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This week's issue

On the cover

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And if not, what have we been looking at?

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News

Views

ADRIANE ESQUIVEL-MUELBERT

Features

The back pages

Expecting better

We shouldn't underestimate the lasting impact of unscientific health advice

OLDER fathers, extreme air pollution, antidepressants and untreated gestational diabetes. These are all factors whose possible links to autism, however tentative, have been flagged in pregnancy handbooks. Such manuals are packed with warnings about everything from diet and exercise to what position a mother-to-be sleeps in, and how these everyday decisions might affect your pregnancy or unborn child. In the midst of so much advice, it can be tempting to adopt a "better safe than sorry" approach.

Now, expectant parents are faced with fresh advice, this time from none other than US president Donald Trump, who warned against taking the painkiller paracetamol (also known as acetaminophen) during pregnancy. While it is true that some studies have found correlations between paracetamol use in pregnancy and risk of autism, there is no convincing evidence that the drug itself is responsible. A recent study of millions of children comparing siblings who were and weren't exposed to it

> **"It is clear that bad health advice can lead to preventable disease and deaths decades later"**

suggests that any observed link may be due to other factors (see page 11).

Taking the cautious approach can also backfire. Over a quarter of a century since it was published, Andrew Wakefield's study that appeared to implicate the measles, mumps and rubella (MMR) vaccine in autism has been refuted, retracted and thoroughly debunked. But that hasn't been enough to kill off the suggestion of a link between this vaccine and autism, despite there being no evidence. There have been 40 measles outbreaks in the US this year, so it is clear bad health advice can lead to preventable disease and deaths decades later.

Unfortunately, years of research into how best to combat misinformation in the internet age has yielded surprisingly few solutions. For all the advice such research has generated, from the merits of "pre-bunking" myths to the need to debunk regularly, once a dangerous piece of health advice shoots to prominence, it is certain to cause harm – especially when future parents feel encouraged to avoid all risk. ▮

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News

WHIPSNADE ZOO

Ornithology

Hatchling offers hope to threatened species

This 8-week-old Socorro dove chick (right) is the first of its kind to hatch at Whipsnade Zoo, in Bedfordshire, UK. The rare bird species, native to Socorro Island, Mexico, was declared to be extinct in the wild in 1972. There are now around 200 Socorro doves in institutions around the world, as part of a breeding programme, with the aim of one day returning the birds to their natural habitat.

Human evolution

Do we need to rewrite our origin story?

A reconstructed skull gives surprising clues to the enigmatic "Ancestor X" – which could completely change our understanding of humanity's evolution, finds **Michael Marshall**

THE origins of our species may lie much further in the past than we thought, and the same may be true of our extinct Neanderthal and Denisovan cousins. According to a new analysis of fossil remains, the shared ancestor of the three groups lived over a million years ago – more than twice as old as previously believed.

"It does mean that we are missing a huge bit of the early story of these lineages, if we're correct about these ancient branching points," says Chris Stringer at the Natural History Museum in London.

The results could help settle the search for Ancestor X: the population that gave rise to modern humans, Neanderthals and Denisovans. They could also mean that the Denisovans were our closest relatives – even closer than the Neanderthals, though not everyone is convinced on this point.

Stringer and his colleagues, including Xijun Ni at the Institute of Vertebrate Paleontology and Paleoanthropology in Beijing, China, re-examined a fossil hominin from Yunxian in central China.

Two partial skulls were uncovered in a terrace above the Han River in 1989 and 1990, and described in 1992. Both skulls had been squashed during their time in the ground. However, the second, Yunxian 2, was less badly damaged.

Stringer, Ni and their colleagues used the latest methods to reconstruct Yunxian 2, including a technique that uses CT scans to digitally separate individual fragments of bone from the surrounding rock and sediment. "It's long and low, with a big brow ridge," says Stringer. It also has "a bit of a beaky nose", and while the teeth are large, the third molars are small.

GARY TODD (CC0)

This squashed skull, from Yunxian, China, could belong to an early Denisovan

The Yunxian 2 cranium is 940,000 to 1.1 million years old. Hominins of that age are often thought to belong to *Homo erectus*, which emerged in Africa around 2 million years ago before spreading to southern Asia, including Indonesia, where it survived until perhaps 108,000 years ago. However, Stringer says this skull doesn't fit the profile. Many of its features are typical of later groups, like the Neanderthals.

To figure out what Yunxian 2 is, the researchers compared it with 56 other hominin fossils. Based on the shapes of the remains, they drew a family tree to denote which were most closely related. From this, they identified three major groups, which include most of the fossils from the past million years.

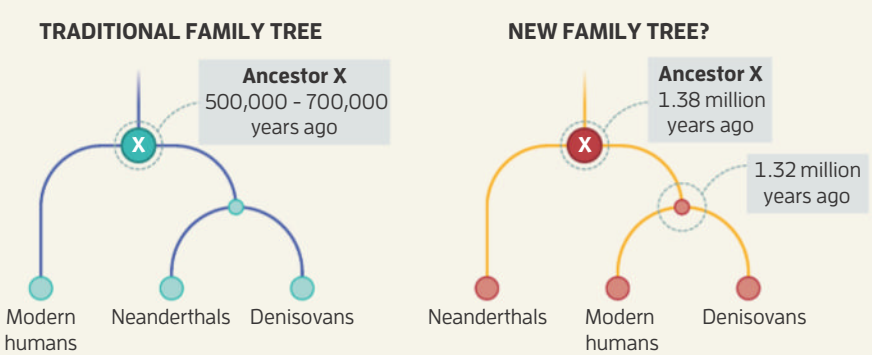
The first was modern humans (*Homo sapiens*). The second was Neanderthals (*Homo neanderthalensis*), who lived in Europe and Asia during the past few hundred thousand years, vanishing around 40,000 years ago. The third was Denisovans, from eastern Asia.

Denisovans were originally discovered in 2010 using DNA from a bone fragment, and it has taken 15 years to identify larger fossils. Stringer was involved in the description of a skull from Harbin in China, dubbed *Homo longi*, which was identified as a Denisovan using molecular evidence in June. Yunxian 2 appears to be an early Denisovan, as do several other Asian fossils (*Science*, doi.org/p7cq).

It is helpful to tie all these fossils into the Denisovan lineage, says

Family ties

The traditional view (left) is that modern humans split from Neanderthals and Denisovans. However, in this reconstruction (right), Neanderthals broke away first, with modern humans and Denisovans separating 1.32 million years ago.



geneticist Aylwyn Scally at the University of Cambridge. "We can get a better idea about where the Denisovans were, how they lived, and what kind of species they were."

The finding that Yunxian 2 is Denisovan rewrites the story of recent human evolution in two ways. First, it appears to change how the three populations emerged. The conventional story, as revealed by genetics, is that an ancestral population – Ancestor X – split into two: one half became modern humans, and the other half became Neanderthals and Denisovans, who split from each other a bit later. However, in this new reconstruction (see "family ties", p6), it was the Neanderthals who broke away first, 1.38 million

"These results could mean that Denisovans were our closest relatives – even closer than Neanderthals"

years ago, with modern humans and the Denisovans separating 1.32 million years ago.

If that is correct, Denisovans were our closest relatives, instead of being equally close to us as Neanderthals were, as the genetics indicates. However, Scally is dubious. That is partly because the history of these populations seems to be complex. "It isn't actually well described by a simple tree," which is the model the researchers used, but rather by a "tangled network", he says. Furthermore, Scally says genetics is a better guide to such relationships than morphology – especially when you have only partial skeletons – and the genetics tells a clear story.

The second change is bigger: all three groups are much older than we thought. Genetics has suggested that the ancestors of modern humans split from the progenitors of Neanderthals and Denisovans around 500,000-700,000 years ago. But Yunxian 2 indicates that the Denisovan group was already separate over a million years ago.

A matter of time

It may be that there isn't a single date for any of these splits, says Scally. They could have been protracted, with groups repeatedly separating and coming together. In that case, Stringer and his colleagues could be right that the divergence began over a million years ago, but it took hundreds of thousands of years to play out.

This longer timeline opens new questions. The oldest known fossils of our species are about 300,000 years old. So, where are all the older ancestors dating back to a million years ago? "Either we don't have them, or they're there and they haven't been recognised," says Stringer.

We also don't know what Ancestor X was like, or where it lived. "Ten years ago, I would have said probably Africa is the ancestry of most of these groups," says Stringer. "It looks more likely that the ancestor was outside of Africa, perhaps in Western Asia," he says. "That would imply that the ancient *sapiens* ancestor must have gone into Africa and then evolved in Africa for most of the rest of that 1 million years."

Stringer says there are few known fossils from western Asia dating to a million years ago, and India has yielded only one hominin fossil. "There's many, many places where we really don't have the evidence," he says.

One source of data may be the Yunxian site. In 2022, a third skull was found there, but it hasn't yet been described. ▮

Solar system

Rare metal hints at Earth's clash with supernova

Alex Wilkins

AN EXPLODING star may have sent cosmic shrapnel flying to hit Earth 10 million years ago, and astronomers have narrowed down the most likely culprits behind this interstellar incident.

Earlier this year, Dominik Koll at the Helmholtz-Zentrum Dresden-Rossendorf in Germany and his colleagues discovered a spike of radioactive beryllium buried in metallic rocks 5 kilometres beneath the Pacific Ocean, which they dated to just over 10 million years old. This form of beryllium is only produced when cosmic rays smash into Earth's atmosphere, so Koll and his team theorised that it could be from a supernova that exploded long ago.

However, there were other possible explanations, such as the sun's magnetic shielding of Earth being weaker at that time, or beryllium being deposited there by stronger ocean currents from Earth's poles, where cosmic rays are more powerful and produce more beryllium.

Now, Efrem Maconi at the University of Vienna in Austria and his colleagues have found two possible supernova sources using data from the Gaia space telescope, which has mapped out billions of stars' current positions and movements in the Milky Way.

By tracing back the orbits of around 2700 clusters of stars in relation to the sun over the past 20 million years, as well as calculating how likely each of these clusters were to produce a supernova over that time, Maconi and his team found that there is a 70 per cent chance a star exploded within around 300 light years of Earth at the time of the beryllium spike, 10 million years ago, and a 30 per cent chance there was no such supernova (*Astronomy & Astrophysics*, doi.org/p7dp).

They pinpoint two possible sources for the explosion, if it did happen. The most likely source within around 200 light years is a relatively young group called ASCC 20, but beyond that, a cluster of stars called OCSN 61 was probably responsible.

Earth may have once been the site of a cosmic collision

TITOONZ/ISTOCKPHOTO/GETTY IMAGES

A further hint is that 10 million years ago, our solar system was in a much busier part of the galaxy, in a vast wave of gas, dust and stars called the Radcliffe Wave.

"If [Maconi] would have said we can completely rule it out and there are no candidates [supernovae], then I would have said, OK, good, that's a solid statement and we can take this explanation off the list, but in this case, it certainly is intriguing," says Koll. ▮

New Scientist Live

Space oddities

Harry Cliff explores cosmic anomalies on 18 October at New Scientist Live **newscientist.com/nslmag**

Ageing

DNA repair dial may affect ageing

When a key protein regulator quietens DNA repair mechanisms, our cells accumulate more mutations, which may cause us to age faster, discovers **Michael Le Page**

A CLUMP of proteins seems to be in charge of the level of DNA repair that takes place in our bodies, determining how fast mutations accumulate in our cells over a lifetime – and might thus affect our rate of ageing and our lifespan.

"It's a very reliable predictor of your lifespan, within humans and within other animals," says Trey Ideker at the University of California, San Diego. His team hopes to find drugs that boost lifespan by improving the levels of DNA repair.

"Cells have repair crews that go out and fix broken DNA, but the level of DNA repair varies"

Other researchers say the evidence this protein complex – a group of two or more proteins that physically interact to perform a specific biological function – affects mutation rates is convincing, but more work is needed to confirm the link with ageing and longevity.

As to why we age, one explanation is that it is a result of the accumulation of mutations in the DNA of cells. As these build up, more and more cellular machinery becomes defective, leading to cascading problems.

Cells do have the equivalent of repair crews that go out and fix broken DNA, but the level of DNA repair varies, which is probably mostly due to genetics.

Now, Ideker's team has assembled several lines of evidence that suggest a protein complex called DREAM is a master regulator that determines this level of repair. Each complex – which can exist in numerous, identical copies in every cell – is formed by the joining of several different proteins, with the acronym DREAM referring to the names of the components.

DREAM was thought to control cell division, but it turns out it also switches off hundreds of genes involved in DNA repair, including the *BRCA2* gene that raises the risk of breast cancer when mutated.

RICHARDBAKER/ALAMY

Ideker's team first developed a measure of DREAM activity by looking at more than 300 genes it controls, with lower gene activity meaning higher DREAM activity. "What this study is trying to show beyond a shadow of a doubt is that high DREAM [activity] is bad for ageing and longevity, and low DREAM is good for longevity," he says.

Using data from studies by other groups of more than 100,000 mouse cells from various tissues, the researchers showed that cells with higher DREAM activity have more mutations. Next, they analysed data from 92 mammal species, finding a strong link between low DREAM activity and longer maximum lifespan.

In another part of their study, the researchers analysed data from studies of the cells of 90 people, including 80 with Alzheimer's disease, finding a link between DREAM activity and the risk of the condition (bioRxiv, doi.org/p7cr).

They also genetically engineered mice to lack DREAM. This was very difficult – not only does each component protein have its own role, but DREAM as a whole has an important function in cell division in early development, meaning mice that lack it don't survive.

To get around this, the team knocked out DREAM when the mice were 8 weeks old, using a genetic system triggered by a drug. These knockout mice had fewer mutations than unmodified mice after dying of old age – for

The genetic secrets of the world's oldest person

DNA repair may be one thing that affects lifespan (see main story) – and centenarians can offer clues to others. Until she died on 19 August 2024, aged 117 years and 168 days, María Branyas Morera, of Spain, was officially the world's oldest person.

When she was 116, a team of researchers collected blood, saliva and stool samples to analyse her genetics, microbiome and lifestyle.

Morera, who showed no sign of dementia, had many gene variants that keep blood lipid levels low, protecting the heart and cognition.

Blood test results also revealed her lipid metabolism was among the most efficient ever reported.

Team member Manel Esteller at the Josep Carreras Leukaemia Research Institute in Barcelona, Spain, says Morera didn't drink alcohol or smoke, and adhered to a Mediterranean diet. She also ate three servings of plain, sugar-free yogurt every day.

The tests suggest Morera retained an efficient immune system into old age and a gut microbiome characteristic of a younger individual (*Cell Reports Medicine*, doi.org/g942ps).

One of the most "startling" findings was the high levels of Actinobacteriota bacteria in her gut, including the well-known probiotic *Bifidobacterium*. This typically declines with age, but is elevated in centenarians and supercentenarians, and is thought to have many anti-ageing benefits.

The team suspects her yogurt consumption helped replenish her *Bifidobacterium* levels.

Finally, the team tried to gauge the difference between Morera's biological and chronological age by creating an "epigenetic clock" based on her DNA methylation – the process in which various genes are switched on and off. "Her biological age was an average 23 years younger than her chronological age, one of the reasons that she was alive," says Esteller. James Woodford

Some people age more rapidly than others

instance, they had 20 per cent fewer deletions and insertions in their brain cell DNA. The knockout mice didn't live any longer, but Ideker says this is to do with the way they were modified. "It does not show any significant lengthening of longevity, but the experimental design was just wrong to look at that," he says. "We now need to do the experiment correctly, where we can associate that with extension of lifespan."

Despite this, Ideker thinks the evidence points to a clear picture. "What our results show is that DREAM is a key player in ageing, and certainly in the accumulation of lifetime mutation," he says.

"These are new and important findings," says João Pedro de Magalhães at the University of Birmingham in the UK. "Their mouse data shows causality between DREAM and mutation levels." But the researchers haven't demonstrated a causal link with ageing, he says. "To do so, they would have to show that mice with lower levels of mutations live longer, which nobody has done so far."

This is why the idea that the accumulation of mutations is a key factor in ageing remains to be established. Some, such as Ideker, point out that conditions like progeria, where people age prematurely, involve a lack of DNA repair. Others, including de Magalhães, point to a lack of evidence that the accumulation of mutations is a factor in normal ageing, apart from increasing the risk of cancer.

Even if the DREAM complex does play a causal role in ageing, its multiple functions will make it tricky to develop treatments. ▮

Environment

Atmospheric chaos raises temperatures in Antarctica

SINCE the start of September, temperatures in the atmosphere above Antarctica have soared by over 35°C (63°F), while wind speeds have halved and ozone depletion has suddenly stalled.

This kind of upheaval should happen only once every 20 years or so, says Martin Jucker at the University of New South Wales in Sydney, Australia. Instead, these events seem to be becoming more frequent, with short-lived disruption occurring last year, and more serious events in both 2019 and 2002.

Jucker says that to have four of these events in less than a quarter of a century indicates alarming changes are under way in the global climate system.

Antarctic atmospheric temperatures should normally be -55°C (-67°F), but since 5 September, they have risen to -20°C (-4°F). While this is still frigid, it means that wind speeds in the stratosphere – the polar vortex – have halved to a relatively calm 100 kilometres per hour.

Because this has happened fairly gradually, it doesn't yet constitute the formal definition of a sudden stratospheric warming event, says Jucker. To hit that threshold, the winds would need to cease altogether during a warming spike lasting days, not a few weeks. However, he says, the implications for the southern hemisphere in the coming months could be significant.

"The implications of this warming for the southern hemisphere could be significant"

Meteorologists in Australia, who had initially predicted a wetter-than-normal spring, are now warning of potential strong westerlies over the Australian continent, leading to warmer, drier conditions.

A couple of scenarios may unfold in the coming weeks, says Jucker. The first is that the polar vortex re-establishes itself and atmospheric temperatures return to the average trendline.

