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Inside the race to
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REVEALS THE
SECRETS OF HIS EPIC
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The hidden tipping points that could trigger disaster

Health

How to maximise the benefits of your morning caffeine hit

Anthropology

The surprising tactics of Ice Age hunters

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FROM THE EDITOR



Since the first confirmed detection of exoplanets in 1992, astronomers around the world have identified thousands of other solar systems scattered throughout space.

The thing is, very few of them look like the Solar System we call home. Some have two stars instead of one at their centres, while others have planets orbiting their stars so closely that any 'rain' falls in the form of liquid metal.

A terrifying thought.

Our Solar System is classed as an 'ordered' system, meaning that, generally, the planets increase in mass the further out from the Sun they are. Very few other systems follow this model. In fact, fewer than two per cent of the systems that we know about do. That alone is enough to make ours special, before we even get on to the subject of life.

So, how did this all happen? The origin story of our Solar System – and, by extension, us – are questions that have occupied the minds of scientists and philosophers for generations. But with every new mission, we're getting closer to answering them. That quest for answers is the theme of Prof Brian Cox's new BBC Two series, *Solar System*. Across the five episodes, he looks at where we are in the story of our origin, as well as the spacecraft, due to launch soon, which will hopefully give us insights into the next chapters.

Maybe, in those chapters, we'll get closer to finding out if Earth really is unique, or if it's just one of many planets that provides a home to intelligent life. Read more about the making of Prof Cox's new series, and the origin story of the Solar System, starting on p66.

Daniel Bennett

Daniel Bennett, Editor

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ON THE BBC THIS MONTH...

Curious Cases: Bubbles

The Curious Cases team takes a fun look at the science of bubbles. What role do they play in the ocean, how do they work in space and could you really make one large enough to wrap around the entire planet?

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Solar System

In this new five-part series, Prof Brian Cox takes us on a tour of the Solar System, from the volcanoes on Venus to the frigid nitrogen glaciers of Pluto.

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Protein: Powerhouse or Piffle?

Social media is full of people with rippling muscles waxing lyrical about the benefits of protein. But how much should we be eating, and can it really help us lose weight and be healthier?

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Could I really land a plane in an emergency? [→p84](#)

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DR EMMA BECKETT

Olive oil is celebrated for its health-giving properties. But could the water leftover from its production be just as good for us? Food scientist Emma gives us the lowdown. [→p32](#)



PROF BILL MCGUIRE

The planet is worryingly close to breaching several climate tipping points, but one of them worries climate scientists like Bill a lot more than others. [→p76](#)



DR SIMON CORK

Demand for the weight-loss drug Ozempic is soaring, but people need a prescription to get it. Could making it available over the counter be the solution? Physiologist Simon investigates. [→p35](#)



JOE PHELAN

Far from being the vicious predators portrayed in movies, sharks are a vital part of ocean ecosystems. But they're under threat. Science writer Joe examines efforts to protect them. [→p46](#)

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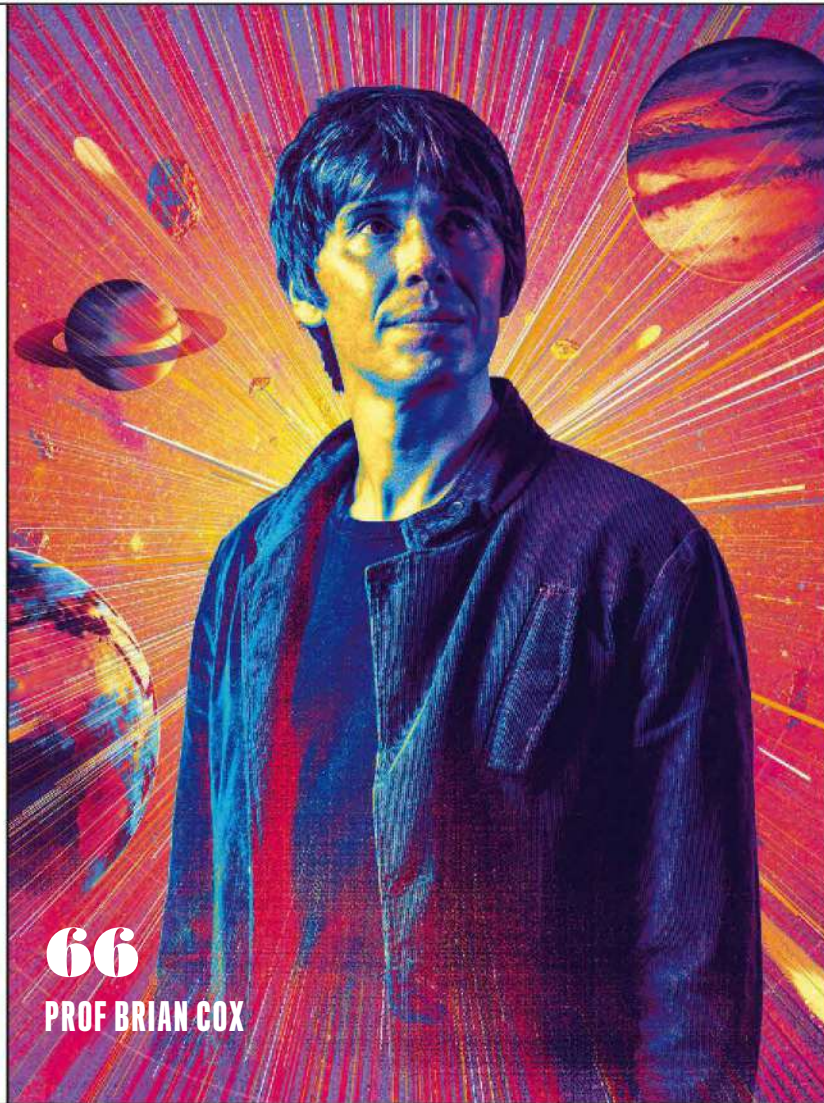
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“PLANTS MIGHT HAVE EVOLVED SPECIFIC TRAITS NOT JUST TO ATTRACT BIRDS AND MAMMALS, BUT ALSO INSECTS”

