”

Using these texts, graphic artist Benoît Bonnemaison-Fitte produced sketches, which police investigator Dominique Ledée transformed using Electronic Facial Identification Technique (E-FIT) software. Armed with the E-FITS, Solinas used a large-format camera to photograph Parisians who closely resembled them.

The final step of the project is a series of books, one for each Dominique Lambert, that document the process from start to finish. Each book is completed by the original passport photo of one of the Dominique Lamberts, hidden in a sealed envelope. You can’t see the photo at the show – you have to buy the books.

Even then, Solinas doesn’t reveal which face completes which series. She just says that some of her portraits do not resemble the original person at all, others come very close and still others resemble a different Dominique Lambert more than the one they should represent.

There is a serious point to this tantalising effort. Each step is inevitably accompanied by both loss and gain of information, making many interpretations possible. Solinas reminds us that official bodies use these tools to represent us. But rather than criticise, she says that *Dominique Lambert* questions “the power of the representation over identity itself”. The result is utterly captivating and very powerful. ■

Laura Spinney is a writer based in Paris, France



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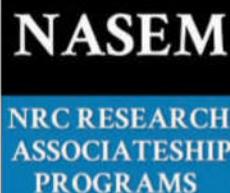


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Flies' visual filters may explain zebra stripes

*From Adrian Bowyer,
Foxham, Wiltshire, UK*

Reviewing Tim Caro's book *Zebra stripes*, Matthew Cobb says that "for reasons that are still unclear, flies dislike landing on striped surfaces" (18 March, p 42). He notes the conjecture that flies cannot see stripes of some widths.

Could the reason instead be the Reichardt-Hassenstein filters that all sighted animals have in our vision neurology? These detect visual flow. You can feel them working if you walk fast down the middle of a corridor (which will feel comfortable) and then do the same close to one wall. Your filters detect the difference between the fast visual flow of the close wall and the slow flow of the far one, making you instinctively want to equalise them to minimise the danger of collision.

The filters give a strong visual flow signal for movement at right angles to stripes, and a weak one for parallel movement. This gives conflicting information about how fast a fly is approaching a striped surface, which would make landing difficult. Hence, maybe, the evolution of zebras' stripes.

Another reason for the brain's border control

*From Chris Good,
Maidenhead, Berkshire, UK*
James Mitchell Crow discusses the blood-brain barrier (18 March, p 34). But he doesn't mention an important reason for limiting the entry of inflammatory cells and cytokines to the brain.

The brain is the only organ (unless you count bone marrow) encased in a rigid container. It has just one significant exit, the foramen magnum at the base of the skull.

Expansion of the brain, such as that associated with haemorrhage, inflammation or injury, can only occur here, which compresses the hindbrain. This process is called coning and is rapidly fatal unless treated. Organisms with brains not protected from the usual processes of inflammation are

less likely to survive, compared with those with an efficient blood-brain barrier. I fear it may be dangerous and counter-productive to interfere with this barrier therapeutically.

How safe are tobacco pouch products?

*From Harry Lake,
Bussum, Netherlands*

I am amazed that you didn't mention the risks of tobacco products such as snus (18 March, p 6). I seem to remember reading over the years about them causing cancers. Has something changed?

*From Lars-Erik Rutqvist,
Scientific Adviser, Swedish Match,
Stockholm, Sweden*
You report smoking rates for men in their 30s in Sweden plunging to 5 per cent. As you say, this is likely linked to 18 per cent of Swedish

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 **@POTUS needs to read this before declaring war on the environment. Shame it's more than 140 characters"**

Glenda Charles commends our report on coral bleaching to the President of the United States (1 April, p 7)

men using snus as a smoking substitute. But is snus safe?

The World Health Organization says that it is "considerably less hazardous" than smoking. The EU Scientific Committee on Emerging and Newly Identified Health Risks says the relative health advantages are "undeniable". In the longer online version of the article you quote a Cancer Research UK official singling out pancreatic cancer as a concern. Swedish men have the lowest rate of pancreatic cancer in the EU. Swedish Match is happy to provide public health bodies with independent scientific evidence.

Could smoking reduction have other causes?

From Tamsin Nicholson,
Glasgow, UK

You say that plain packets help Australian smokers quit (4 March,

p 6). But couldn't the decrease in Australian smokers after the advent of plain packaging be caused by other facets of an anti-smoking campaign?

It may be a "record decline", but is it dramatically different from the decrease in smoking since the anti-smoking campaign began?

The editor writes:

■ Several readers asked similar questions. The introduction of plain packaging coincided with an abrupt steepening in the trend line for declining smoking rates.