Alternatively, the anomaly could continue, with some suggestions that the polar vortex could slow further or cease altogether. As a result, northern latitudes of the southern hemisphere could be in for hotter, drier weather.

While the cause of the anomaly hasn't yet been scientifically established, Jucker thinks that the increase in sea surface temperatures due to climate change, by between 1°C (1.8°F) and 2°C (3.6°F) in the Pacific, is driving the current slowdown in the polar vortex.

"We have just generally had very weird weather for the last two years and that all coincides with this very big jump in ocean temperature," says Jucker.

Edward Doddridge at the University of Tasmania, Australia, says the list of extreme changes at the bottom of the world keeps getting longer. In the past few years, there has been sea ice loss, heatwaves, widespread breeding failures at emperor penguin colonies and a dramatic slowing in the Antarctic overturning circulation, an important movement of ocean water.

"Antarctica keeps surprising us. While each of these changes is concerning in its own right, my biggest worry is that we are starting to see changes that not only reinforce themselves, but also cascade through different parts of the Antarctic environment, says Doddridge.

Sea ice loss in the summer enhances the breakup of ice shelves and causes ocean warming. These warmer ocean waters melt the remaining ice shelves faster, and this fresh water slows down the Antarctic overturning circulation," he says. ▮ JW

Temperatures above Antarctica are far warmer than usual

MICHAEL S. NOLAN/ALAMY

New Scientist Live

Climate injustice

Friederike Otto explores the link between climate and inequality on 19 October newscientist.com/nslmag

Climate change

Have we cracked one of the world's toughest climate problems?

Madeleine Cuff

COMMERCIAL-SCALE carbon-capture systems for cement plants are now being deployed, raising hopes that one of the trickiest industrial sectors to decarbonise could finally be on the path towards net-zero emissions.

The world's first carbon-capture plant on a cement works has been up and running in Norway since June, with the first "zero-carbon cement" products due to be delivered to the UK and elsewhere in Europe this month, according to the plant's owner, Heidelberg Materials in Germany.

Meanwhile, the construction of a carbon-capture installation at the Padeswood cement plant in north Wales will begin within weeks, following a subsidy deal agreed between the UK government and Heidelberg Materials.

"It's a good step forward," says Paul Fennell at Imperial College London, speaking of the projects in Norway and the UK.

Cement is responsible for around 8 per cent of global carbon emissions, according to the think tank Chatham House. Much of this carbon dioxide is produced directly by the chemical process of making clinker, which is the main ingredient for Portland cement, the most commonly used type of the building material. "If you're going to have ordinary Portland cement, you've got this issue that you're producing large amounts of CO_2 just from the intrinsic chemistry," says Fennell.

Capturing the carbon dioxide produced from the process is widely seen as the only scalable way to decarbonise this aspect of cement production. But it is expensive, costing €50-€200 to capture, transport and permanently store a tonne of carbon from cement production in Europe, according to analysis from Dutch bank ING.

The development of Heidelberg's Brevik plant in Norway has been subsidised by its government. The carbon-capture infrastructure captures 50 per cent of the cement plant's total emissions. It works by using an ammonia-derived solvent, called amine, to extract CO_2 from the exhaust gases at the cement plant. The captured CO_2 is then released from the solvent, liquified and pumped beneath the Norwegian seabed.

Padeswood cement plant in north Wales will have carbon-capture technology

PADESWOOD CCS

The Padeswood plant will use the same amine-based technology, but will remove roughly 95 per cent of the plant's emissions once the carbon-capture-and-storage infrastructure is up and running in 2029, says Heidelberg Materials' UK CEO Simon Willis. That is equivalent to around 800,000 tonnes of CO_2 per year. The Padeswood plant will capture more carbon than the Brevik one because the latter could not get the extra energy power supply required to run it at 95 per cent.

Financial backing from governments is essential, says Leon Black at the University of Leeds in the UK. "There is no way that carbon capture and storage could be commercially viable without state support," he says.

But there are hopes that costs could fall in the future, as new technologies help to make it more energy efficient. ▮

Palaeontology

Mummified cheetahs may have been trapped in caves

THE mummified remains of seven cheetahs, some dating back thousands of years, have been reported in caves in Saudi Arabia – the first naturally mummified big cats ever found by scientists.

Cheetahs (*Acinonyx jubatus*) were eradicated from the Arabian peninsula decades ago, but Ahmed Boug at the National Center for Wildlife in Riyadh, Saudi Arabia, and his colleagues have now reported details of seven mummified cheetahs, along with the skeletal remains of 54 others, which they found during surveys in the Lauga cave network in northern Saudi Arabia in 2022 and 2023 (*Research Square*, doi.org/p7cp).

The mummies – defined by the preservation of their soft tissues due to a halting of the decay process – date from between about 4000 and 100 years ago.

"The findings are truly remarkable," says Anne Schmidt-Küntzel at the Cheetah Conservation Fund in Namibia.

"The relatively constant temperature and low humidity of the cave environments would have been conducive to the mummification process," according to the researchers' paper.

It is unclear why the cats were in the caves, as cheetahs aren't known to use them as dens or to store carcasses. None of the five caves they were found in contained a water supply when surveyed.

Many of the remains were found in just one cave, accessible by a sinkhole. It is possible the cheetahs fell in and couldn't get out, says Schmidt-Küntzel. The remains of other animals have also been found in the caves, including those of a wolf, a striped hyena and a red fox.

"The constant temperature and low humidity would have been conducive to mummification"

When the team evaluated 20 of the complete cheetah skulls, they found that six were those of adults and the rest were from animals that were 6 to 24 months old. The presence of so many young cheetahs hints that adult females may have been using the caves to shelter with them, says Schmidt-Küntzel. ▮

Chris Simms

What we know, and don't, about the link between painkillers and autism

The US government's decision to caution against taking a common painkiller during pregnancy lacks support from scientific evidence, finds **Grace Wade**

THE US government announced last week it will update labelling on the common painkiller paracetamol, also called acetaminophen, warning that use during pregnancy may increase the risk of autism and ADHD in children. Yet no evidence shows a causal relationship between the medication and autism spectrum disorder (ASD). Most studies, including a recent analysis of more than 28,000 autistic people, suggest genetics are a primary contributor to the condition.

"These initiatives will likely sow confusion around how and when to treat pain or fever during pregnancy"

The announcement comes after the country's highest ranking public health official, Robert F. Kennedy Jr, pledged in April to identify the causes of autism by the end of September. US President Donald Trump touted the initiative as taking "historic steps to confront the crisis of autism" during a press conference on 22 September.

This framing reveals either a misunderstanding or a misrepresentation of what we know about autism. There is no crisis – rates of autism began to increase rapidly in the 1980s as diagnostic criteria for the condition expanded. Over the past few decades, a higher level of awareness and recognition of the symptoms of autism has also contributed to an increase in autism diagnoses.

As for the cause of the condition, there is little evidence suggesting paracetamol is to blame. It is true that multiple studies have found an association between paracetamol use in pregnancy and increased risk of autism in children. A recent analysis of 46 studies found 27 of them identified a significant association between using paracetamol in pregnancy and children having a higher risk of neurodevelopmental conditions, such as autism. But just because there is a relationship doesn't mean paracetamol causes autism – other factors could be at play.

For example, a 2024 study of nearly 2.5 million children found a slightly higher risk of autism in those exposed to paracetamol during pregnancy, but after comparing children exposed to the painkiller with their unexposed siblings, the effect disappeared. "It was the family history that mattered and not the use of paracetamol," said Dimitrios Siassakos at University College London in a press statement.

Most research shows genetics is a primary contributor to the condition. For instance, a 2019 study of more than 2 million people across five countries estimated that about 80 per cent of autism risk comes from inherited genetic factors. More recently, Varun Warrier at the University of Cambridge and his colleagues analysed data from more than 28,000 autistic individuals and found that genetic variants explain about 11 per cent of the variation in age at diagnosis.

Mixed messages

Despite this, during the press conference, Trump said pregnant women shouldn't take paracetamol for pain or fever during pregnancy unless they "can't tough it out", and they "should talk to their doctors for more information".

However, the US Food and Drug Administration (FDA) acknowledged in a press release that a causal relationship between paracetamol and autism hasn't been established, and paracetamol remains the safest widely available painkiller for use during pregnancy, in a notice to physicians.

CHUNG/POLITICO/BLOOMBERG VIA GETTY IMAGES

Robert F. Kennedy Jr. and Donald Trump announced the policy at a press conference

During the press conference, the FDA also announced it will approve the drug leucovorin for cerebral folate deficiency, a condition that some research indicates upwards of 40 per cent of autistic people also have. It impairs uptake of vitamin B_9 in the brain, resulting in symptoms similar to autism, including communication and sensory processing issues.

Leucovorin, a form of vitamin B_9, is already available for treating deficiencies of this vitamin as well as side effects from certain cancer medications. Early evidence suggests it might improve some severe autism symptoms, too. For instance, a 2016 study treated 23 autistic children with language impairments using two doses of leucovorin daily, while a separate group of 25 children received a placebo. After 12 weeks, 65 per cent of children receiving leucovorin saw a clinically meaningful improvement in verbal communication compared with 24 per cent of those in the control group.

But so far, all of the studies on leucovorin and autism have been small, and most indicate only modest improvements. A larger clinical trial is underway, the results of which are expected next year.

Following the announcement, the US Department of Health & Human Services clarified in a statement that "while promising, it is important to note that leucovorin is not a cure for ASD and may only lead to improvements in speech-related deficits for a subset of children with ASD".

Kennedy and Trump portrayed these policy changes as remarkable progress. But the science suggests neither avoiding paracetamol in pregnancy nor taking leucovorin will significantly affect autism. Instead, the most likely outcome of these initiatives is they will sow confusion around how and when to safely treat pain or fever during pregnancy. ▮

Health

Hope for Huntington's treatment

A breakthrough therapy for Huntington's disease could also be applied to other brain conditions, finds **Grace Wade**

AN EXPERIMENTAL gene therapy has become the first treatment to successfully slow the progression of Huntington's disease. While the findings are still preliminary, the approach could be a major breakthrough and may lead to new therapies for other neurodegenerative conditions, like Parkinson's.

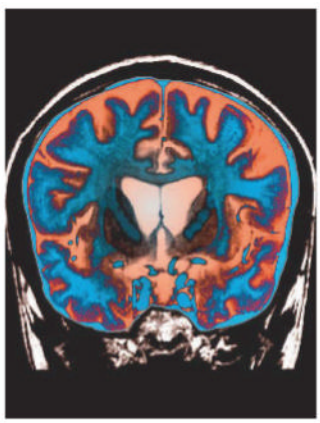
How does the therapy work?
The treatment, called AMT-130, targets abnormal proteins in the brain that are responsible for the progression of Huntington's disease. People with the condition have a genetic mutation that causes the normally-benign huntingtin protein to accumulate in toxic clumps inside brain cells, ultimately killing them. Over time, this leads to memory loss, difficulty walking, slurred speech and other symptoms.

The experimental therapy, developed by the Dutch biotechnology company uniQure, stops the production of these mutant proteins by delivering genetic material

"This gene therapy has the potential to transform the treatment landscape for Huntington's disease"

to brain cells packaged inside a harmless virus. This material then directs cells to produce a small genetic molecule, called microRNA, which is designed to intercept and disable the instructions for producing the toxic protein.

How and where is it delivered?
The treatment targets two brain regions first affected by Huntington's: the caudate nucleus and the putamen. Both are located deep inside



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Huntington's disease is caused by toxic proteins forming inside brain cells

the brain, so doctors use real-time brain scans to guide a thin catheter into them. The entire procedure takes 12 to 18 hours. One injection seems to be enough to permanently lower levels of mutant huntingtin in the brain.

How effective is the gene therapy?
Preliminary results released by uniQure suggest it slows the progression of Huntington's disease by about 75 per cent.

The finding comes from a clinical trial led by Sarah Tabrizi at University College London and her colleagues, in which 17 people with Huntington's received a high dose of the treatment. Three years later, the researchers compared declines in cognition, movement and daily functioning with those of similar, untreated individuals. Declines that would normally be seen in one year of disease progression occurred in the treated patients over four years on average, Tabrizi told BBC News.

Those who received the treatment also saw lower levels of a protein indicative of brain damage in their cerebrospinal fluid. "These findings reinforce our conviction that AMT-130 has the potential to fundamentally transform the treatment landscape for Huntington's disease," said Walid Abid-Saab at uniQure in a statement.

Are there any side effects?
While uniQure hasn't published complete data on the therapy's side effects, it said so far the drug appears to be safe and well-tolerated. The most common side effects were headaches and confusion, which either resolved without treatment or with steroids to reduce inflammation.

When will it become available?
In a press release, uniQure said it expects to submit an application to the US Food and Drug Administration early next year, and, pending approval, the product could launch before 2027.

"However, it is still early days and a lot more testing is needed to see if there are side-effects of this new gene therapy, how long the benefits last and how well it works in the long term," said Zofia Miedzybrodzka at the University of Aberdeen in the UK in a statement.

Could this approach help treat other brain conditions?
If this gene therapy proves to be successful, it could lead to therapies for other neurodegenerative conditions, such as Parkinson's disease and dementia, said David Rubinsztein at the University of Cambridge in a statement. Researchers would just have to tweak the genetic material so it targets the toxic proteins that drive those conditions. ▮

Chemistry

Secret ingredient to making the ultimate plastics is revealed

Karmela Padavic-Callaghan

A SPRINKLING of nanoparticles could be the solution to a problem that has long plagued plastics manufacturers – namely, how do you make a material that is strong, tough and easy to work with?

Hu-Jun Qian at Jilin University in China and his colleagues call this the plastics trilemma: making a polymer stronger, or harder to deform, tends to make it more brittle, or less tough, while attempting to improve both of these properties at once normally makes the material more viscous and harder to work with.

To get around this, the researchers mixed nanoparticles made from polystyrene with several commonly used plastic materials. For example, they added the nanoparticles to PEMA, a polymer that is used to make hearing aids and artificial nails, and PVC, which is used in construction and packaging.

The team put the resulting materials through a series of tests to see, for example, how much they could elongate before breaking. In general, the new materials showed better-than-usual performance across different tests, sometimes dramatically – they found that PEMA was about 50 per cent stronger when fortified with nanoparticles (*Physical Review Letters*, doi.org/p7cs).

To better understand this effect, they also carried out computer simulations of the new materials. For the case of plastics under stress, these simulations showed that nanoparticles can move and redistribute within the material, thus allowing it to deform more slowly and smoothly. Their ability to move was similarly beneficial for plastics flowing more easily when melted.

Qian says the new approach is compatible with existing industrial processes and could be scaled up to large quantities. ▮

Quantum physics

Ultracold clocks could reveal how quantum physics alters time

WHAT does the passage of time look like for a truly quantum object? The world's best clocks may soon be able to answer this question, testing how time can stretch and shift in the quantum realm and allowing us to probe unexplored areas of physics.

The idea that the passage of time can change, or dilate, originates in Albert Einstein's special theory of relativity. Einstein showed that as an object approaches the speed of light, time appears to run slower for it than for a stationary observer. He extended this idea with his general theory of relativity, showing that a gravitational field has the same time-warping effect. Igor Pikovski at Stevens Institute of Technology in New Jersey and his colleagues wanted to understand whether something similar could happen to time in the microscopic quantum world, as measured by an ultracold clock made from ions.

"The fluctuations of a quantum object could dilate a clock's measurement of time"

"Any experiment that we have to date always senses something like classical time, time that doesn't have anything to do with quantum mechanics," says Pikovski. "We realised that there is a regime where, with ion clocks, this description simply fails."

Such clocks are made from thousands of ions that are cooled to temperatures close to absolute zero by being hit by lasers. At these extreme temperatures, the quantum states of the ions and the electrons within them can be very precisely controlled with electromagnetic forces. Accordingly, the ticks of ion clocks are set by these electrons repeatedly oscillating between two specific quantum states.

Because their operation is dictated by the laws of quantum mechanics, these clocks were the perfect setting for Pikovski and his colleagues to explore how relativistic and quantum effects may mix to affect the clocks' ticks. Pikovski says the researchers have now identified several instances where this ought to happen.

One example stems from the fact quantum physics abhors nothingness. Instead of being able to stand absolutely still and frozen, even at extremely low temperatures, quantum objects must fluctuate, randomly gaining or losing energy. The team's calculations showed these fluctuations could dilate a clock's measurement of time (arXiv, doi.org/p7pd). The effect would be tiny, but very likely to be observable with existing ion clock experiments.

The researchers also mathematically modelled what would happen if a clock's ions were "squeezed" to produce a "superposition" of several quantum states. They found the clock's ticking, as determined by the electrons in the ions, would become inextricably connected to the motion of the ion itself – the ions' and electrons' states would become quantum entangled. "Normally in experiments, you need to play tricks to engineer entanglement. The fascinating thing here is that it comes whether you want it or not," says team member Christian Sanner at Colorado State University.

We may soon understand how time can stretch and shift in the quantum realm

Pikovski says it makes intuitive sense that a quantum object in a superposition of states couldn't experience just one sense of time, but the effect has never been observed in an experiment. It should be possible in the near future, he says.

Turning the clock forwards

Team member Gabriel Sorci at Stevens Institute of Technology says the next step is to add another crucial ingredient – gravity. Ultracold clocks can already detect time dilation due to minuscule changes in the strength of Earth's gravitational pull, for instance when raised up even a few millimetres, but exactly how that effect would mix with the clock's inherent quantumness is an open question.

"I think that this is actually quite reasonable to do with the technology that we currently have," says David Hume at the US National Institute of Standards and Technology in Colorado. He says the biggest challenge would be preventing tiny disturbances from the clock's environment overpowering the effects hinted at by Pikovski's team. If successful, such experiments would allow researchers to probe physics phenomena they never could before, even though quantum theory and the theory of special relativity are two pillars that have long held up much of contemporary physics, he says.