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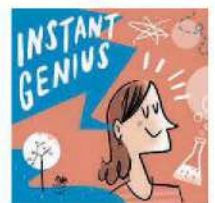
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EYE OPENER

A new level of power tool

ROME, ITALY

This is no ordinary drill. It's a robotic device that has been built to search for water on the Moon. It's one part of the Package for Resource Observation and in-Situ Prospecting for Exploration, Commercial exploitation and Transportation suite of instruments (PROSPECT to its friends), which the European Space Agency hopes to send to the Moon in 2028.

The drill (called ProSEED – PROSPECT Sample Excavation and Extraction Drill) features a multispectral imager and other sensors to detect and analyse the mineralogy of the regolith at its intended landing site of the lunar South Pole. Once the sensors pick up the right signs, the drill will bore more than a metre (3ft) into the surface to hunt for frozen water and other volatiles (easily vapourised chemicals).

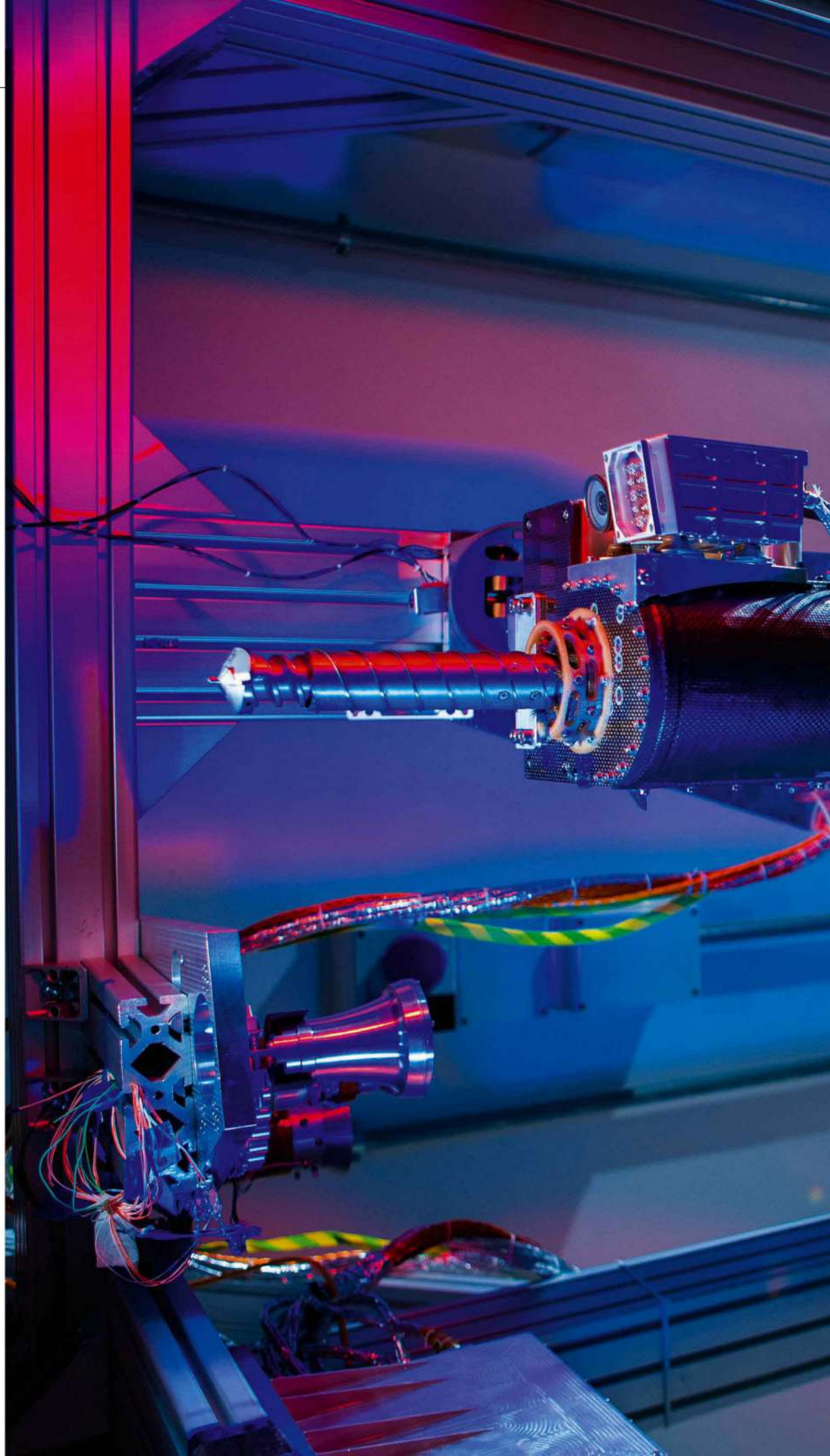
Samples obtained by the drill will then be passed to a mini laboratory that also forms part of the PROSPECT suite. Here, the samples will be heated to analyse their constituent chemicals from the gases they release. PROSPECT will also test specific processes that could be applied for mining substances like Helium-3 in the future.