The carbon emissions from building islands

From Daniel Hackett,
London, UK

Does anyone else see an irony in the Maldives building up islands or constructing new ones as sea levels rise (25 March, p 12)? The

energy used will release more carbon dioxide, as will the planes bringing in tourists, with their own enormous footprints.

This is a microcosm of the spiral of hedonistic lifestyle we have got ourselves into ever since we started on the industrial bandwagon.

It's time for a big – global – cost-benefit analysis of what we are expecting to take from the environment and what we put out. It may already be too late, but we must continue to try.

Are emotions a palette built from primaries?

From Giuseppe Sollazzo,
London, UK

Lisa Feldman Barrett argues that the way our brain interprets any single emotion is culture-dependent and we "rewire" our brain to conceptualise different

emotions (11 March, p 40). Whenever the article mentions one of these "new" emotions, they are always explained as a combination of others.

For example, the Japanese *arigata-meiwaku* is the negative feeling when someone does you a favour that you didn't want.

I wonder whether there is in fact a set of "primary" emotions which, like primary tastes, forms a basis on which cultural concepts of emotions build.

Lisa Feldman Barrett writes:

■ One version of the classical view does propose that a small set of emotions are "basic" and universal. But research shows that people in different cultures have different emotions that feel to them like "primaries". For example, in situations where a Westerner might feel sad, Tahitians feel an emotion called ➤



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pe'ape'a which is more similar to "ill" or "fatigued".

We define dimensions because they are useful

From Steven Day, Mayfield East, New South Wales, Australia

Stuart Clark asks whether there are really just three dimensions (4 March, p 31).

Weren't the three dimensions created by us as a convenient mathematical way to understand and measure spaces and to plan and construct things?

Shouldn't the question be "Can we better understand, measure, model and make things by using a mathematical method that has more dimensions than the traditional three?"

Life in a universe with an infinite speed of light

From Ron Partridge, Sittingbourne, Kent, UK

Stuart Clark suggests that, if the speed of light were infinite, "cause would sit on top of effect and everything would happen at once" (4 March, p 29). But would all

physical movement, nuclear reactions and biological evolution become instant?

Wouldn't a major effect be to provide the universe with an absolute time, uniform for all frames of reference everywhere?

Albert Einstein's argument against simultaneity would fail, since we could then ascertain whether any two events anywhere were simultaneous by simple observation.

Time would just rumble on, a constant framework for the other main forces of nature.

From Roy Harrison, Verwood, Dorset, UK

Clark mentions the experiment by US physicists Albert Michelson and Edward Morley that tried to measure the then-expected difference in the speed of light in "the direction of Earth's rotation" and at right angles to it.

It's worth recalling that this difference was expected to be caused primarily by Earth's rotation around the sun (with a velocity of 110,000 kilometres per hour) not that on its axis (1700 kilometres per hour).

Modifications to what kind of gravity?

From Ian Payne, Coulsdon, Surrey, UK

Mark Anderson (7 January, p 9) tells us that Erik Verlinde's new theory of gravity builds on Mordehai Milgrom's modified Newtonian dynamics (MOND) theory. But does the new theory still support space-time in which gravity is linked to the curvature of space? Does it have time dilation and does it explain the precession of Mercury? In other words, is it rather a Modified Einsteinian Dynamics?

All medical data must be kept secure

From Sam Edge,

Ringwood, Hampshire, UK

In your report on the roll-out of two apps that help people monitor their health at home by UK National Health Service trusts, I didn't see any mention of data security (18 February, p 11).

Have any of these apps been independently security audited? Apart from the dangers of

personal data theft, subverting them to mislead healthcare professionals could cause real harm to patients by misdiagnosis.

These apps are being used for diagnosis, so they should be formally approved under the EU medical device directives.

Another reason not to give up bread for Lent

From Richard Weeks, Felixstowe, Suffolk, UK

The information in *New Scientist* comes to my rescue again. I had been thinking of decreasing my carbon dioxide emissions in Lent by switching to unleavened bread and eliminating the generation of yeasty gases. However, since "the equivalent of half a kilogram of carbon dioxide goes into the atmosphere for every loaf" (4 March, p 14), it seems my sacrifice would only be symbolic.

End of an era

From Brian Cordon,

Wirksworth, Derbyshire, UK

F. White suggests we should leave the naming of the new geological period to whoever inhabits it (Letters 18 March). I have thought for many years that we humans are presently living in the Endocene period.

For the record

■ **Thar she blew.** The early 1900s was when blue whale numbers crashed because of factory-ship whaling (18 March, p 44).