"Experiments like this are exciting because they force these theories to confront one another in a domain where there is a chance we can learn something new," says Alexander Smith at Saint Anselm College in New Hampshire. KPC

FLASHMOVIE/GETTY IMAGES

New Scientist Live

Everyday quantum physics

Mithuna Yoganathan shows how the quantum world is all around us on 19 October newscientist.com/nslmag

Space

Our black hole is windy, after all

First predicted in the 1970s, we may now have proof of wind coming from Sagittarius A*

Alex Wilkins

WE HAVE found hot wind blasting out from our galaxy's supermassive black hole for the first time, which could help explain its mysterious inactivity.

Compared with many other supermassive black holes that lie at the centres of galaxies, our black hole, called Sagittarius A* or Sgr A*, is relatively quiet. It doesn't shoot out vast, powerful jets like black holes in many other galaxies do, which are so bright we can spot them even in the earliest moments of the universe. But all supermassive black holes, including Sgr A*, are thought to produce winds – wafts of hot gas blasted out from near the black hole's event horizon, where gas is swirling and violently heating up.

These winds, however, have never been conclusively detected in Sgr A*, despite being predicted since the 1970s. This is partly because it is so difficult to observe the region around our galaxy's black hole, a tightly packed melange of stars, dust and gas called the circumnuclear disc (CND).

Now, Mark Gorski and Elena Murchikova at Northwestern University in Illinois have measured the innermost region of the CND in far greater detail than before using the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile. They found large regions of cold gas they didn't expect to be there, as well as a clear cone of hot gas cutting through it, which appears to be the missing wind (arXiv, doi.org/p69g).

Finding so much cold gas around the black hole at this distance was unexpected, says Gorski. The conventional wisdom was there was no point looking for it, as it probably didn't exist, he says. "When I presented this image to [my colleague], I said, 'Well, we have to focus on this now, because it has been such a problem for over 50 years'."

Gorski and Murchikova took five years of observations of the innermost part of the CND from ALMA and produced a map of cold gas within a few light years of Sgr A* that was 100 times sharper than previous observations. They achieved this by simulating how the bright light from Sgr A* flickered, and then subtracting it from the dim light of the cold gas.

"Measuring this wind could help us understand why Sagittarius A* is relatively inactive"

From this, they could see a clear cone in which there was barely any cold gas. When they laid X-ray data – emissions produced by hot gas – overtop they found the two regions matched almost perfectly. They calculated the total energy needed to blow hot gas through this cone is equivalent to about 25,000 suns, meaning it can't have been produced from nearby stars, and there are no obvious supernovas that might have generated the hot gas either. This suggests the wind is coming from Sgr A* itself.

Measuring this wind could help explain why Sgr A* is relatively inactive and help us better understand black hole evolution.

If the results are confirmed, it could tell us more about the black hole itself, says Ziri Younsi at University College London, such as its direction of spin. ▮

For more on black holes, see p28

Environment

Climate change is making trees in the Amazon grow larger

THE average size of trees in the Amazon rainforest has been steadily increasing as carbon dioxide levels have risen, meaning these larger trees play a more important role in maintaining the forest as a carbon sink.

How forests will react to a changing climate is an open question. One hypothesis is that larger trees will decrease in abundance because they are more susceptible to climate-linked phenomena such as drought. Understanding this is crucial for future climate models because forests take up huge amounts of CO_2 from the atmosphere.

Adriane Esquivel-Muelbert at the University of Cambridge and her colleagues at the RAINFOR Amazon Forest Inventory Network have been measuring the diameter of trees in 188 plots with an average area of 12,000 square metres across the Amazon basin. The monitoring periods varied, but some were as long as 30 years. During that time, CO_2 concentrations in the atmosphere rose by nearly a fifth.

They found that, on average, trees have increased in diameter by about 3.3 per cent each decade (*Nature Plants*, doi.org/p69c).

Team member Rebecca Banbury Morgan at the University of Bristol, UK, says the structure of the Amazon rainforest is changing consistently across the whole basin. "We have more bigger trees and fewer smaller trees, so the average size has shifted up towards those bigger trees."

Normally the average diameter of trees in an area of undisturbed old-growth forest would stay roughly the same, she says, as saplings take the place of fallen big trees and grow. The researchers think the Amazon trees are responding to the increase in atmospheric CO_2 by growing more and accumulating more biomass.

PAULINE KINDLER

Measuring the diameter of a tree can tell us how much it has grown

This means the big trees are disproportionately important to the amount of carbon the forest can hold, and the consequences of losing them would be greater, says Esquivel-Muelbert.

"The important finding is that CO_2 has been acting as a fertiliser, increasing tree growth, and in many ways that is reassuring, because wood is a globally significant carbon sink," says Peter Etchells at Durham University, UK. "However, will this continue to be the case as the climate continues to change, potentially shifting the balance between growth, nutrients, temperature and CO_2?" ▮

Chris Simms

Quantum computing

Qubit breakthrough could lead to bigger quantum computers

Karmela Padavic-Callaghan

A DEVICE with more than 6000 quantum bits, or qubits, has smashed a previously-held record and is the first step towards building the largest quantum computer yet.

There is currentlyF no single, consensus design for building a quantum computer, but researchers believe that for these devices to be useful, they will have to comprise at least tens of thousands of qubits. The current record holder is a machine from Atom Computing, with 1180 qubits, but Hannah Manetsch at the California Institute of Technology and her colleagues have now built a device with 6100 qubits (*Nature*, doi.org/p66d).

Each of these is a neutral caesium atom cooled to temperatures close to absolute zero and controlled by laser beams, with all 6100 of them arranged in a neat grid. The researchers designed the qubits to have properties exceptionally suitable for use in computations, says Manetsch, although they haven't yet performed any.

For instance, they tuned the lasers' frequency and power to ensure that the naturally fragile qubits maintain their quantum states and that the whole grid remains stable for as long as possible, which will enable more accurate computations and longer runtimes for an eventual quantum computer. The team has also tested how well the lasers can move qubits between different parts of the array, which will be an important part of running computations, says team member Elie Bataille, also at the California Institute of Technology.

Mark Saffman at the University of Wisconsin-Madison says that the new experiment is encouraging as proof that neutral atom quantum computers can be made very large, but more experimental tests need to be done before the team's setup could be considered a fully fledged quantum computer. ▮

Neuroscience

Babies' brains 'tick' more slowly than adult ones

Carissa Wong

LEILA CUTLER/ALAMY

Infants are seeing many things for the first time

WHEN a baby tries to make sense of what they have seen, their brain activity seems to tick at a slower rhythm than it does in adults, which may help them learn new concepts.

Our brain processes sensory stimuli using networks of neurons. If a neuron receives a strong enough signal from another neuron, it transmits the signal to more neurons still, producing synchronised waves of electrical activity where many neurons switch between activated and silent states.

Such brainwaves occur at various frequencies. When a given brain region displays a range of frequencies simultaneously, a higher proportion of its neurons may synchronise with certain frequencies more than others. For instance, previous studies show that the adult visual cortex displays a wide range of frequencies when people see things, but proportionately more neurons seem to synchronise with waves at 10 hertz, or cycles per second.

To learn whether the same applies to infants, Moritz Köster at the University of Regensburg in Germany and his colleagues recruited 42 babies aged 8 months old, via their parents. The team recorded the infants' brain activity – using electrodes placed on their scalps – while they watched dozens of friendly cartoon monsters flash up on a screen for 2 seconds each, across about 15 minutes.

"The brain activity of infants suggests that they are in a constant learning mode"

The researchers made use of the fact that brainwaves tend to pulse in time with rapidly flickering images, providing a way to test how many neurons synchronise with various frequencies in visual parts of the infant brain. Specifically, they flickered each monster on and off at eight frequencies, ranging from 2 to 30 hertz.

By analysing the brain recordings, they found that the visual cortex produced waves of synchronised activity in time with the flickering cartoons. But the brainwaves were the most fired up at 4 hertz, which suggests more neurons synchronised with this flickering frequency than with others.

This 4-hertz signal was present in the background even when the brain adjusted to seeing flickering at other frequencies, such as 15 hertz (bioRxiv, doi.org/p692).

This rhythm falls within a band of frequencies known as theta, which has been linked to forming new concepts. "It suggests infants are in a constant learning mode," says Köster.

The researchers also found that 4-hertz brainwaves, but not those at other frequencies, in the visual cortex seemed to spread to neural circuits in other brain regions involved in concept formation.

Repeating the experiment in seven adults, the team confirmed prior findings that their visual brain circuits are most strongly activated by a 10-hertz frequency.

Adults have experienced many things, so the visual part of their brains seems to be tuned to tick at a higher frequency, which studies suggest may help them to block out unimportant information, says Köster.

Further studies are needed to establish whether exposure to images flickering at 4 hertz could enhance the ability of infants to learn new concepts, says Emily Jones at Birkbeck, University of London. ▮

New Scientist Live

How the brain invents your reality
Daniel Yon explores how our brains interpret the world around us on 18 October newscientist.com/nslmag

Solar system

Venus has lava tubes, and they're a bit weird

Alex Wilkins

JSC/NASA

A computer-simulated global map shows volcanic activity on Venus's surface

WE NOW know that massive underground tunnels, carved by lava, exist on Venus – and they are surprisingly wide and different from those on any other planet.

Lava tubes – tunnels carved out by molten rock – exist on Earth, the moon and Mars. Smaller planets with low gravity tend to form more cavernous tubes, in part because the rock walls are less likely to collapse with weaker gravity.

Scientists had seen hints of these lava tubes on Venus, from holes and pits that appear to have formed on its surface, but it was unclear whether these were caused by lava tubes beneath them or by other geological processes, such as from an active fault line.

Now, Barbara De Toffoli at the University of Padova in Italy and her colleagues have found direct evidence of lava tubes on Venus. They also appear to be surprisingly wide and of a comparable volume to those on the moon, despite Venus being more like Earth in terms of its mass and gravity.

"Earth lava tubes have smaller volumes, Mars tubes have slightly bigger volumes, and then the moon's tubes have even bigger volumes – and then there's Venus, completely disrupting this trend, displaying very, very big tube volumes," De Toffoli told the Europlanet Science Congress in Helsinki, Finland, in September. "This is already giving away the fact that there's likely something more on Venus playing a significant role."

Using radar and mapping data from past missions, De Toffoli and her team analysed how these pits lined up and were arranged near large volcanoes. They found four clear examples that didn't have any other geological explanation. The pits also lined up with the steepest part of the volcanoes' slopes, which is the direction the lava would have travelled, and the ratio of their depth and width was consistent with other known lava tubes.

The tubes' unexpected size suggests that the extreme Venusian environment might affect how molten rock moves under its surface, said De Toffoli, and isn't just dependent on gravity like lava tubes on other planets. ▮

Neuroscience

Mapping a brain doesn't reveal all its secrets

Karmela Padavic-Callaghan

IF WE can fully map the structure of our brains, will we be able to understand how they work? That is the goal of researchers attempting to build a wiring diagram, or connectome, of our neural pathways – but now it seems uncovering the secrets of the brain may not be so simple.

You can think of the connectome as a map of all the possible roads along which neural signals can travel. But now Sophie Dvali at Princeton University and her colleagues have discovered that some of these roads are underused.

The researchers looked at the connectome of the nematode worm *Caenorhabditis elegans*, and compared it with a record of the worm's neural signals, which they assembled by stimulating each neuron and tracking how the signal it emitted moved through the connectome. This is possible in the worm because it has only around 300 neurons in its entire nervous system.

By treating the two datasets as mathematical networks, the team could determine whether groups of neurons that are very densely interconnected in the connectome also tend to exchange a large number of signals. They found that this isn't always the case (*PRX Life*, doi.org/p658).

"Neurons are known to communicate in ways beyond the 'wires' that connect them"

Dvali says that there were some examples of overlap for high connection density and signal exchange, such as for groups of neurons responsible for how the worm eats, where the two networks matched really well, or neurons involved in how it moves backwards, an important manoeuvre for a worm escaping danger. In the latter case, the neurons were very connected in both networks though not in an identical way. But, more generally, there were enough discrepancies that the team says the connectome of an organism isn't enough to predict all of its behaviour.

Taking the scenic route

Team member Andrew Leifer, also at Princeton University, says that the difference may be because signals between neurons don't always take the shortest path, and there are also known cases where neurons can communicate in ways beyond the "wires" that connect them. "We're used to using the connectome for guiding our research, and often it's very helpful and informative, but in many cases there's so many connections that we wished we had more information," he says.

"Connectomics data is often criticised as, 'Oh, you get only structure. You don't get behaviour.' And this paper is really probing that question to what degree we can [connect the two]," says Albert-László Barabási at Northeastern University in Massachusetts.

Next, the researchers want to expand their study to account for how signals spread through the connectome when multiple neurons get stimulated simultaneously, and to look at more complex animals like a fruit fly larva, which has the largest whole-brain connectome described to date. "We are under a revolution right now of mapping out the brain," says Barabási. ▮

Particle physics

Elusive particle may be in reach

We may have already created entities similar to axions, the leading candidate for dark matter

HYPOTHETICAL particles called axions have been sought by physicists for decades, as they are the leading candidate for what makes up dark matter. But we may not need new experiments to find exotic particles similar to axions – evidence of them could be hiding in data from particle collider experiments we have already done.

The Large Hadron Collider (LHC) at the CERN particle physics lab near Geneva, Switzerland, reveals new particles by accelerating and crashing together others we already understand quite well, such as protons and ions, and then analysing the resulting debris.

Now, Gustavo Gil da Silveira at CERN and his colleagues have considered another possibility: if a proton or an ion emitted a new particle as a result of being accelerated on its way to getting smashed into bits, would we be able to tell? Their analysis suggests sometimes we could.

Axions were first theorised in the 1970s as part of the solution to why there is more matter than antimatter in the universe. The search for experimental signatures of axions has been unsuccessful, but it has raised the possibility that other axion-like particles could exist. Because these would have very low masses, they would be similar to particles of light, or photons, which are massless – and have been successfully smashed together at the LHC.

This happens when accelerated protons or ions get so energetic they start radiating photons as they approach each other, so their surrounding photons also collide. The researchers modelled this scenario, but with axion-like particles in place of photons. Their calculations showed accelerating protons would emit more axion-like particles than accelerating ions, and both would also be emitting photons at the same time. Consequently, the team identified collisions between protons and lead ions as a good place to look for clues of axions crashing into photons (*Physical Review Letters*, in press). That exact collision – between protons and lead ions – was carried out at the LHC in 2016, and the team suggests data from the experiment could hide hints of axion-like particles.

> **"Evidence of these exotic particles could be hiding in data from particle collider experiments"**

Lucian Harland-Lang at University College London says this is an interesting and new way to find constraints on which undiscovered particles could exist, but it could also be challenging to implement. "These sorts of collision events do not happen very often, and when that is the case we have to be very sure that there are no background processes that might mimic what we are looking for," he says.

It is also tricky to access old LHC data, says da Silveira. But future work at the LHC could be more promising. "We could tune the detectors in order to find this particular signal," he says. ▮ KPC

New Scientist Live

The search for dark matter

Chamkaur Ghag delves into the fascinating world of dark matter detection on 18 October newscientist.com/nslmag

For more on exotic particles, see p20

Palaeontology

Dino that chomped on crocodiles named as a new species

A DINOSAUR that may have been one of the fiercest of the Cretaceous period has been excavated in South America – with an extinct crocodile's leg in its jaws.

The remains of the dinosaur, named *Joaquinraptor casali* – a species of megaraptor that is new to science – were discovered in the headwaters of the Rio Chico river in Patagonia, Argentina, in 2019. It is thought that it lived just before the extinction of the non-avian dinosaurs, 66 million years ago.

Now, Lucio Ibiricu at the National Scientific and Technical Research Council in Chubut, Argentina, and his colleagues have studied the fossil in detail, and were surprised by what they found in the mouth of the near-complete skull.

ANDREW MCAFEE, CARNEGIE MUSEUM OF NATURAL HISTORY

MATT LAMANNA

An artist's reconstruction of the dinosaur in action (left) and its massive thumb claw (above)

"The humerus, or legbone, of an extinct crocodile relative was between the jaws of *Joaquinraptor* and directly in contact with the teeth," says Ibiricu. "This discovery is suggesting, though not proving, that the new megaraptor may have been eating the crocodyliform [the clade that modern crocodiles belong to] when it died."

The researchers are still studying the crocodile's humerus to determine how big it may have been, but preliminary work suggests it was large, says Ibiricu.

In addition to recovering most of the dinosaur's skull, the team also excavated its vertebrae, feet, two claws, and an arm, leg and hand (*Nature Communications*, doi.org/g94kmn). The thumb claw, which is the size of a human forearm, would have been able to tear open the soft tissue of its prey, he says.

Other megaraptoran fossils have been found in Asia, Australia and elsewhere in South America, but *J. casali* is the first to be found by scientists that lived so close to the end of the Cretaceous period and, also, one of the most complete.

The team determined the dinosaur would have been at least 19 years old when it died, based on the microstructure of its tibia. It also would have been about 7 metres long and weighed at least a tonne. ▮ **James Woodford**

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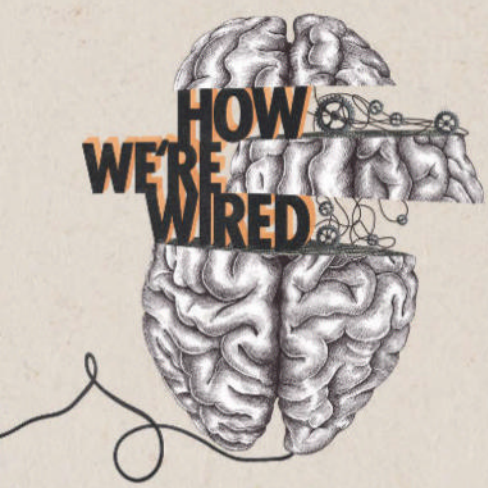

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A trip into alt-history

What might have happened if we had embraced psychedelic research, rather than banning it, wonders **Tim Hayward**

IN THE early 1950s, Albert Einstein, Carl Jung, Graham Greene and many other leading figures from science, philosophy, culture and politics were featured in plans for a gathering – dubbed "Outsight" – where they would take powerful psychedelics. Things took a different turn, but I am fascinated by what might have been.