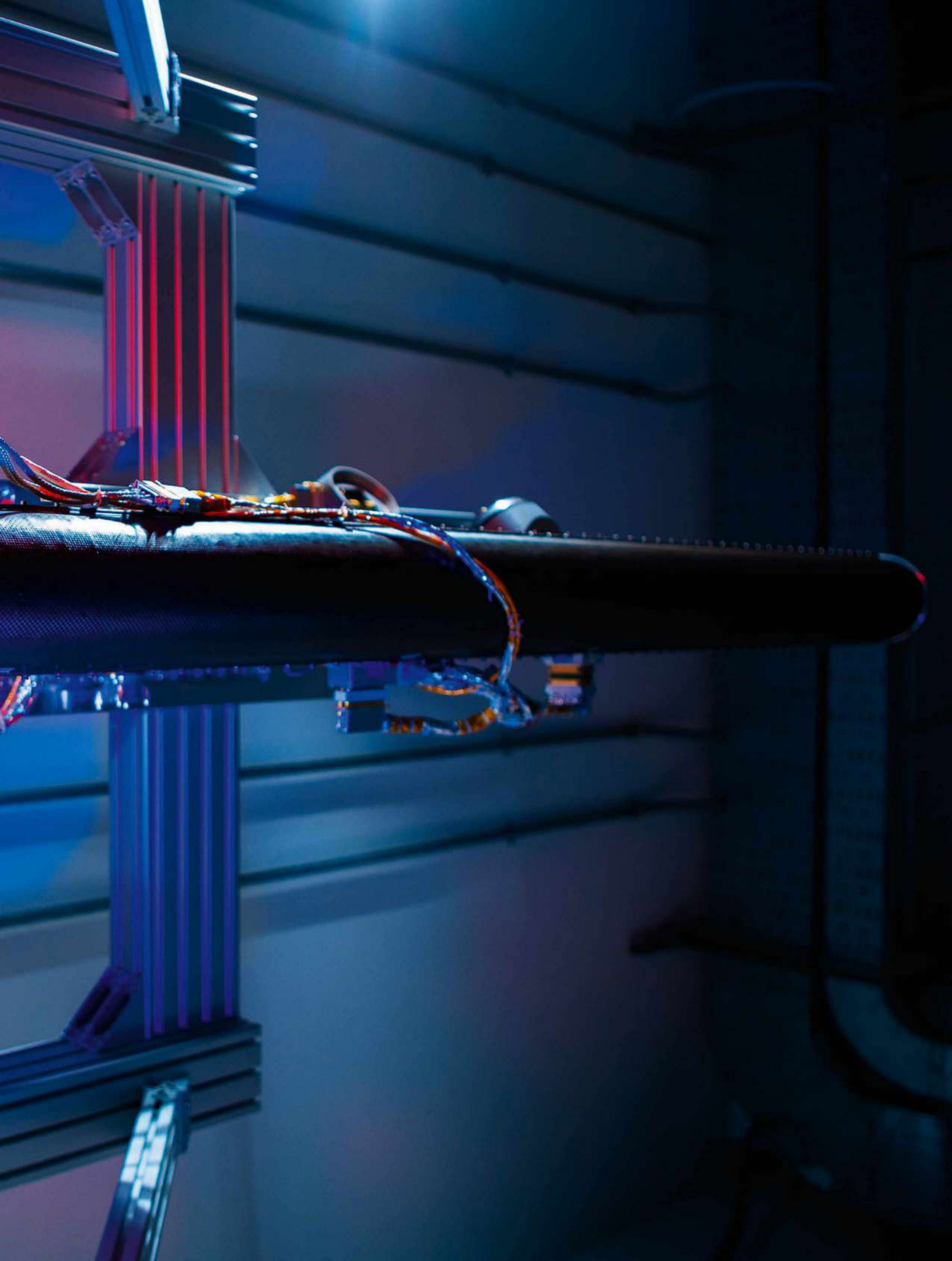
LEONARDO SPACE

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EYE OPENER

Deeply strange

NAZCA RIDGE, CHILE

First discovered in 2016, 4,290m (approx 14,000ft) below the surface of the Pacific Ocean near Hawaii, the Casper octopus is a remarkable species. Ghostly in appearance due to a lack of pigment, it takes its name from the famously friendly cartoon spectre.

Eight years after the discovery of the species, this example was observed by researchers from the Schmidt Ocean Institute during an expedition to the Nazca Ridge off the coast of Chile.

The Casper octopus is remarkable for another reason besides its appearance and preference for deep waters: its parenting. After attaching a clutch of about 30 eggs to a dead sea sponge, the octopus will wrap itself around them until they hatch, which takes years. During that time, the octopus doesn't eat and gradually wastes away.

There's much we still don't know about this strange creature, including why it has such short arms. "It's possible they don't stretch out and grab prey, as other octopuses do, but rather they position their bodies directly over prey hiding in the soft seabed," says Dr Helen Scales, a marine biologist.

ROV SUBASTIAN/SCHMIDT OCEAN INSTITUTE

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EYE OPENER

A star is born

This isn't one image, but a mosaic of many, combined to form a massive view of NGC 1333, a star-forming cluster around 960 light-years from Earth. Sitting deep within the Perseus molecular cloud, the cluster had been hidden from view until it was captured by the James Webb Space Telescope (JWST) in August.

Hubble captured an image of the Perseus cloud back in 2003, which, while impressive, didn't show anything like the detail visible in this one – much of the star-forming activity seen here was obscured by the cloud's dust.

"JWST behaves like the thermal-imaging cameras used by search-and-rescue teams to see through smoke or dust. Its sensitivity to longer wavelengths of light, together with its superb resolution, allows us to peer into the dusty, star-forming regions so that we can get a better look at individual stars in the process of forming," says Dr Claire Davies, a physics and astronomy lecturer at the University of Exeter.