■ **The tectonic plates of Europe and North America are separating** (UK and Australian editions, 18 March, p 51).

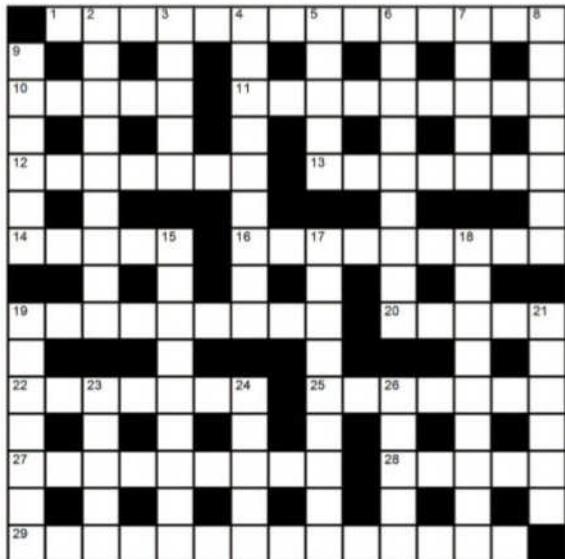
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CROSSWORD

Compiled by Richard Smyth



Crossword No5

ACROSS

- 1 The manipulation of materials on the scale of atoms or small groups of atoms (14)
10 African hooved mammal of the family Giraffidae (5)
11 Scientist who studies the measurement and representation of the Earth (9)
12 A visualisation of the movement of groundwater through aquifers (4,3)
13 Rod-shaped bacteria (7)
14 The injection of fluid into the lower bowel for medical purposes (5)
16 The part of the human brain that
- covers the insular cortex (9)
19 Compound with the chemical formula CH₂ (9)
20 To find and resolve defects (in software, for example) (5)
22 A 10-legged creature (7)
25 In meteorology, a rapidly rotating column of air (7)
27 The toughest form of natural diamond (9)
28 Solution of sodium chloride in water (5)
29 Part of the digestive tract that includes the caecum, colon and rectum (5,9)

DOWN

- 2 An instant of realisation, revelation or creative impulse (3,6)
3 Constellation in which the stars Rigel and Betelgeuse are found (5)
4 9° (6,3)
5 Informal term for a thermonuclear weapon (1-4)
6 Fatty substance in olive oil (5,4)
7 Oxford college whose alumni include two science Nobel laureates (5)
8 Chemical element, atomic number 39 (7)
9 "A mathematician is a device for turning ___ into theorems" - Alfréd Rényi (6)
15 In geometry, a line whose distance from a given curve
- approaches zero as they get closer to infinity (9)
17 An anode or cathode, perhaps (9)
18 The apparent oscillating movement of an orbiting body such as the moon (9)
19 British ___ Journal, scientific periodical founded in 1840 (7)
21 Hollow mineral masses found in some sedimentary and volcanic rocks (6)
23 Sampling tool for retrieving sediments, pollen or ice, for example (5)
24 Outlet for removing water from a system or blood from a wound (5)
26 Term for an automaton popularised by Karel Čapek (5)

Answers to Crossword No4

ACROSS: 6 GLYCINE, 7 LEECH, 9 MEME, 10 VACUUM PUMP, 11 ANGSTROM, 13 ONLINE, 15 IDEA, 17-L-DOPA, 18 AIDS, 19 LINEAR, 20 EXPOSURE, 23 PLANCKS LAW, 26 CUBE, 27 RANGE, 28 MELANIN.
DOWN: 1 CYBERSPACE, 2 SILVER, 3 NERC, 4 GLAUCOMA, 5 NEAP, 6 GLENN, 8 HOMINID, 12 MOORE, 14 LEAP SECOND, 16 DAIMLER, 17 LORIKEET, 21 POWELL, 22 RUBIN, 24 NINE, 25 LAMP.

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PAUL MCDEVITT

THE UK has rolled out a new, 12-sided pound coin (given the pound has been hit hard by Brexit, we assume the original design had 14 sides). Still, John Crofts relays that his local church is doing its bit to tidy up any resulting scrap: "Arnold Methodist Church is pleased to announce a Free Collection Service for all of your old redundant pound coins," a circular reads. "For the next few months, during the Sunday morning service, a receptacle will be passed round to enable you to deposit all your old pound coins, which will be disposed of in an environmentally friendly way."

Feedback is moved to add that pound coins can also be disposed of at newsagents, anyone depositing more than four at a time with the cashier is entitled to a free copy of *New Scientist*.