I have been investigating psychedelics for *The Trip*, a new BBC Radio 4 series. I had previously written about the unsettling, vivid hallucinations I had while in a coma in hospital with covid-19. This was something I wasn't keen to repeat, but I wanted to understand why people were deliberately seeking out psychedelic experiences, visiting places where the laws are different or taking risks (legal and otherwise) at home to seek healing or fulfil other unmet needs.

ADRIÀ VOLTÀ

It was never a given that the international community would come to broadly prohibit psychedelics. The enquiring minds of scientists from Humphry Davy, who experimented with the effects of nitrous oxide in 1799, to Humphry Osmond, who coined the word psychedelic in the 1950s, saw that chemically-induced altered states required rigorous, thoughtful cross-disciplinary study.

Before the US-led war on drugs began in the 1970s, there was a range of promising research into the therapeutic potential of psychedelics. There had also been a long history of their use by Indigenous cultures in sacred and ritual contexts. But rather than science being allowed to follow its course, everything was driven underground. As a result, it feels to so many of us that these substances, derived from fungi and plants or synthesised in labs, are somehow other. It is this otherness that astonished me in its ability to linger.

Today, psychedelic research is picking up steam once again around the world, looking at whether such drugs can help with depression, addiction, PTSD, eating disorders, dementia and intergenerational trauma. There is work on their possible use to extend the window for recovery after a stroke, giving more time for rehabilitation, and even as a way to understand consciousness.

As we spoke to researchers quietly and objectively testing substances such as psilocybin and DMT in clinical settings, it all felt like a world away from the psychedelic narratives of popular culture. These molecules have profound, lasting effects upon the mind and our perceptions of reality. It is hard to understate how strange it now seems that we chose to simply cut off broad avenues of inquiry, and refused to allow our best minds to see where they might really lead.

Conversations with today's researchers are as interesting as it gets, but for me I can't shake off the "what if?". With a global mental health crisis, governments and health systems are desperate for new treatment options. Public funding is being cut and is under threat in many territories. At the same time, big business, with its profit motive, is taking a keen interest, with implications for the accessibility of new treatments. Things are changing, fast.

Once you attempt a clear-eyed look at the history of humanity's relationship with psychedelic molecules, the story is one of a giant, self-inflicted wound. Ultimately, the funding for Outsight didn't come through and a very different era began. The war on drugs all but closed down research into a whole class of substances for decades, with ramifications lasting to this day.

The story of these substances is a warning. Politics can't be allowed to impede scientific discovery. Looking around the world today, I see an urgency – I would say a moral imperative – to protect and nurture the conditions in which science can get on with the job. The stakes are too high not to. ▮

Tim Hayward is a writer, journalist and broadcaster. *The Trip* is available on BBC Sounds

Field notes from space-time

The matter in hand

Why would anyone bother to create facilities that make particles called B mesons? Because they may solve two of the universe's big mysteries, says **Chanda Prescod-Weinstein**

Chanda Prescod-Weinstein is an associate professor of physics and astronomy at the University of New Hampshire. She is the author of *The Disordered Cosmos* and the forthcoming book *The Edge of Space-Time: Particles, poetry, and the cosmic dream boogie*

Chanda's week

What I'm reading
I have just finished Gazan physics student Wasim Said's Witness to the Hellfire of Genocide, *a harrowing memoir.*

What I'm watching
I am finally watching The Wire *after years of avoiding it.*

What I'm working on
I'm revisiting cosmological perturbation theory, which used to annoy me.

This column appears monthly. Up next week: Graham Lawton

DID you know that, in physics, we have beauty factories? This has nothing to do with art or glamour. Instead, I am talking about experiments where electrons and their antimatter counterparts, positrons, are collided together to produce particles called B mesons.

These are made of quarks, the subatomic particles found within ordinary matter. But while such matter is almost exclusively composed of electrons, up quarks and down quarks, a B meson is made up of a beauty antiquark and an up, down, charm or strange quark.

This make-up gives B mesons an extremely short existence, far removed from daily life, so you might wonder why anyone would bother devoting whole facilities we now call B factories to making them. The answer is that B mesons can help us solve a big mystery of the universe: why there is more matter than antimatter.

We know that every type of particle has an antiparticle, but when we look at the universe, we mostly see particles, not antiparticles. So the universe appears full of electrons, but not of positrons – identical to electrons, but with an opposite charge.

Mesons are interesting because they exist between matter that is abundant in the universe and antimatter, which is not. As such, we may be able to exploit them to learn more about the asymmetry between matter and antimatter. Understanding this would explain why there is anything lasting in the universe at all, since matter and antimatter tend to annihilate on contact. We create B factories because they can help us explain why the universe isn't empty.

Things get even more complex when you consider that mesons also have their own antimatter counterparts. Each B antimeson is made of a beauty quark and an up, down, charm or strange antiquark. In the case of B mesons made with strange or down quarks (known as the neutral because they have no electric charge), the particles oscillate between being mesons and antimesons. In other words, neutral B mesons are spontaneously non-binary.

It is these neutral B mesons that are key to understanding the matter-antimatter asymmetry. Although their non-binary nature is a prediction of the standard model of particle physics (which catalogues every particle ever seen), we can look to see whether the oscillations are exactly half and half. Are the particles we first make in the collisions more likely to be mesons or antimesons? If there were an asymmetry in these oscillations, this might explain the matter-antimatter asymmetry.

> "B factories may help us understand something we are certain exists, but have never seen in the lab: dark matter"

In 2010, researchers at the Fermilab DZero collaboration claimed to see a 1 per cent difference, but no other work has confirmed this result. The possibility remains intriguing, especially since research not involving oscillations has definitively observed differences.

B factories may also help us understand something we are certain exists, but have never seen in the lab: dark matter. You may recall that this dark matter has been detected by observing its gravitational impact on visible matter. We are fairly sure that about 85 per cent of the universe's matter is this invisible stuff, yet to be explained by the standard model.

Formulating a theory to explain dark matter means hypothesising a new particle – or particles. Some of them may interact with existing particles in ways that are hard to detect. The mechanism allowing these interactions is often known as a mediator. Since mediators are also difficult to detect, this sounds hopeless. But while we may never see a mediator directly, given the right conditions, we can hope to see the particles they decay into – such as electron-positron pairs. This is where B factories can help: they are designed to isolate the products of electron-positron collisions (the products of matter and antimatter colliding).

As someone outside collider physics, I find one of the most interesting things about this research is how it keeps experiments alive long after they stop generating data. For example, the BaBar experiment at the SLAC National Accelerator Laboratory, near Silicon Valley, was shut down in 2008, but researchers are still sifting through the data and using it, including to educate the next generation of physicists.

In 2022, Brian Shuve at Harvey Mudd College, near Los Angeles, and an undergraduate team tested a new idea against almost 20-year-old BaBar data. I heard about this because, among other things, the idea proposes that a hypothetical particle called the axion would act as the mediator between visible matter and dark matter. Regular readers may recall that my main research is axions as dark matter.

So do either of these scenarios (mine or Shuve's) capture how our universe really works? We may just find out as part of the effort to understand the matter-antimatter asymmetry. ▮

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Beautiful bats

The Genius Bat (Oneworld)
Yossi Yovel

THESE endearing photos of bats are a far cry from how these animals are often perceived – linked to fictional evildoers, or blamed for real-life diseases, most recently covid-19, due to the viruses they harbour.

But the mammals deserve far more sympathy and attention, argues ecologist Yossi Yovel, based at Tel Aviv University in Israel, in his forthcoming book *The Genius Bat: Understanding our most mysterious mammal*. Although bats do host viruses, the evidence suggests that the SARS-CoV-2 coronavirus didn't come directly from them. In any case, he says, bats are a vital part of ecosystems, pollinating plants and keeping insect populations in check.

Across the 1400-plus species of bat, there are boundless variations. Take the resourceful Honduran white bats (*Ectophylla alba*, near left at bottom). These snow-white puffballs are found across Central America, where they fashion temporary tents from large-leafed plants like heliconias to sleep in.

Then there is Pallas's long-tongued bat (*Glossophaga soricina*), which loves nectar, using a tongue the length of its body to stab deep into flowers, like that of the banana plant (far left). These bats insert and remove their tongues up to 10 times per second, collecting nectar.

The final image is of the striking trefoil horseshoe bat (*Rhinolophus trifoliatus*), whose nose is shaped like a three-leafed clover. The bat is antisocial: after hunting small insects at night, most horseshoe bats return to their roost, but trefoils prefer to sleep alone on branches, just a metre or so above the ground.

Alex Wilkins

On a war footing

Conflicts have shaped human evolution, but how do our brains determine the way they play out? **Elle Hunt** explores a guide to the neuroscience of warfare

Book
Warhead
Nicholas Wright
Pan Macmillan (UK); St Martin's Press (US)

DEPENDING on your individual mettle, it is either an uneasy moment to be reading a book about war or a timely one. Given the assassination of right-wing activist Charlie Kirk, Russian drones being shot down in Polish airspace and Israel's ongoing assault on Gaza, a third world war has felt imminent in recent weeks.

Warhead, an ambitious new book by neuroscientist Nicholas Wright, sheds light on what might be going on in the minds of those responsible for navigating conflicts – and how their very human decision-making might lead to escalation or resolution.

Wright's research looks into neuroscientific, behavioural and technological insights that are useful for understanding and navigating international confrontations. He has also advised the US Pentagon Joint Staff for over a decade. Wright speaks with authority about what goes down in war rooms and in the minds of world leaders; in *Warhead*, he attempts to take the civilian reader there.

Early on, Wright argues that our experience of conflict was at least as influential on the evolution of our species as the discovery of fire. From there, he leads the reader on a systematic tour of the brain's different parts and their relevance to conflict.

The cerebellum and brainstem, for instance, are home to "elementary drives" that support and inform our fight to stay alive, both as individuals and as a collective. Wright suggests that it was memories of the first world war's devastating loss of life that made the UK and France so cautious in dealing with Adolf Hitler in the run-up to the second world war.

He points to this as an example of a particular "model of the world": an internal sense of reality, which our brains construct from past experience and expectations, that influences our actions. Drawing on other battles and pivotal moments throughout history, Wright illustrates the ways in which the brain's primal responses and processing may have played a part in conflicts.

> **"The many choices that may determine victory or defeat reflect our thresholds for risk and self-control"**

For instance, France's decision to open Paris to the Nazis – against the urging of Winston Churchill – spared the city the airborne destruction wrought on Warsaw in 1939, but worsened the UK's prospects in the war.

This is an example of our brains making a prediction error, Wright argues, and failing to consider all the outcomes or options that are unpalatable in the short term. These many piecemeal – but consequential – choices, which may ultimately determine victory or defeat, all tax the brain and reflect our individual and collective thresholds for risk, self-control or delayed gratification, he writes.

To help the casual reader understand the "dauntingly complicated" design of the brain, Wright supplements his examples of battles and wars with more familiar references, such as aspects of animal behaviour and popular culture. Some of these are laboured or digressive, but they are mostly helpful for grounding abstract or technical ideas.

One key question, however, remains peripheral: why do we have wars at all? Wright argues that they are inevitable, a product of our wiring and the reality of competition. As such, he is impatient with pacifists who fail to engage "beyond the truth that war is bad", as well as with a blanket strategy of either aggression or appeasement, both of which he shows can sometimes escalate emergent threats.

Understanding our brains, impulses and potential blind spots will only become more crucial as wars are increasingly fought at a distance through military technology and artificial intelligence, argues Wright. But the qualities that he espouses as being essential for battle – wisdom, self-knowledge, emotional regulation – seem conspicuously lacking in our current crop of world leaders, and he isn't forthcoming with suggestions for how to foster them.

For people who seek out books about war and military strategy, *Warhead* presents an original angle with some illuminating insights. But if you struggle to accept large-scale conflicts as inevitable and are worried about a third world war, don't expect to feel reassured. ▮

Buildings destroyed by Israeli airstrikes in Gaza in 2023

YAHYA HASSOUNA/AFP VIA GETTY IMAGES

Elle Hunt is a writer based in Norwich, UK

Pacifying your period

A new book suggests lifestyle changes could help address PMS, but its approach is overly simplistic, finds **Alexandra Thompson**

Book

The Period Brain
Sarah Hill
Vermilion (UK); Harvest (US)

ROMY ARROYO FERNANDEZ/NURPHOTO VIA GETTY IMAGES

The menstrual cycle and other aspects of women's health have long been understudied

WHEN I lived with my parents, my mother said she could always tell when my period was approaching: I raided the snack cupboard a little more frequently and became a lot more irritable. I remember all hell breaking loose when she accidentally bought chicken breasts instead of thighs on a night I was supposed to cook.

Such outbursts are typical of premenstrual syndrome, or PMS, a common condition that is the focus of the book *The Period Brain: The new science of why we PMS and how to fix it*. Author Sarah Hill, who has also written about the effects of birth control on the brain, sets out how readers can ease PMS symptoms, with a particular focus on lifestyle changes.

Women's health has been neglected by the scientific community for decades, and Hill – who has a PhD in evolutionary psychology and runs a health and relationships lab at Texas Christian University – should be well placed to fill these voids. All too often, though, her arguments fall flat.

At one point, she partly attributes PMS to the fact that women are told to consume roughly 2000 calories a day on average, when research suggests they actually need an additional 140 calories during the luteal phase of their cycle – the time when an egg travels to the uterus before a period, which coincides with when PMS usually occurs. Hill argues that by sticking to these guidelines, we develop cravings and a preoccupation with food, then binge eat, making ourselves feel worse.

At the risk of being anecdotal, I don't know any women who calorie count to this extent, or any who would deny themselves a 140-calorie snack – less than the amount you get with a handful of crudités with hummus – if that is what they felt their body needed. It seems to me that Hill is vastly oversimplifying the onset of PMS.

And while she certainly references a lot of scientific research, Hill rarely provides details on how many participants were in a given study or how long an intervention was tested for. Sample sizes are particularly important to know, as small ones can miss a lot genetic variation.

The potential influence of genetics on PMS is something Hill merely touches on. While no PMS-related genes have been identified, we know the condition is more common in identical twins than in fraternal twins, which suggests it has a strong genetic component. We are also confident there is a genetic element to other aspects of the menstrual cycle, such as its length and when menopause occurs, so it would come as no surprise if PMS were added to that list.

Hill frequently recommends easing symptoms through poorly tested supplements, getting more sunlight or varying our exercise regimen across the menstrual cycle (and to be fair, there could be something to that last one). But it would be nice if she acknowledged that the debilitating effects experienced by so many could be because of their genetics, rather than a less-than-perfect lifestyle.

One thing I agree with Hill on is the need for more research at different stages of the menstrual cycle to understand how this affects drug metabolism or the body's response to psychological interventions like therapy. I also agree that it might be easier for us to deal with mood swings if we remind ourselves that they might be a natural response to fluctuating hormones. Perhaps some rationalising by me could have avoided chicken-gate.

I didn't come away from *The Period Brain* with any "light bulb" moments on how to ease PMS. But each book published on women's health represents another step towards reducing the stigma of conditions like PMS and might encourage more research, which, of course, can only be a good thing.

New Scientist *recommends*

Jacob Aron
News editor
London

Just over 50 years ago, US astronauts and Soviet Union cosmonauts met in space for a ceremonial handshake. This mission serves as the background for former Canadian astronaut Chris Hadfield's latest alt-history space thriller, **Final Orbit**, which introduces an accident that kills half the crew.

Meanwhile, Hadfield revives the cancelled 1960s Shuguang space programme in order to place the first Chinese astronaut in orbit almost three decades earlier than in reality. With these pieces in place, he tells the story of a clandestine three-way space conflict, and gives us possibly the most realistic depiction of a "battle" between two spacecraft ever written.

As in his previous books, Hadfield expertly weaves fact, fiction and

his own experiences in orbit to produce a novel that is both technical and entertaining. If you can't stand Tom Clancy-esque discussions of how exactly you plumb a nitrogen tank on a spacecraft, this may not be for you, but I am finding Hadfield to be a master of the genre.

The TV column

Master manipulators

New Netflix show *Wayward* is set at a strange academy in small-town Vermont that promises to "solve" adolescence. **Bethan Ackerley** discovers a troubled world where the adults are out to get the kids

Bethan Ackerley is assistant culture editor at *New Scientist*. She loves sci-fi, sitcoms and anything spooky. Follow her on X @inkerley

NETFLIX

Abbie (Sydney Topliffe, left) and Leila (Alyvia Alyn Lind)

LIKE most people, I suspect, I don't really like thinking about my teenage years – a time of too much brooding and too little self-awareness. But despite any lingering embarrassment I might feel, I have never seen adolescence as some mistake or aberration we would ideally do away with.

That's not the case for many characters in *Wayward*, an eight-part mystery series from writer-comedian Mae Martin. It is set at a mysterious academy in the fictional small town of Tall Pines, Vermont, that promises to pacify unruly teens and solve adolescence. Head of the school is Evelyn Wade (Toni Collette), a towering presence who dominates the "progressive, intentional community" of Tall Pines with her saccharine, New Age philosophy. But peel back a few layers and there is little love and light to be found in the town.

Our window into Tall Pines Academy is Abbie (Sydney Topliffe), a stoner tomboy from Canada who isn't living up to her father's expectations. After she sneaks out one night to meet her best friend Leila (Alyvia Alyn Lind), a troubled, grieving girl who is deemed to be a bad influence, Abbie's parents arrange for her to be abducted in the night and taken to Evelyn's school. On arrival, she is stripped of her possessions and encouraged to snitch on her fellow students for the tiniest infraction.

Meanwhile, police officer Alex Dempsey (played by Martin themselves) and his pregnant wife Laura (Sarah Gadon) are new to the town. Their home was gifted to them by Evelyn because Laura is a particularly beloved graduate of Tall Pines Academy. When Alex encounters an escaped student tearing through the woods, consumed by terror, he resolves to investigate the school.

> "The scariest part is the therapyspeak, with cruelty disguised as a way of protecting mental health"

Tall Pines is full of small-town creepiness: the residents are overly interested in Alex and Laura's unborn child; there is a mysterious door etched on their basement wall; Laura is plagued by the constant croaks of toads. That's before we even get to the academy, where former students, now employed by Evelyn and renamed after animals, speak breathlessly about the transformative effects of their time at the academy.

But the scariest part of *Wayward* is the therapyspeak. The series takes on the phenomenon of weaponised psychobabble, abject cruelty often disguised as a way of protecting mental health – especially that of adults.

Take poor Abbie, whose acts of ordinary, adolescent rebellion are pathologised by her parents. Because they want her to be someone else, they pretend she is harming them and send her off to be cured of her androgyny and get away from friends like Leila.

Everyone at the academy is a master manipulator, but none more than Evelyn. She can turn the "honesty is the best policy" trope into hot-seat "treatment", where students are berated by peers armed with cruel "truths", until they crack. "It's a way of holding yourself accountable," says Evelyn, over dinner.

There are so many interesting ideas in *Wayward*, but it is often more stimulating to think about the show than watch it. Sadly, after some stellar first episodes, it falls apart, ending mundanely. Yet I was temporarily won back in the final minutes, when the motivations of a character who felt thinly drawn are finally, fantastically realised.

If you feel compelled to revisit your adolescence, *Wayward* is worth a watch. If not, there may be better uses of your time. ▮

TV

Wayward

Mae Martin

Netflix

Bethan also recommends...

Film

Hereditary

Ari Aster

Toni Collette also shines in Hereditary, *another tale of intergenerational trauma. She plays artist Annie, whose family is plagued by odd occurrences in the wake of her mother's death.*

Book

Abolish the Family

Sophie Lewis

Tracing 200 years of the movement to abolish the family, Lewis argues for better ways to care for children than privatised units. No need to totally buy into the thesis to get something from the book.

Editor's pick

Keep digging in the hunt for Martian life

20 September, p 10

From Ernest Ager, High Peak, Derbyshire, UK

With the recent news of some possible signs of ancient life on the Martian surface, there will naturally follow the usual comments – that even if there were any life long ago, there won't be any living now, due to the hostile surface conditions.

However, once life started on Earth, it quickly spread to an enormous range of habitats, such as deep underground. It can survive in the absence of light, without oxygen and by using chemical redox reactions as an energy source.

If we find that life did indeed start on Mars and was present for a reasonably long time, I would suggest that it is highly likely that it still exists somewhere there, possibly below the ancient seabeds. As the atmosphere was slowly lost and the planet cooled, life would gradually have migrated deeper and evolved to the new conditions.

Comparing artificial apples and pears

30 August, p 19

From Michaella Pettit, Zurich, Switzerland

Sophie Attwood's comment piece questioned why people resist fake meat but embrace synthetic bodily enhancements. Two points struck me. First, Botox has been around for decades longer than artificial meat. Comparing public attitudes without accounting for the time each technology has had to become familiar feels misleading. It would be fairer to compare reactions at similar points in time after their invention.

Second, encouraging people to adopt lab-grown meat without caution seems premature. Emerging research on the negative health effects of ultra-processed foods suggests we should fully understand their potential impacts before urging widespread consumption. Blind enthusiasm risks overlooking important safety and nutritional questions.

Climate shock or signal for geoengineering?

13 September, p 40

From Sam Edge, Ringwood, Hampshire, UK

The indications that reductions in particulate pollution may be exposing the real extent of climate change is disturbing. But for some to argue we should therefore ease pollution rules is like trying to say that two wrongs make a right.

From Don Sandom, Reading, Berkshire, UK

Previously, proponents of geoengineering solutions to global warming have suggested that reflective aerosol particles could be sprayed into the upper atmosphere to achieve the same sunlight-reflecting effect as aerosol pollution. Opponents argue that this idea seems risky. I would have thought that what has been observed in the Pacific and Indian oceans as a result of pollution shows, to the contrary, how effective upper-atmosphere aerosols can be in reducing incoming radiation. Surely this is an idea worth pursuing.

Fermented food is about more than gut microbes

13 September, p 24

From Peter Niepel, Kaitaia, New Zealand

I would like to comment on your review of the book *Ferment*. I am a German artisan baker, mostly making German sourdough. I also grew up with lots of fermented foods and I would say I have some good knowledge about them.

A crucial factor is which of the microorganisms in these foods survive our digestive system. The stomach is very acidic. From what I have learned, most of the microorganisms are destroyed in that environment. What my research has shown is that most fermented dairy products will provide microorganisms to our guts because these survive the stomach. Sourdough, sauerkraut and so on don't provide a lot of gut microorganisms. Their advantage lies in being more digestible.

To read about the future of fermented foods, see page 32

Plenty of space for carbon storage in everyday life

13 September, p 10

From Martin van Raay, Culemborg, The Netherlands

Fortunately, there are more ways to store carbon dioxide than just underground. Trees and other plants also store it and when we use them to, say, build high-rise buildings or furniture, or make car parts (flax and hemp can be used in door panels and dashboards), we store CO_2 for years, and possibly for centuries in some cases. By turning CO_2 into useful products, capturing it will become profitable, not just necessary.

On the space-time vs spacetime debate

6 September, p 22

From Bernd-Juergen Fischer, Berlin, Germany

When it comes to the phrase space-time, Chanda Prescod-Weinstein ponders what is in a hyphen? Space answers to the question "where?", time to the question "when?". Space-time answers to the question "when and where?". "Spacetime" answers to no question at all. It is a new concept that needs a lot of explaining ("what?") and probably even a new interrogative ("whern", maybe?).

Otroverts can unite and possibly love cats

Letters, 13 September

From Ametrine Lavender, Hebden Bridge, West Yorkshire, UK

Robert Sugden says otroverts, people who naturally don't conform to groups, will never form their own groups for the obvious reason. But a few decades ago, people would have said the same about autistic people. Yet since the arrival of the internet, they have formed online groups to share experiences, developing guidelines that have since helped enable real-world spaces developed "by and for autistics".

It has made all the difference to many autistic people to have social spaces where we can be our authentic autistic selves in autistic company, and in the company of respectful, neurotypical allies keeping to the same rules.

From Paul Mostyn, Leeds, UK

Sugden's witty letter about being an otrovert prompted me to reread Rami Kaminski's original article. I happened to be stroking my cat, whom I respect and admire, at the time, and it struck me that cats are extreme otroverts, the polar opposite to dogs. Our cat exploits us mercilessly, while being totally indifferent to our continued existence. He also studiously ignores all other cats. Does this explain the widely held belief that people are either cat people or dog people?

Grim reaper, I call you and raise you 100

20 September, p 30

From Jim Ainsworth, Kingsland, Herefordshire, UK

How to make it to 100? I'm determined to live to 200. Or die trying.

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CHRISTIAN GRALINGEN

What's inside a black hole?

Are black holes really what they seem, or could they be hiding something else, asks **Stuart Clark**

SOME things in cosmology may simply be unknowable. Why is there something rather than nothing? What lies outside the universe? What is inside a black hole? That last one has been niggling at astrophysicists for more than a century, but they may finally be on the brink of figuring it out.

The traditional answer is that inside a black hole is a singularity: an infinitely small point of infinite density. If singularities are real, that could tell us something profound – not just about black holes, but also about our understanding of physics writ large. But nothing, not even light, can escape a black hole, so it has long been thought impossible to tell if these seemingly implausible points truly exist, or if there is some unknown physics that stops them from forming. But if there are no singularities, are black holes really black holes?

A new breed of astronomer is currently developing both the theories and the tools that may help to figure out exactly that.

"We've entered a new era. The subject has been transformed from a purely mathematical discipline, disconnected from observation, to a growing field with rich connections between theory and experiment. It feels like it's a bit of a golden era," says Alexandru Lupsasca, a black hole researcher at Vanderbilt University in Tennessee.

This new era has been ushered in by the quest to find a theory beyond general relativity, which is our current best description of gravity. In 1915, Albert Einstein famously derived the field equations of general relativity, describing the ways the space-time continuum – the invisible "fabric" of the universe – can expand, warp and twist depending on the amount of mass or energy contained within it.

No sooner had Einstein published the equations than the seed of their destruction was discovered by the physicist Karl Schwarzschild. While serving in the German army during the first world war, Schwarzschild used Einstein's equations to find a number now known as the Schwarzschild radius.

Searching for singularities

This essentially tells us at what size a celestial object will become a black hole based on its mass. So long as the object is larger than the Schwarzschild radius, it will continue to exist as normal. But if it should become smaller, then the gravity its matter produces will be so strong that nothing in the known universe can resist it. The matter inside the Schwarzschild radius – which now defines a spherical boundary known as the event horizon – collapses unimpeded to form a singularity.

This gives us the traditional structure of a black hole: a singularity surrounded by an event horizon. Once you have crossed the event horizon, you are lost to the universe, as the pull of the black hole's gravity is overwhelming.

But to physicists, singularities spell problems – they shouldn't physically exist. "Singularities are nonsensical. The formation of a singularity is just a statement that the equations themselves are saying, 'Hey, we don't know what's going on and we need to be replaced by a deeper theory,'" says Lupsasca.

The conundrum is that there is now an overwhelming body of evidence that black holes do exist. Astronomers see them all over the universe: at the centres of galaxies, in the aftermath of stellar explosions and, thanks to the work of the Laser Interferometer Gravitational-Wave Observatory (LIGO), in the way they set the very universe quivering.

LIGO announced its first direct detection of these subtle ripples in the fabric of the universe, called gravitational waves, in 2016. They are key predictions of general relativity and are best generated by the collision of two black holes. A few years after the first LIGO detection, in 2019, the Event Horizon Telescope (EHT) Collaboration released the first-ever image of a black hole. Suddenly, the astronomical community started to realise that black holes were no longer the sole purview of theoreticians.

"For sure, the fact that there's better observational data has made people think more about black holes. Just because you have more data, you can essentially investigate more about these objects," says Raúl Carballo-Rubio at the International School for Advanced Studies in Italy, who has been investigating how these new observational techniques might help finally answer the question of what's really inside a black hole.

Just because black holes seemingly do exist doesn't mean that singularities must also be real. In fact, there is a widespread view among astrophysicists that they aren't, and their appearance in the equations simply tells us where to look for new physics. "We have Newton, we have Einstein, and then we have the next layer of reality beyond Einstein's theory. Singularities tell us where to look for it," says Carballo-Rubio.

To unlock this next layer, physicists have proposed new physical processes that halt the formation of singularities. Theorists call it regularising black holes, and (perhaps confusingly) refer to the singularity-free black holes they can concoct in this way as "regular" black holes.

The most common approach involves a hypothetical new force of nature that resists gravity and grows in strength as the density of matter increases. It would become strong enough to make its presence felt at only the extreme densities found inside a black hole, which explains why we haven't seen it in the universe at large. Inside a black hole, however, this force would produce a core of extremely – but not infinitely – dense matter. ›

It may sound relatively simple, but as Carballo-Rubio says, actually proving that such a force exists is another matter entirely. To nail it down, astronomers will have to find some sort of observational signature beyond the black hole itself. "When you regularise a black hole, this can change its gravitational field. So you will expect to have some small effects that can show up outside of the black hole," says Carballo-Rubio.

For example, the black hole might spin differently, or it might warp the space-time outside it in unexpected ways. Both these potential effects have been generally known since the 1970s, when physicist James Bardeen investigated whether there were observational signatures that could confirm or refute the existence of a singularity inside black holes. But without the technology necessary to make these observations, the ideas languished. Now, technology is finally catching up with Bardeen's half-century-old work, and his ideas are being revived.

One particularly promising idea now getting a new life is Bardeen's calculation of the paths that light rays would take when passing a black hole at various distances. Most photons of light would hurtle right past the black hole, slingshotted away by its gravity. The closest-in would be caught and fall into the event horizon.

Between these two possibilities, he identified a critical area close to the event horizon where photons could be temporarily captured into orbits around a black hole before heading back off into the universe. It meant that a black hole would always be surrounded by a bright ring of these escaping photons.

They are the luckiest photons in the universe because they have come as close as anything possibly can to a black hole without being lost forever. And any deviation from the photon ring's expected shape and size according to relativity could be the smoking gun of new physics within the event horizon.

Analysis of the EHT's 2019 black hole image revealed that the light around the black hole itself was a combination of glowing material falling to oblivion, and light from the photon ring. But to find any telltale deviation from general relativity, those two sources of light will have to be separated from one another. Although upgrades currently taking place to the EHT will boost its sensitivity, to really disentangle the photon ring from the inflowing matter would require a bigger telescope. That is a considerable problem because the EHT already combines data from radio telescopes spread across the planet, making it, in effect, a telescope the size of Earth.

This is where a proposed new mission comes in. The Black Hole Explorer (BHEX) would extend the EHT into space. If funded by NASA next year, it would be due to launch in 2031. It isn't so much the amount of light the mission's craft would capture, but rather its distance from ground observatories that would supply the information needed to sharpen the images.

Black hole shadows

At 20,000 kilometres from Earth, it would allow EHT to produce the most detailed images ever taken of black holes – or anything in the universe, for that matter. "All of a sudden, you will be able to see the photon ring clearly," says Michael Johnson at Harvard University, a member of the scientific collaboration proposing the mission.

The light around black holes could reveal their secrets, but so could their darkness. If there is new physics to be found, it might also show up in the size of a black hole's shadow, the dark circle around it caused by extreme distortion of space-time. Any new physics could cause the shadow's size to differ from that expected from general relativity, but the trouble is that many of the effects are extremely subtle. "Now it's really a matter of understanding how good your observations need to be in order to be able to tell these differences apart," says Carballo-Rubio.

In 2022, Rahul Kumar Walia at the University of KwaZulu-Natal in South Africa and his colleagues used EHT measurements to test four different proposals for "regular" black holes. They examined the observations of Sagittarius A*, the supermassive black hole at the centre of the Milky Way – our galaxy – and used them to calculate the predicted size of the black hole's shadow using those four regular black hole space-time models. In most cases, they found that the predictions were within 10 per cent of each other, well below the current observations' ability to distinguish between them. They ruled out only one of the four proposals – but perhaps BHEX and the next generation of black hole observatories could do better. The bottom line is that, although we have been able to start the search for regular black holes, we may have to wait a while before we have the observational ability to hunt for them in earnest.

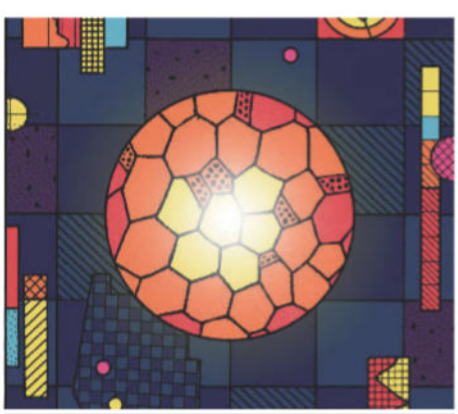
However, there is another approach to removing the singularity that would be associated with much more noticeable observational effects. It is drastic: what if there are no such things as black holes at all? What if we have been fooled all these years by things that just look like them?

These objects would be stranger than even regular black holes. They would not only do away with the singularity, but with the event horizon as well. In short, they wouldn't be black holes; they would only mimic the appearance of black holes from a distance. Up close, they wouldn't have a horizon, but a surface.

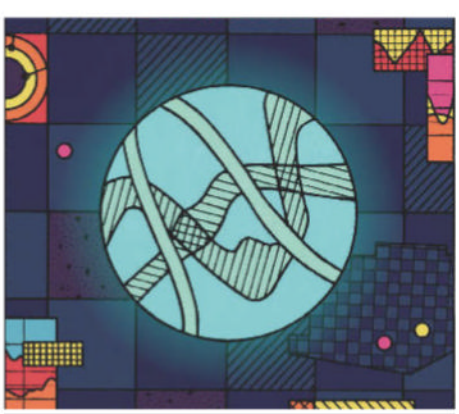
Perhaps the most popular possibilities for such entities are gravastars, short for gravitational vacuum stars. First proposed in 2001 by Pawel Mazur at the University of South

Black hole mimickers

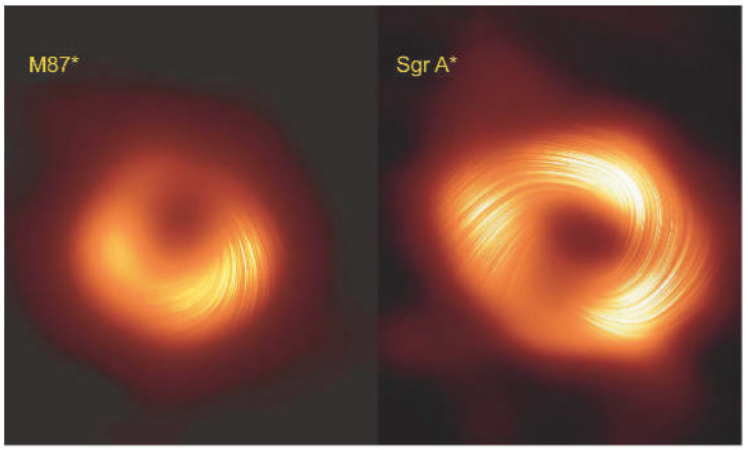
These hypothetical objects would look like black holes from afar, but they lack singularities and event horizons, making them impostors.