FOLLOWING the recent attack in central London, politicians are once again lining up to demand that mathematics, like terrorism, be outlawed. UK Home Secretary Amber Rudd told the BBC's Andrew Marr that end-to-end encryption was "completely unacceptable", calling on internet

giants to make everyone's communications insecure.

Readers will remember that the previous home secretary, Theresa May, became fed up with waiting for drugs to be proven harmful before they were banned, and banned the sale of all things that could possibly affect citizens' minds, known and unknown, unless otherwise exempted.

We can only presume that Rudd will soon outlaw anyone having secrets without government pre-approval, and ban anti-surveillance measures such as gummed envelopes, curtains and whispering.

SPARE a thought for the discerning audiophile, faced by ever more innovative ways to separate them from their cash. Feedback readers will no doubt recall the peerless sound quality offered by eye-wateringly expensive vacuum-sealed, gold-plated audio cables that are immune to radio interference, corrosion and the advent of robust digital signals.

The wallets of those attending last month's Headroom trade show in London could do with similar

UK baker Warburtons is to open a new R&D centre in Bolton. "This will be daunting work," writes Tom Patton, "as they'll be trying to invent the best thing since sliced bread."

protections against interference, after Metropolis Studios announced the world's most expensive headphones would be on show.

A press release boasted that delegates would be able to try out a pair of Sennheiser HE 1 headphones, or walk away with them for a cool £55,000. For this much money, musical aesthetes might prefer having their favourite band play live in their own sitting room instead.

PREVIOUSLY Feedback discussed the concept of the Erdős-Bacon-Sabbath number, a way to measure the connectedness of those in the fields of science, film and music (18 February).

Richard Chapman says this technique "may come up with some unexpected results when expanded to all figures of note", in all walks of life. Feedback doesn't like the idea of having to choose a paragon for each field – the sportiest, the cleverest, the fairest – students of Greek mythology will tell you wars have been fought over such accolades.

In any event, the results may not be interesting: we suspect the UK is already organised according to degrees of separation from figures of note, with the hypothetical zero point floating somewhere over Eton.

FIGHTING the good fight, Australia's consumer advocacy group CHOICE has been putting the Geoclense Home Harmonizer through its paces.

Bernie Broom directs us to their review of what is succinctly described as a "block of green plastic with a plug", which promises to somehow shield the home against all kinds of invisible electrosmog, from stray Wi-Fi beams to electromagnetism leaching from those cheap, non-vacuum-sealed, gold-plated audio cables.

Unfortunately, the Geoclense failed to perform in any of the tests, proving incapable of altering electromagnetic fields, the Earth's magnetism, light levels or negative ions. However, it did pass one test with flying colours: when plugged into the mains, the block of inert resin consumed no

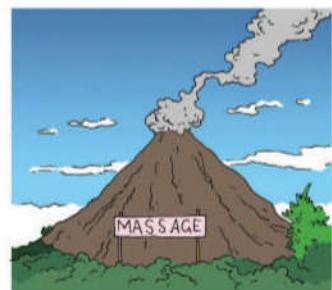
electricity whatsoever – prompting reviewer Ashley Iredale to wonder why it needs plugging in at all.

"Our testing shows Geoclense has all the effectiveness of a tin foil hat, but lacks the hat's potential for use in food preparation," writes Iredale. "If you are thinking of blowing \$150, why not buy a roll of aluminium foil instead? The money you save could buy you a subscription to CHOICE – a resource that's been proven to work."

ON TO the mountains of Chile, from whose fertile soils sprout radio telescopes in ever greater diameters, leaving us bereft of superlatives (25 February).

M. Mycle reports that "the olive packers solved the problem long ago. On the shelves of my local grocery I find: small, medium, large, colossal, mammoth."

However, our investigations find that even the olive industry appears to have run short on terms: the commercial terms beyond mammoth are given by some as "super mammoth", and, er, "super super mammoth".



KARMA Beauty in Colchester, UK, has a hot offer for customers, reveals Philip Woodcock. He sends Feedback a flyer announcing their "new molten lava stone massage", which is "designed to melt away deep tension". It certainly will, Philip thinks, as well as taking any nearby tissue. Effective, but hardly a recipe for repeat custom.

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.

Whither wasps?

I grow several varieties of soft fruit, so I am used to an annual battle with wasps. Last year (2015), I only saw a few small ones. This year (2016), I have not yet seen any at all. What causes yearly fluctuations in the wasp population?

■ “Wasp years” – those occasional years when wasps abound – occur in irregular cycles with no marked periodicity. In the UK between 1864 and 1931, wasps were abundant in 10 of those years and scarce in another 10, with peaks separated by between two and 16 years. The last major wasp year in the UK was 2013.