GRAVASTAR
Bubble of dark-energy-like vacuum surrounded by a shell of matter



ELECTROWEAK STAR
Regular matter kept from collapsing by strange particle interactions



ESO

The Event Horizon Telescope has imaged two supermassive black holes

"What if we have been fooled by things that just look like black holes?"

Carolina and Emil Mottola at the University of New Mexico, gravastars are regions of space filled with a concentration of repulsive energy similar to dark energy, which on a large scale is hypothesised to be responsible for accelerating the universe's expansion. A gravastar is therefore a bubble of energy surrounded by a thin, ultra-dense shell of ordinary matter.

Black hole mimickers are something of a theoretician's dream, as they require only a knowledge of mathematics and an active imagination to conjure them up. Unsurprisingly, a number of ideas have been proposed. These include boson stars, which could be agglomerations of hypothetical particles called axions; fuzzballs, which come from string theory and would be tangled balls of atomic strings; and electroweak stars, which would be made of ordinary matter but prevented from collapsing into black holes by hypothetical interactions that could take place between particles via the combination of electromagnetism and the weak nuclear force.

Despite being conceptually diverse, the one thing all mimickers have in common is a surface, and that means they could be distinguished through gravitational waves. When a gravitational wave observatory detects two objects merging, the signal is a characteristic "chirp". For black holes, the characteristics of the chirp are dictated only by their masses and spins. For black hole mimickers, however, the detectors would also be able to hear echoes caused by reflections from the surfaces of the merging objects.

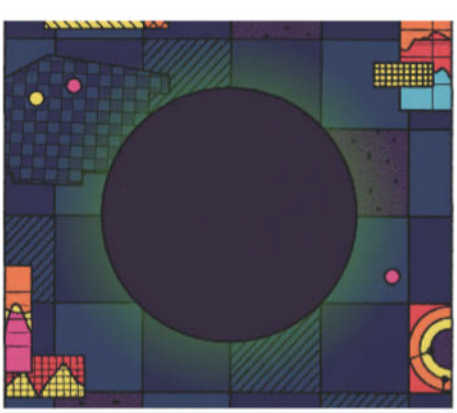
Some tentative evidence for such echoes was presented by Jahed Abedi, then at the Sharif University of Technology in Iran, and his colleagues in 2017 for three merger events, but other searches have come up empty. Nami Uchikata at the University of Tokyo, Japan, and her colleagues found nothing but noise in their analysis of events from three of LIGO's observing runs. However, it isn't time to rule out echoes just yet.

"This means the echo signals are quite faint, even if they exist," says Uchikata. "Or it might be because the echo mechanism is beyond our current understanding and we are failing to catch the signal within our current analysis frameworks." In other words, a lot more merger events are needed to draw any definitive conclusions. To that end, the researchers are currently analysing events from the fourth LIGO observing run, which is ongoing. Another drawback is that they have to use templates derived from theoretical models to tell them what the echo signature might look like. So, if theorists haven't yet come up with the correct description of a mimicker, the researchers may be unable to extract the signal from the data, even if it is there.

In the meantime, the search continues. "It is always about where the new physics kicks in," says Carballo-Rubio. If that happens inside the event horizon, then we must consider regular black holes. If the new physics makes its presence felt just outside the event horizon, then the universe will be full of mimickers – and black holes as we currently conceive of them won't exist at all.

But what if we find no new physics and confirm that singularities are indeed real? "If singularities do exist in nature, black holes would be some kind of 'universal shredder'," says Carballo-Rubio. Just as an office shredder destroys documents, so a black hole would do this for all matter and energy unlucky enough to fall inside – nothing could survive. This would force a rethink of some foundational ideas in physics, such as the idea that information in the universe cannot be destroyed.

More than this, we will have to accept that certain places in the universe are fundamentally unknowable. Physicists have long hoped that singularities are an inconvenience that would eventually be brushed away by new physics. If they can't be, however, that could mean the inside of a black hole isn't a place where new physics applies, but is somewhere where all the laws of physics break down irretrievably. "Personally, that is also an exciting result," says Uchikata. But it would also be a troubling one, forcing us to concede that the universe is not entirely ruled by physics – and that the one place we can never see, the inside of a black hole, is also somewhere we can never truly understand. ▮



BOSON STAR
Sphere of proposed dark matter particles called axions

FUZZBALL
Ball of tangled-up bundles of energy called atomic strings

Stuart Clark is an astronomy journalist

Our fermented future

A microbial revolution is promising extraordinary new foods and novel ways to boost gut health, finds **Graham Lawton**

SHUTTERSTOCK; STOCKFOOD

Fermented foods and drinks come in a variety of forms, from kombucha to kimchi

"IT'S blue cheese, but not as you've ever known it before," says Paul Dyer, as we peer into a fridge full of very special cheeses that he helped create. When I try a sample, it blows my socks off – the best I have ever tasted.

The cheese is a Danish blue co-created by Myconeos, a company Dyer founded in Nottingham, UK. Myconeos doesn't make the cheese, but it bred the fungus that gives it its unique taste. For centuries, blue-cheese-makers have relied on the same old strains of *Penicillium roqueforti*, which is why the classic blues all taste essentially the same. But not anymore. Thanks to a breakthrough that Dyer and his colleagues made a couple of years ago, cheese-makers suddenly have a range of new strains to play with. The first of the resulting new generation of cheeses is already on the market.

These cheeses are part of a wider revolution in food production dubbed fermentation 2.0. We rely on fermentation to produce about a third of our food intake, but the process has remained unchanged for millennia. Now, Dyer and other innovators are exploring a vast and largely uncharted "fermentation space" to create previously unknown foods and drinks with novel flavours and textures – not only dairy-based cheeses, but also new forms of miso, tempeh and kombucha, vegan cheeses that actually taste good and entirely new comestibles, some made from food waste. They are also exploring the possibility of using fermentation 2.0 to boost our health.

"People are realising there's potential to make new combinations of microbes and substrates, and foods that haven't been put together before... searching out new flavours and new opportunities to improve human health," says Benjamin Wolfe at Tufts University in Massachusetts.

Fermentation is one of the most ancient forms of food processing, predating the agricultural revolution by several thousand years. It is simple in essence: take a raw substrate, add some microorganisms, and wait. The microbes digest the substrate and release all sorts of interesting flavours and textures, often transforming it into something new – think of the difference between raw milk and cheese.

Today, fermented foods and beverages make up a large proportion of the human diet and come in a wide variety of forms – bread, cheese, yogurt, beer, wine, coffee, chocolate, miso, salami, kimchi, sauerkraut, tempeh, soy sauce, kombucha, fish sauce and hundreds more. Every cuisine includes ferments, and almost every conceivable class of food is fermented somewhere in the world.

The earliest ferments, which include a type of flatbread made by Natufian hunter-gatherers 14,000 years ago in what is now Jordan, were almost certainly "spontaneous" or "wild" fermentations, meaning that the fermenting was done by microorganisms already living on the raw food or in the environment. That is probably how all fermented foods were discovered, according to Wolfe. Ancient people noticed that when certain foods were accidentally left to spoil in particular ways, some developed interesting and delicious flavours, and they often lasted longer.

"Fermented foods are largely happy accidents just using whatever food we had in the environment and whatever microbes happen to be around," he says. These were then recreated and refined over many generations.

And that is where things stood for centuries, until the late 19th century. In the 1850s, Louis Pasteur had discovered that the souring of milk and production of alcohol from sugar – at that point thought to be purely chemical processes – were in fact caused by microorganisms, namely lactic acid bacteria and single-celled yeasts.

Further research identified four principal groups of fermentation organisms: yeasts for bread, wine and beer; lactic acid bacteria for yogurt, cheese, sausages, kimchi and sourdoughs; acetic acid bacteria for vinegar and kombucha; and moulds, or filamentous fungi, for fungal-ripened cheeses, salami, miso, soy sauce and many more.

Fermentation 2.0

These discoveries led to the invention of standardised starter cultures: off-the-shelf microbial concoctions designed to be added to substrates such as milk, grains and vegetables and ferment them to perfection. This took the chance element out of fermenting and allowed artisanal processes such as cheese-making and bread-baking to be industrialised. The majority of fermented foods we buy today are made this way.

But even with the invention of starter cultures, the range of fermented foods didn't expand. That, however, is now changing, thanks to fermentation 2.0.

The seeds of this revolution were sown in the early 2000s, when new techniques such as metagenomics and metabolomics allowed food scientists to analyse exactly ›

what is going on, microbially and molecularly, in fermented foods. "We've done this really neat work of mapping out those traditional ferments and figuring out what are the microbes and what are the metabolites that are in there," says Wolfe. The health benefits of fermented foods have also started to be explored (see "Health boost?", right).

A decade ago, armed with this new understanding of the fermentation process, Michael Gänzle at the University of Alberta in Canada created a "periodic table" of fermented foods. Inspired by Dmitri Mendeleev's periodic table of the elements, he drew up a chart with 118 cells and systematically placed examples of fermented foods into each one. Each column was dedicated to a certain type of ferment – wine, beer, bread, cheese, soy products, meat and more – with flavour intensity increasing from left to right and top to bottom.

The table started as a teaching aid, but it raised a question: just as the original periodic table revealed gaps that were later filled with newly discovered elements, could a table of ferments point to spaces that could eventually be occupied by new ferments?

Gänzle's table was full, so Wolfe and his colleagues tried a different approach. They mapped all known ferments onto a multi-dimensional graph, which they called "fermentation space". Similar ferments are clustered together, with a bloc of meat and fish products on one side, a bloc of dairy on the other and a swathe of vegetable ferments in between them. "The closer they are to the other, that means they have very similar substrates and very similar microbes," says Wolfe. But the graph wasn't full – there are two yawning gaps that he says are waiting to be filled (see "Fermentation gaps", right).

"I think there's potential for completely new ferments that haven't been created through an accidental process," says Wolfe. "Taking the base layer of traditional ferments and then building on that, tweaking that, moving things around, adding new microbes."

The simplest route to a novel ferment is what is known as a crossover – transplanting the microbiome from a traditional fermented food onto a substrate it hasn't been used on before. A few years ago, chef Lars Williams, who was then head of R&D at the world-famous restaurant Noma in Copenhagen, Denmark, started experimenting with novel misos. Traditional miso is made by growing the filamentous fungus *Aspergillus oryzae* on steamed white rice, transferring the resulting mould – called kōji – onto salted soybeans and

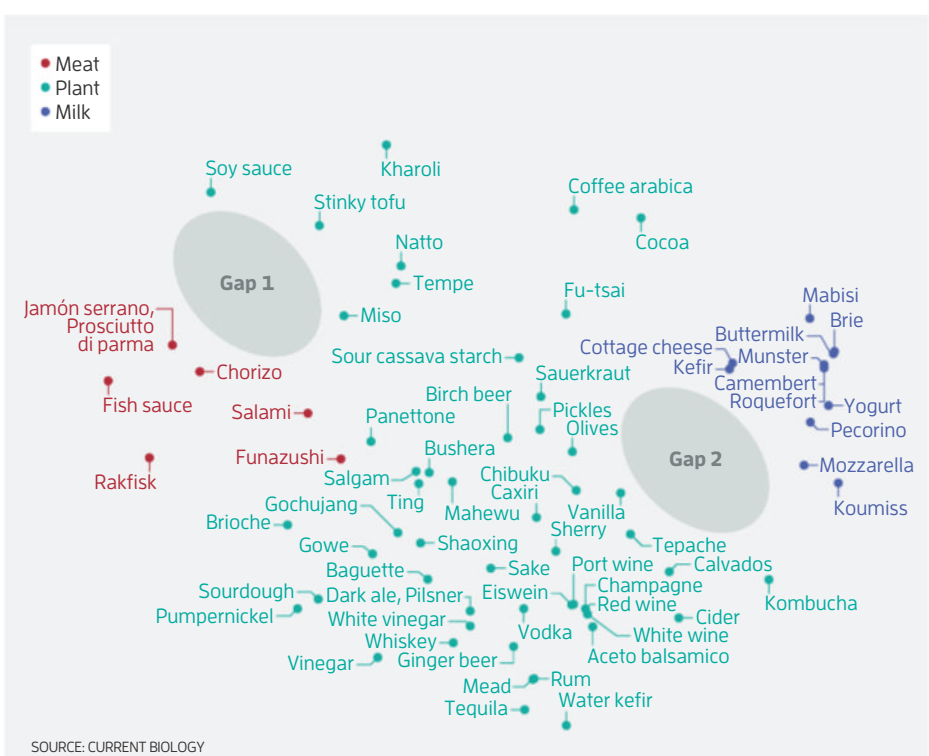
ASHLEY COOPER/ALAMY

CONTEMPEHRARY

Traditional ferments include cheese (left), while new Nordic-style tempehs are made from split peas, fava beans and seaweed (below)

Fermentation gaps

When all known fermented foods are mapped onto a multidimensional "fermentation space" according to the ingredients and microbes used and other variables, two key gaps emerge – indicating potential new ferments



SOURCE: CURRENT BIOLOGY

leaving the mixture to ferment, sometimes for years, creating a rich, umami paste with multiple culinary uses.

Noma's philosophy is to use only local ingredients, so Williams grew the mould on pearl barley and then transferred the kōji to Nordic legumes, including Gotland lentils, lupin seeds and, most successfully, yellow peas. The resulting miso – which Noma called "peaso" and now sells through its online store – was "remarkable", says food scientist Josh Evans, who was then at the Nordic Food Lab, a research institute attached to Noma. "The flavours were more than the sum of their parts; it had all of these amazing fruity aromas in it," he says.

You don't even have to ferment legumes to make new misos. In 2021, a team led by Eddy Smid at Wageningen University & Research in the Netherlands created a dairy miso by applying kōji to quark cheese. The result was a sweet paste with blue cheese notes.

Williams and others have also experimented with crossover fermentations of kombucha, traditionally made from sweetened tea inoculated with bacteria and yeasts. Various new substrates have been tried – herbal teas, coffee, ginger, fruit and vegetable juices, milk, and even waste products like whey and banana peel. "They develop these flavours that you would never find in raw, unfermented juice," says Evans, who is now at the Technical University of Denmark, near Copenhagen.

Another space that is ripe for the filling: plant-based cheeses. Most vegan cheeses are simply unfermented blocks of oils and starches that don't really mimic cheese. Those that are fermented score better in taste tests, but they still perform worse than dairy-based cheese.

That may be because the organisms used in the fermentation are standard cheese-making microbes, which aren't adapted to non-dairy substrates. "They haven't been optimised at all to, say, cashews or coconut," says Dyer. Myconeos is currently screening its library of penicillins to find ones that reliably and deliciously ferment plant-based milks into cheese. "So you're more likely to get vegan cheeses that taste more like the dairy originals," says Dyer.

Another technique being used in crossovers is solid-state fermentation, where the microbes grow on a solid medium rather than in a liquid one. This is how the Javanese staple food tempeh is made, using moulds from the genus *Rhizopus* to ferment blocks of soybean. For the past few years, Contempehrary, a small company in Nykøbing Sjælland, Denmark, has been creating and selling Nordic tempehs made from split peas, fava beans and seaweed.

Solid-state crossovers have even been used to create entirely novel foods. In 2023, a research team led by Vayu Hill-Maini at Stanford University was experimenting with the filamentous mould *Neurospora intermedia*, which is the main fermenter in red oncom, a tempeh-like food from Java produced from pulp leftover from processing soybeans into tofu and soya milk.

They discovered that the fungus can convert rice starch to glucose, and so they created a solidified, unsweetened rice custard and surface-fermented it with *N. intermedia* for 60 hours. This created an intense sweetness, lots of interesting flavours and also turned the custard bright orange and fluffy due to the fungal spores. Hill-Maini shared the recipe with his collaborator Rasmus Munk, head chef at the Michelin starred restaurant Alchemist in Copenhagen, and he put it on the menu.

Many of these crossover fermentations take substrates that would otherwise go to waste and turn them into edible products. That is one of the main motivations for developing novel fermentations, says Evans. Globally, around a third of food goes to waste, and food waste is responsible for around 8 per cent of total greenhouse gas emissions.

Traditional fermentation is already used to turn waste into food – red oncom is an example of this. But there are many other kinds of ›

Health boost?

Studies increasingly link consumption of fermented foods, particularly dairy ferments, to a reduced risk of heart disease, type 2 diabetes and obesity. For instance, consumption of yogurt is linked with a lower risk of developing type 2 diabetes, possibly due to compounds called bioactive peptides released by the fermentation process. And a clinical trial showed that a diet high in fermented foods resulted in a greater diversity of gut microbes and a reduction in levels of inflammatory compounds in blood. However, there is a long way to go before the health effects of ferments are firmly established.

Nevertheless, these discoveries raise the possibility of designing novel fermented foods not only for their taste, but for enhanced levels of beneficial compounds or their ability to boost our gut microbiome. It is very early days, but studies already indicate that new kinds of fermentations of tea, soymilk and oats can enhance levels of substances with health benefits.

"We don't really yet know the baseline benefits of the traditional ferments," says Benjamin Wolfe at Tufts University in Massachusetts, "but that doesn't mean we can't start tinkering. So, for example, if we find that a particular metabolite made by a particular microbe is beneficial for reducing inflammation in the gut, you might be able to use novel fermentation to get that into a diversity of fermented foods. If it's just in yogurt, how could we get it in sourdough or miso?"

"Fermented foods are largely happy accidents just using whatever microbes happen to be around"

Pulp leftover from tequila production can be used to make bread

SUSANA GONZALEZ/BLOOMBERG VIA GETTY IMAGES

unused waste that could be fermented to create new foods. In Mexico, for instance, scientists have used agave bagasse – a byproduct of tequila – to create a new type of sourdough bread. Evans and his colleagues recently created a soy sauce fermented from the waste products of mushroom farming. Once the fruiting bodies have been picked, the underground parts of the fungus and the growing medium – often coffee grounds – are usually discarded, but that is a waste.