The key to wasp numbers is the successful establishment of nests in spring. Weather plays a crucial part. Unseasonal warm weather in late winter can bring queens out of hibernation prematurely and they then fail to find food and die. Clement spring weather is essential during the vulnerable period when the queen builds the nest on her own and also has to feed her daughters, until these worker wasps can take over the role of foraging for food and building materials.

Once the colony has roughly 20 adult workers, the queen has probably won the wasp lottery of life. Apart from human and badger interventions, such nests will generally thrive until new queens are reared in late summer and autumn.

One phenomenon seems to occur after a major wasp year.

If many queens are searching for a nest site in spring, there can be intense competition for suitable places and usurping another queen's nest becomes common. Nests with several dead queens in their entrance bear testimony to attempts at takeovers.

*Philip Spradbery
Yarralumla, ACT, Australia*

Philip Spradbery is author of *Wasps: An account of the biology and natural history of solitary and social wasps* (Sidgwick & Jackson, 1973).

Ant hill mob

While mowing the grass, I noticed that in several places ant nests were situated under clumps of daisies. Do the ants choose to nest under daisies, or do these flowers grow where they do because of the ants' activity?

(Continued)

■ In the 29 October 2016 issue, the Last Word quotes the lyrics of Lonnie Donegan's *My Old Man's a Dustman* as saying, “He's got such a job to pull them off that he calls them daisy roots.” After checking several lyric websites, I confirmed my suspicion that it is actually, “He's got such a job to pull 'em up that he calls them daisy roots.”

The picture painted is one of the singer's father looking silly because he hasn't pulled his boots up enough. The previous line is, “He looks a proper nana in his great big 'obnail boots....” So it is the look that matters, and it says

nothing about any problems getting the boots off.

*Andrew Baker
Epsom, Surrey, UK*

On the farm

It always seems that, in any wind farm, at least one of the cluster of turbines isn't turning. What is the reason for this? Is it undergoing repair or are there other, more interesting, factors at work?

(Continued)

■ Wind turbines need a minimum wind speed, called the cut-in speed, to generate electricity. Below this, they are usually switched off to minimise wear. The wind speed can vary across a large site, so that it is only above the cut-in speed in some places. The cut-in speed also varies with turbine size and design, so on a wind farm with a mix of different makes of turbine, the wind might be fast enough to operate some, but not all, of them.

Another issue is that wind slows down as it passes through a turbine, creating a “wind shadow” effect behind. Wind farms are usually laid out so no turbines are in the shadow of any others when the wind blows from its prevailing direction. But when it comes from other directions, it may drop below the cut-in speed at a downwind turbine. Therefore this turbine will be switched off while the others continue to run.

In some countries, wind farms aren't allowed to cast moving

shadows on nearby houses, which causes indoor light levels to fluctuate. This effect is called shadow flicker. Here, wind farms are laid out so no turbine casts a shadow on a house for a significant percentage of time. But when one does create a shadow, the turbine is turned off for a time.

Similarly, some countries limit the amount and type of noise a wind farm can produce, to avoid

“In some countries, wind farms are not allowed to cast moving shadows on nearby houses”

disturbing local residents. Noise production can vary with wind speed and direction, so when local limits would otherwise be exceeded, one or more turbines may have to be shut down.

*Colin Watters
Molesworth, Cambridgeshire, UK*

This week's question

GIVE US A CLUE

I do cryptic crosswords. On my first attempt, I usually finish about half the clues and get stuck. When I return to the crossword the following day, even if I haven't been consciously thinking about it, I usually get a few more clues very quickly. But after half an hour at most, I become stuck again. What's going on?

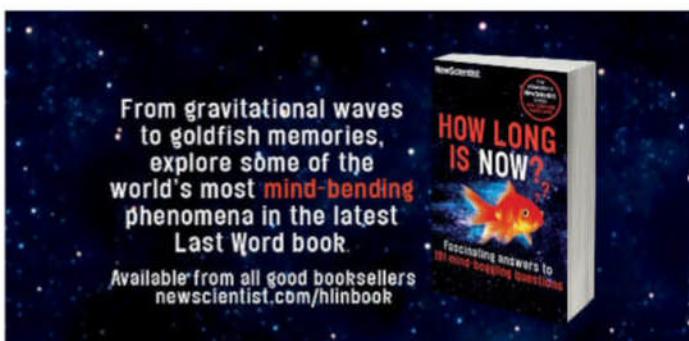
*Melanie Green
Hemel Hempstead,
Hertfordshire, UK*

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By Brigitte Lacombe



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