"There's a lot of flavour left, a lot of nutrition left, it's just a question of how to unlock it," says Evans. "We ferment it like a traditional soy sauce, and then you have this delicious mushroomy, coffee-y, intense soy sauce that's super rich in protein, very nutritious." He and his colleagues also tried fermenting the roots of Belgian endives, which are intensely bitter and usually left in the ground to rot. By wild fermenting the roots they produced something surprisingly good. "We got all these amazing citrusy notes, and we were like, oh, actually, we should make a tonic water with this," he says.

According to Hill-Maini, *N. intermedia* alone has the potential to transform many classes of food waste into edible products. He tried it on 30 different forms of food waste, including grain husks, the inedible parts of fruits and vegetables and various byproducts from food processing. It grew well on all but three of them. The goal now is to see which of these waste streams can be converted into foods that consumers will willingly eat.

ALEXIS PANTOS

Remains of bread (above) found at a 14,000-year-old fireplace in Jordan (left) is evidence of one of humanity's earliest ferments

New microbes

Crossover is far from the only option. Another technique being explored is engrafting, where the microbiome from one traditional ferment replaces another. Researchers at Japan's National Agriculture and Food Research Organization in Tsukuba, for example, have been experimenting with brie-style cheeses ripened with kōji moulds. Traditional surface-ripened cheeses are coated with the mould *Penicillium camemberti*, which forms the cheese's bouncy white rind and helps to develop its flavour. Replacing it with kōji moulds produces a finished product that is similar, but not identical, to Camembert. Researchers at the Shanghai Engineering Research Center of Dairy Biotechnology in China, meanwhile, are experimenting with using a different kōji mould, *Monascus purpureus*, in place of *P. roqueforti*. The fungus is red and produces a red-veined cheese with a distinctive flavour.

These mix-and-match techniques also hold the promise of enhancing the health properties of fermented foods.

The next frontier is to exploit microbes that haven't been used before. Traditional ferments barely scratch the surface of microbial diversity. "There are probably many microbes out there that have the potential to generate completely new fermented foods, but we just haven't been looking for them," says Wolfe. "That's another way to bring in novel flavours and novel properties." Such products are already starting to see the light of day: a company called Lachancea in Raleigh, North Carolina, for example, brews beers with novel yeasts extracted from the guts of bumblebees and wasps.

There is also the prospect of tweaking existing fermentation microorganisms to create something new and different. That is the route Dyer and his colleagues have gone down. For centuries, the moulds used to ripen blue cheeses were propagated asexually, but a few years ago, scientists at Myconeos managed to coax them into having sex. "Sex means that you get lots of variation in the progeny," says Dyer.

They crossed moulds from stilton, gorgonzola and roquefort, and then inoculated cheese with the offspring. "We got some that tasted a little bit like the parents," says Dyer. "But then we got one that was way out there. We had some professional tasters in, and they said it was the best blue cheese they'd tasted." That was the extraordinarily tasty Danish blue I tried in Nottingham – an intense explosion of flavour and aroma, blue to its core, but with no hint of the acrid ammonia or sweaty-socks notes that often come with that territory. Plus, some flavour notes I had never experienced before.

Myconeos has also found a way to get *P. camemberti* to breed sexually, creating the possibility of new surface-ripened cheeses. These, too, rely on strains that have been used for centuries.

There is a lot more to be discovered. Fermentation space is potentially vast, but largely unexplored. "We defined the space only by existing foods and microbes," says Wolfe. "But I think there could be more beyond that. If someone starts making a food with completely different microbes and completely different substrates, that would be a whole new part of [the] fermentation space, something completely new. Not everything that we'll find in those spaces will be delicious. But I see some exciting new foods in the future." If they're as good as the cheese, I'm all in. ▮

Graham Lawton is a staff writer at *New Scientist*

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‘We’re precipitating an extermination rather than an extinction event’

Broadcaster and campaigner **Chris Packham** tells Thomas Lewton about his mission to take on fossil fuel giants, what fuelled his connection to the natural world, and how he copes with the backlash to his activism

BECKI GILL

WILDLIFE broadcaster Chris Packham’s kinship with the natural world began before he could even speak. As a young child in his parents’ small back garden in Southampton, UK, he became fascinated with tadpoles, snails and ladybirds. Soon his bedroom filled up with jam jars and tanks, and then the garden was crammed with enclosures. His obsessive interests expanded from moths and newts to include foxes and kestrels.

Packham puts this intense curiosity down in part to being autistic. He says this shaped his keen ability to focus and find patterns – and his need to shelter from overwhelming social interactions. On and off screen, Packham isn’t afraid to speak his mind. He is a vocal supporter of environmental issues and animal rights, with campaigns aiming to put an end to game shooting and industrial farming. This has won him no shortage of enemies. In 2019, dead crows and a fox were left hanging on his gatepost, along with a death threat; a couple of years later a Land Rover was blown up outside his house.

But these attacks have only made Packham more resolute in trying to persuade other people that we already have the solution to save the natural world. *New Scientist* spoke to him about his latest campaign to end fossil fuel advertising and sponsorship in the UK, his upcoming TV series about evolution and how we can achieve a sustainable future on Earth.

Thomas Lewton: Whenever I watch the BBC’s *Springwatch*, it is clear you have a deep connection with the natural world. Does being autistic help you to form this connection?

Chris Packham: I think I was drawn to studying the natural world because of my ability to see things in great detail very rapidly and remember them. I have always found it easier to identify behaviours, or elucidate patterns of anatomy, physiology or whatever it happened to be. That curiosity about the natural world seemed to have been there almost inherently. My father was a marine engineer and my mother was a legal secretary, so the interest didn’t originate from them, but they certainly helped fuel it.

I was an avid collector of living animals

as a child. There were always things in jam jars and tanks in my bedroom. But when I got to about 12, my father bought me some binoculars. From that point onwards, I became less interested in keeping animals and more interested in watching them out in the wild.

I had an obsessive interest in natural history, and it would ricochet from one species or group of species to another. I suppose we call it "focused interest" now, but I'll stick with obsession. The more you can focus on a singular task or objective, the easier it is to exclude distractions. And then you tend to get to the bottom of what you're trying to understand. That's what excites your curiosity.

Those are incredible abilities. Being neurodivergent can, of course, also be challenging. How would you encourage others who are autistic or who have other forms of neurodivergence to think about how they experience the world?

It's about focusing on the opportunities and attributes that you might have rather than just the challenges and difficulties and embracing where that takes you. When I was a kid, I thought I was drawn to the woods by all those things that I wanted to see or catch at the time. But in reality, I was finding solace and respite there because I wasn't being judged by my peers. I felt very comfortable there.

I found I could totally immerse myself in the experience. Many people can identify a tree ›

"To address climate breakdown, we must move towards a far greater degree of equality"

"I'm asking a significant part of the population to change its mind and habits a bit more quickly than feels comfortable"

JIM WEST/ALAMY

A major environmental goal is to fuel economic growth while using resources sustainably

by its shape, or by its leaves, or by the pattern on its bark. But I can identify trees by the sound that rain makes on their leaves if I'm sitting underneath them with my eyes closed. That's not a tremendous skill. Anyone could learn that. But that's the sort of degree that I want to engage with nature.

You have dedicated much of your life to protecting nature. Why do you think you have faced a backlash to this activism?
Like many other people, I'm asking a significant part of the population to change its mind and habits a bit more quickly than feels comfortable. Humans, as we know, are remarkable animals. We're intelligent, adaptable, creative, imaginative, innovative. We're brilliant in many ways – but we're not very good at changing our minds.

But at this point it's very clear that unless we do change our minds and therefore our practices, we're going to be in even deeper trouble than we are already in. I try to [point out] that there are opportunities to deal with these problems. Let's take them while there's still a chance to do good and find positive outcomes. A section of society is reluctant to do that. And a tiny minority will push back in an aggressive and violent way.

What keeps you going in the face of this violence?
I genuinely don't care. I'm a very determined person. I can't be swayed from a course of action if I believe it's the right course of action. I've never picked a fight because I thought I could win it. I've always picked my fights because I thought they were the right fights to pick at the time. Winning isn't about crossing a line or getting a medal; winning is about not giving up.

At this point in time, that is the thing that you know people of my ilk – activists, campaigners, protesters – need to hold closest to their hearts. It's very difficult at the moment. It's very, very difficult.

In what way?
We're being persecuted, you know, through an unjust legal system in terms of public protest in the UK. If we want to protest today we just don't know where we stand. We don't know if we will be arrested for wearing a T shirt, holding a placard or banner. We're up against the terrible things which are happening in the US and other parts of the world when it comes to rolling back environmental protections, legislation and, indeed, environmental sciences.

Ultimately, though, I still think we are a wonderful species. We have the tools, technology and abilities at our disposal to make sure that we can adapt to the problems we've already generated. It's just that we don't have anyone out there with the gumption to roll them out broadly enough and rapidly enough to make a difference. So, I've got to help drive that.

You recently launched a petition to end fossil fuel advertising and sponsorship in the UK. Is this a major barrier to action on climate change?
Well, in the UK, fossil fuel companies actually don't spend too much money on advertising in the grand scheme of things, but they spend it in a very targeted way: they target decision-makers and politicians and others. People are being manipulated by mistruths.

But what we are increasingly seeing is billions of pounds being poured into sports sponsorship [by fossil fuel companies]. It subliminally ekes its way into people's lives, and they see those companies as doing something advantageous. It's normalising their business.

Their business has no right to be normal any more. It's destroying our planet. There's no ambiguity about it. We need to stop them being able to greenwash their dirty linen in public through that sort of sponsorship.

I mean, the idea that British Cycling is sponsored by Shell is like a bad joke. Cycling, something we do that is healthy, which combats carbon emissions. As is, I have to say, the continued acceptance of fossil sponsorship within some of our public institutions like the Science Museum and the British Museum, it shouldn't be allowed.

NewScientistLive

Hear more from Chris Packham at this year's New Scientist Live. On Sunday 19 October he will talk about the six species that have had the biggest impact on his life, then later explore neurodiversity with cognitive neurologist Gina Rippon.

For more information, visit newscientist.com/nslmag

KEVIN BRITLAND/ALAMY

Spending time in nature is one way to cut consumption

What does a sustainable future look like to you? It's very difficult, obviously, to look into a crystal ball, given advances in technology and now the very rapid advances that we see in climate breakdown. But what I think we need is a change in mindset. Firstly, everyone goes on about economic growth. But growth comes at the cost of consumption, and we live on a finite planet. So, quite clearly, we cannot continue to grow if we're using all those resources in an unsustainable way.

People need to rethink what they want out of life. Does that consumption really make us happy? What are the rewards that we get out of life? Whether you're into walking in the woods, whether you're interested in art, singing, dance or whatever it happens to be that excites you in life, it doesn't have to come at the cost of accumulating loads of stuff.

What other shifts in mindset are needed? Do you think people should consider not having kids as part of achieving a sustainable population? We have to be very careful when we're talking about overpopulation. Obviously, the more people on the planet, the more consumption takes place. The question is, of course, who's consuming it? And in many parts of the world, where populations are growing most rapidly, that isn't where consumption is the greatest.

If everyone on Earth consumed resources at the same rate as people in the US, then we would need about five Earths to sustain this demand. We can only consume so much because of the resource poverty of other people in the world who are underusing the world's available resources. I'm a very firm believer that when it comes to addressing climate breakdown, we must move towards a far greater degree of equality.

One of the most embarrassing things about the COP climate summit is that leaders fail to agree to significantly subsidise poorer countries in the world who are suffering most from climate breakdown. It's that sort of pervasive greed which is the handicap.

On another note, you are finishing filming a BBC TV series about evolution, which is coming out next year. Evolution takes place over innumerable generations, billions of years. What can humans learn from that deep-time perspective about their place within nature? Well, firstly, how lucky we are to be here. Mutations happen unpredictably. And the fact that they occur in a place where they can actually succeed is quite odd. I mean, the chances of human life evolving are infinitesimally small. And very often evolution comes down to serendipity.

Secondly, evolution gives us perspective on the damage humans are inflicting on the natural world now. We look at a number of mass extinction events in the series, and they aren't always catastrophic. You know, a meteorite takes out all the dinosaurs, which was a disaster for the dinosaurs, but hey, we mammals had a great time in the aftermath. All of those niches that were previously unavailable, mammals evolved to fill them.

So, at the moment, we're precipitating an extermination rather than an extinction event, since it's us that's driving it – and we need to get our language right. But whatever we do to the planet, life's tenacity will mean that it will survive and, you know, it will be beautiful, maybe even more beautiful all over again. ▮

ANDREA DOMENICONI/ALAMY

People protest over Shell's sponsorship of British Cycling

Thomas Lewton is a features editor at *New Scientist*

FRIENDLY BACTERIA

The gut experts for 90 years

Yakult has a long heritage and an amazing amount of science behind its iconic little bottle. Founder, Japanese scientist Dr Shirota, spent many years investigating the benefits of intestinal bacteria.

In 1930, he succeeded in selecting and cultivating a unique strain of lactic acid bacteria that was robust enough to reach the gut alive and increase the bacteria in the gut.* He used this strain, now known as *L. casei* Shirota, to make a fermented milk drink. And so, in 1935 the first bottle of Yakult was produced.

Fast forward 90 years, Dr Shirota's work is continued with passion by hundreds of scientists and researchers seeking future applications for this unique bacteria.

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*Yakult's bacteria *L. casei* Shirota, increase both the lactobacilli and bifidobacteria in the gut.

The back pages

Stargazing at home

Superb supermoons

If you are a fan of the moon, then the next four months will give you something special to watch out for, says **Abigail Beall**

Abigail Beall is a features editor at *New Scientist* and author of *The Art of Urban Astronomy*. Follow her @abbybeall

THE next few months will be a wonderful time for moon lovers, because we have four supermoons coming up – in a row. These exceptional full moons are the Hunter's moon in October, the Beaver moon in November, the aptly named (for the northern hemisphere, at least) Cold moon in December and January's Wolf moon. The key to being a supermoon is that it appears a little bigger and brighter than a regular full moon.

A supermoon occurs when a full moon happens when our satellite is at its closest point to Earth on its elliptical orbit around the planet. This makes it appear up to 8 per cent bigger and 15 per cent brighter than a regular full moon – things that skywatchers all over the world can see.

The closest full moon of the coming months will occur in November, but it is unlikely that the difference between this supermoon and the others will be noticeable. The best time to look at a supermoon is when it is rising or setting: being near the horizon gives the moon the illusion of looking even bigger – compared with objects in our immediate vicinity.

The first supermoon will occur on 7 October. If the night is clear, you should be able to see the moon fully lit up in the night sky as soon as the sun has set, wherever you are.

Even if you miss this, it is still a lovely time to check out the moon, because in the days following the full moon, it will creep across a busy part of the sky towards the constellation of Taurus. As it travels, there will be lots of objects to pick out.

PARKER SEIBOLD/THE GAZETTE/AP PHOTO/ALAMY

By 10 October, the moon will be waning, but still more than 75 per cent illuminated, and it will appear next to the Pleiades in the night sky. The Pleiades is a group of stars that is also known as the Seven Sisters. It is an open cluster, describing a collection of young stars that formed at the same time, and is about 440 light years away.

To the naked eye, only the brightest stars are visible – hence the name, Seven Sisters. They appear roughly in the shape of a square with a line coming out of one corner, like a mini version of the Plough, or Big Dipper.

By 14 October, the moon will be less than 50 per cent illuminated, so it will look just less than a half moon, and it will be next to the planet Jupiter. If you have binoculars or a small telescope, you might be able to make out some of Jupiter's four Galilean moons, its largest satellites.

If you want to study the moon in even more detail, then take a look at it through a telescope on 30 October, when it will be in its first quarter phase. For a few hours every month, there is a chance to see some fascinating optical illusions called the lunar X and V. These are shapes that appear on the moon's surface.

Then, by early November, it will be time for the next supermoon. ▮

Stargazing at home appears every four weeks

Next week
Mathematics of life

These articles are posted each week at newscientist.com/maker

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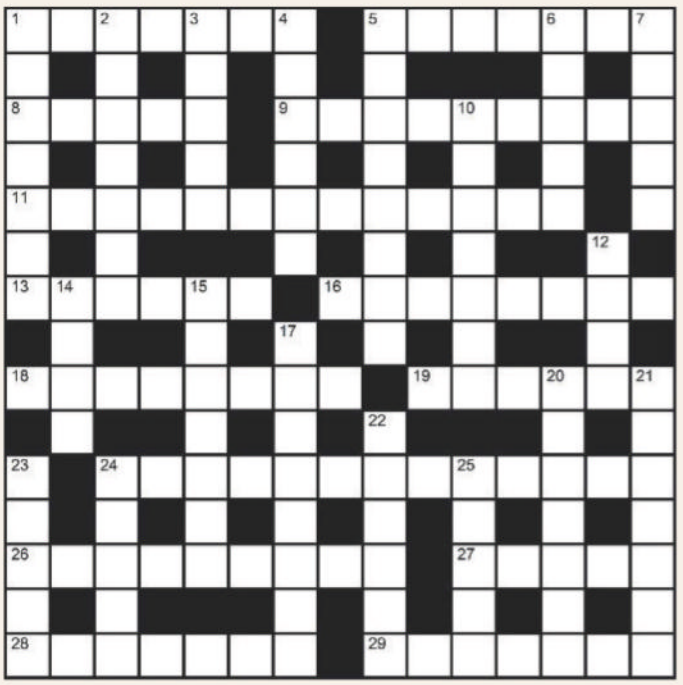
Quick crossword #193 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1 Bi (7)
5 Skin pigment (7)
8 Colourful, spring-blooming bulbiferous flower (5)
9 Clinging marine crustaceans (9)
11 Process of bringing something up to date (13)
13 Japanese car-maker (6)
16 kB (8)
18 Relatively massive elementary particle, t (3,5)
19 Dropsy (6)
24 Straightforward, efficient user interface or camera (5-3-5)
26 Tropical disease also known as schistosomiasis (9)
27 Smell (5)
28 Interestingly unfamiliar things or organisms (7)
29 Upper part of the throat (7)

DOWN

1 Viscous petroleum derivative (7)
2 Temperature at which a mixture partially melts (7)
3 Higher, superior (5)
4 Vehicle that uses two or more power sources (6)
5 ____ acid, another name for HCl (8)
6 Synthetic textile (5)
7 Concerning the nose (5)
10 Fatty tissue (7)
12 Stalk (4)
14 Fe (4)
15 Common name for Al_2O_3 (7)
17 Single-celled organisms (8)
20 The study of living systems (7)
21 Bacterial disease that causes black skin lesions (7)
22 Entrance slip road (2-4)
23 Filament (5)
24 Disease caused by a serotype of enterovirus C (5)
25 Plant pore (5)

Our games are now solvable online
newscientist.com/games

Quick quiz #322
set by Tom Leslie

1 In a typical ant colony, what sex are the worker ants?

2 What is the full name of the steroid molecule known colloquially as tren?

3 Who was the first woman to hold a professorship at Oxford or Cambridge?

4 What name is given to the decrease in electromagnetic wavelength caused by an object's movement towards an observer?

5 Adaptations in which structure give lions the ability to roar?

Answers on page 47

BrainTwister
set by Peter Rowlett
#93 Counting Gaps

You have a set of cards where each card has a single number written on it. The number 1 is written on two cards, the number 2 is written on two cards and 0 is written on one card.

Can you arrange the cards side by side in a line so there is one card between the two 1s and two cards between the two 2s? (The 0 card can be placed anywhere in the line.)

Can you follow similar rules (with n cards between the two cards numbered n) to arrange a set of cards that has two copies of each number from 1 to 5 and one 0 card?

Can you follow the same rules to arrange similar sets of cards whose numbers range from 1 to 3, 1 to 4 and 1 to 7, but that don't include a 0 card?

Answers next week

Weird water

How would the world be different if water didn't display a meniscus or surface tension?

Ron Dippold
San Diego, California, US
In its most basic form, surface tension is the tendency of liquids to bead up rather than spread out because they are more attracted to themselves (cohesion) than they are attracted to other things, for example the air or a surface (adhesion). So, the liquids act like they have a thin, elastic membrane on them. In the absence of other forces, every drop of liquid would tend to be a sphere.

I will only consider liquid-to-air interfaces here, since if liquid-to-liquid surface tensions were to disappear, cell membranes couldn't form, and there could be no life as we know it.

To start with, there would be various minor but noticeable differences. Water wouldn't bead up, it would run right down your window or off leaves, depriving plants of some water. The thin liquid film protecting the surface of your eyeballs relies on surface tension, so your eyes would be unprotected and dry.

"If there were no surface tension in water, it wouldn't be able to exist in a liquid state. Life on Earth would be impossible"

The biggest catastrophe would be the loss of capillary action. If a tube is narrow enough, and the water adheres to the tube more than it coheres to itself, you get a convex meniscus, where the liquid spreads a bit along the tube to adhere to the surface. Then more of the liquid is attracted to the liquid that is further along. This repeats, so the liquid moves further along the tube until, if the tube is vertical, the weight of the liquid stops it. You can see this by sticking a transparent straw in a cup of water. The liquid in the straw will be slightly higher than the liquid in the cup. The liquid metal mercury has surface repulsion, so it would do the opposite.

Capillary action gives you "free" liquid movement along a tube, even against gravity. Without it, a staggering number of physical and biological functions would be compromised. The tiny air sacs in your lungs where oxygen and carbon dioxide are exchanged with your blood would be crippled. Expelling mucus from your lungs would be much harder.

In the world of technology, inkjet printing relies on capillary action to pull tiny bits of ink through a tube. There are industrial uses too, like heat pipes and microfluidic devices, and medical uses like pregnancy tests and covid-19 tests. All of these would no longer work.

So this apparently tiny change would have more consequences than anyone could possibly enumerate, but it would certainly be bad for us. If it had always been like this, then life, if it existed, would be totally different. Needing windscreen wipers seems like a small price to pay.

Chris Daniel
Colwyn Bay, Conwy, UK
In a body of water, cohesive forces between H_2O molecules act in all directions, resulting in a net force of zero, but at the surface, the molecules bond only with others below them and to the sides. This imbalance of forces causes them to be pulled more tightly together, resulting in skinning or surface tension. When water meets another surface with a lower surface energy, such as the side of a glass container, a meniscus is formed that rises until it is balanced by the force of gravity. When unconstrained, water will try to minimise its surface energy and therefore its surface area by forming spheres such as those found as droplets of mist, fog and rain.

Some insects, such as pond skaters, make use of surface tension by skimming on the surface of ponds, their feet indenting but not breaking the surface of the water. Light objects like leaves and even sewing needles can be supported in the same way.

If there were no surface tension in water, then there would be no cohesive forces anywhere in the water and it wouldn't be able to exist in a liquid state. Life on Earth would then be impossible.

While surface tension cannot be eliminated, it can be greatly reduced with the use of surfactants, organic molecules that have water-loving, or hydrophilic, heads and water-hating, or hydrophobic, tails. The heads of the molecules (which may or may not be charged) intersperse themselves among the water molecules at the surface, reducing the net force or surface tension between them. This, in turn, reduces the angle of the meniscus, allowing the water to spread more easily onto other surfaces.

Surfactants in detergents cause water to penetrate fabrics or wet the surface of dishes, the hydrophobic tails attaching themselves to dirt and grease that can then be washed away. Similarly, surfactants in emulsifying agents allow oil-water mixtures such as mayonnaise or paint to become homogeneous by preventing the oil molecules from coalescing and separating from the water.

ADAM BURTON/ALAMY

Why do rainbows refract light into many colours, but cloud inversions don't?

This week's new questions

Cloud colour **Why do rainbows refract light into several different colours, but we don't see the same effect with cloud inversions?** ***Tony Sandy****, Alness, the Highlands, UK*

Itching to know **Why do we itch in random places? What makes this impulse manifest on, say, an elbow at one moment, but the back of a knee at another?** ***Rachel Loden****, California, US*

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Tom Gauld
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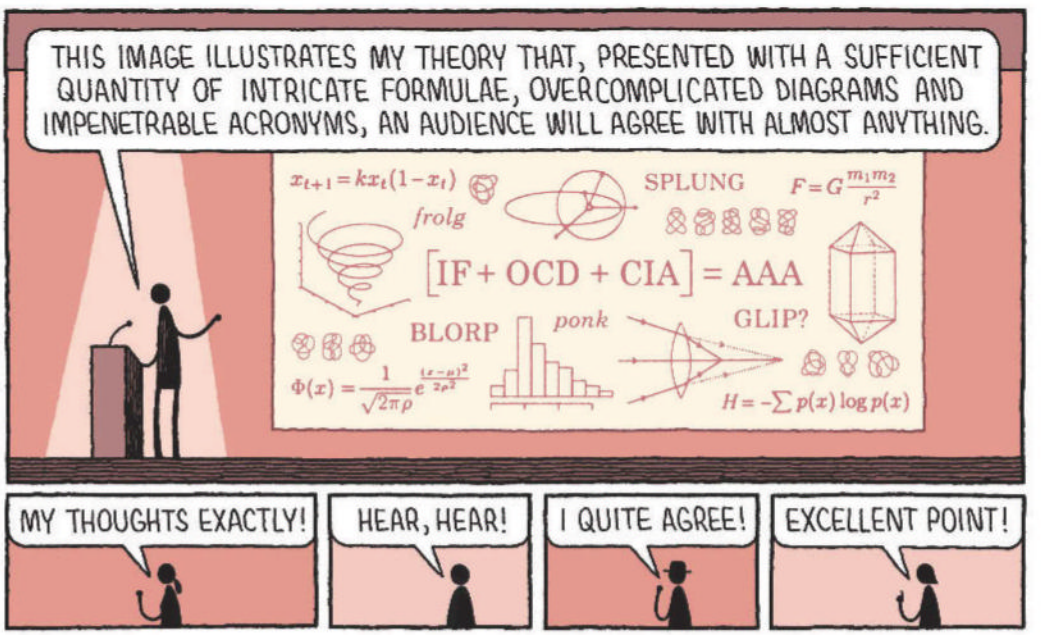


Staying warm

When getting dressed in the morning, I want to warm up as quickly as possible. Should I put on my trousers or my top first?

Mike Tipton
University of Portsmouth, UK
The question seems to suggest that the person is cold on awakening in bed. So, the first bit of advice would be to get a thicker quilt. It is easier to stay warm than it is to get warm.

Assuming mild, generalised cooling has occurred, the blood flow to the skin will have shut down (vasoconstricted), reducing skin and limb blood flow to low levels. In this state, most heat loss occurs from the torso and head (conduction through the tissues), so a top (with a hood) will slow body heat loss more than trousers. But the sensation of being cold is strongly driven by the temperature of the hands and feet. Due to the vasoconstriction, these will be the coldest parts of the body, so warming them up will help.

"In a cold room, your core body temperature must be maintained at about 37°C, but your lower legs and arms can be at around 31°C"

If it were me, I would put a top on first, then a woolly hat and socks, or, better still, have a shower. Active heating (warm water) is much quicker than passive heating by insulation (clothing) in this situation.

Hillary Shaw
Newport, Shropshire, UK
Definitely put your top on first. In a cold room, your core body temperature must be kept at about 37°C (98.6°F), but your lower legs and lower arms can be at around 31°C (87.8°F). This is why you see postal workers still wearing shorts in winter.

Herman D'Hondt
Sydney, Australia
Let me ask you a question. On a cold winter's day, would you prefer to go outside in shorts, but with a warm jacket? Or would you prefer to go topless, but with warm trousers? That should make it clear that you will lose more heat through your torso than through your legs. Hence, to warm up quickly, put your shirt on first.

Time rules

Why are there 60 seconds in a minute and 60 minutes in an hour? Who decided on this and when? (continued)

Duncan Boyd
Burlington, Ontario, Canada
Previous answers have sensibly referred to the Sumerian base-12 and Babylonian base-60 numerical systems, but I am surprised no one has noted that the second corresponds to a human's typical resting heart rate. Using the pulse as a timer would have complemented the top-down approaches used to divide the day into hours and provided a useful means to track brief time periods. Or maybe it is just a coincidence.

Answers

Quick quiz #322 *Answer*

1 Female
2 Trenbolone
3 Dorothy Garrod
4 Blueshift
5 The hyoid apparatus

Cryptic crossword #171 *Answers*

ACROSS 1 Clamour, **5** Float, **8** Torte, **9** Boulder, **10** Centrifuges, **13** Ermine, **14** Health, **17** Electrolyte, **20** Chinook, **21** Vapid, **23** Boggy, **24** Sidecar

DOWN 1 Cuticles, **2** Air, **3** One-iron, **4** Rebuff, **5** Flung, **6** On display, **7** Taro, **11** Numbering, **12** Shredder, **15** Evolved, **16** Stakes, **18** Epoxy, **19** Scab, **22** PVC

#92 Squares in piles *Solution*

For the squares of the numbers 1 to 7, we can make a pile of 1, 4, 16 and 49 and a pile of 9, 25 and 36, both of which add up to 70.

If we swap the 4 and 36, we can add 64 to get a pile of 1, 16, 36 and 49 and a pile of 4, 9, 25 and 64, both of which add up to 102.

It isn't possible to have two equal piles when we add 9^2, since the squares of the numbers 1 to 9 add up to 285, which is odd and so can't be split into two piles.

What's in a squeak?

Feedback's experience of mice is sadly confined to the dead ones (or, sometimes, barely alive ones) that one of our felines insists on bringing into the house. This means we have heard more than our fair share of squeaks.

So we were taken aback to learn that mouse squeaks have been almost entirely ignored by science. Reporter Alex Wilkins assures us that it is true, having read a recent study in *Biology Letters* entitled "Hidden in plain sound: the scientific potential of house mouse squeaks".

The thrust is that studies of house mouse vocalisations have focused on ultrasonic sounds that humans can't hear. Possibly these felt novel and surprising, so they stole the limelight. Meanwhile, the authors say, audible squeaks "have received less attention", leading to a "dearth in squeak-focused research".

This is clearly a mistake. The squeak has "considerable scientific potential", they say, because "the extent to which squeaks convey information about the vocalizer and affect listener behaviour across different social contexts has yet to be thoroughly studied".

Feedback suspects squeaks are a highly effective communication. We recall from reading Terry Pratchett that the grim reaperish character known as the Death of Rats could convey a lot with a well-chosen SQUEAK. Maybe we need a slogan. What do we want? SQUEAK. When do we want it? SQUEAK!

Puninative determinism

Sometimes nominative determinism comes at us in a slightly roundabout way.

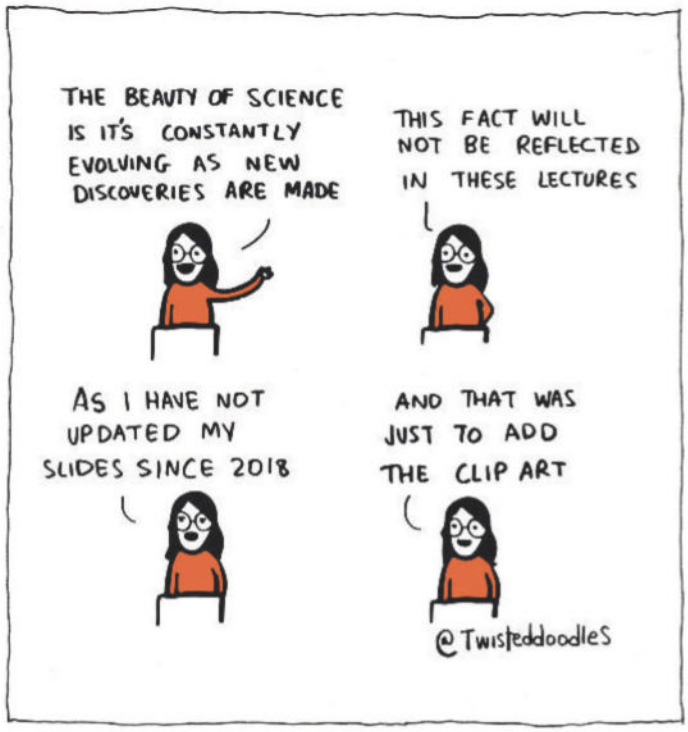
Paul Meara points out that a recent feature on body clocks (2 August, p 30) featured Angela Relógio, a researcher at MSH Medical School Hamburg in Germany, who is also the chief executive officer of a company called TimeTeller.

Unfortunately, Feedback doesn't speak Portuguese, or we would have known, as Paul does, that "relógio" means "clock".

Likewise, Feedback is aware that there are decades of research into the role of a protein called amyloid in Alzheimer's disease.

We were therefore even more taken aback to learn that the UK's University of Dundee has an Alzheimer's specialist called, er, Amy Lloyd.

Twisteddoodles *for New Scientist*



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Tough as nails

On 18 September, the most important prizes in the scientific calendar were announced in a scientist-studded ceremony: the Ig Nobels. These famously celebrate whimsical and offbeat research that nevertheless has significance. Or, as the creators of the event put it, "achievements so surprising that they make people LAUGH, then THINK".

Feedback didn't go to the event. Luckily the entire show is available to watch online.

Of the various awards, we were most intrigued by the Literature prize. This was given to teacher and clinician William Bennett Bean (1909-1989), "for persistently recording and analyzing the rate of growth of one of his fingernails over a period of 35 years".

His work on this included a 1953 study, titled simply "A note on fingernail growth", in which Bean set out "observations made over the past 10 years".

Several more in a similar vein followed, culminating in 1980's magnum opus "Nail Growth. Thirty-Five Years of Observation", published in the *Archives of Internal Medicine*. Feedback obtained this climactic nail paper and chewed our way through it.

Bean describes his study as "a very long record of the growth of human deciduous tissue" that "provides a slowly moving keratin kymograph that measures age on the inexorable abscissa of time".

What of the findings? Bean's first discovery was that the various nails grow at paces that are different, and that this is consistent over time.

"In simple terms, toenails grow more slowly than nails of the hand, and the nail of the middle finger grows more rapidly than the nails of either the thumb or the little finger or the other two middle fingers. By measuring one nail, the rate of growth can be calculated for all." After that, the discoveries racked up at about the speed nails grow.

Some factors, however, can cause a detectable slowing of nail growth. Bean had the mumps in 1950 and this caused a "decided slowdown", but after he recovered "there was a compensatory speed-up". Finally, he identified long-term slowdown. "The average daily growth of the left thumbnail, for instance, has varied from 0.123 mm a day during the first part of the study when I was 32 years of age to 0.095 mm a day at the age of 67."

Our only question is why it has taken the Ig Nobels so long to give Bean a prize, when he was so clearly an Ig-worthy researcher.

Other prizes went to research into "the extent to which a certain kind of lizard chooses to eat certain kinds of pizza", "what a nursing baby experiences when the baby's mother eats garlic" and "whether cows painted with zebra-like striping can avoid being bitten by flies".

Feedback particularly appreciates the Chemistry prize, awarded for trying to find out whether eating food enhanced with indigestible Teflon makes you feel full on fewer calories, a project that sounds an awful lot like an alcohol-fuelled dare. An experiment on rats suggested it works and is non-toxic, but nevertheless we wish to caution readers not to try this at home.

To be on the safe side, maybe we should just bulk up our food with powdered nail filings.


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