The glowing patches of orange gas swirling around the centre are a telltale sign of intense star-forming activity. The swirls form when the material ejected from young stars collides with the surrounding cloud.

NASA/ESA/CSA

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LETTER OF THE MONTH



A section of Brunel's atmospheric railway can be seen in Didcot, today

Brunel's other railway

May I add to your fascinating piece, 'The unexpected return of pneumatic tubes' (September, p40)?

First, I well remember the network of pneumatic vacuum tubes in Buttons store in Luton in the 1950s. These were so sales notes and receipts could be placed in canisters and sent between the sales counters and office. There was an interesting 'sucking' sound when the vacuum tubes were opened.

Second, there's a long history of vacuum and air-pressure railways in the UK and around the world. The most famous one in the UK was Brunel's Atmospheric Railway (albeit based on air pressure, rather than a vacuum) in South Devon in the late 1840s, of which there are many remains today.

Unfortunately, these early air-based railways often suffered from climatic damage to leather seals and, in some cases, from rats enjoying the tallow greasing of the seals.

Richard Lindley, via email

Dirty water

It was good to see a dispassionate breakdown of the issue of water companies contaminating waterways in 'Sewage in the UK's waterways: The facts' (August, p22). It really helped me understand how spills can occur legally and illegally, and how they're causing the poor water quality we keep hearing about.

Luke Russell, Wakefield



The problem of sewage in Britain's waterways needs to be addressed

Complaining about the noise?

When answering the question, 'How do whales sing under the sea?' (August, p86) Dr Helen Scales mentions that some ships' propellers make it difficult for baleen whales to hear each other, as there's an overlap in frequency with their songs. Could this be a reason why orcas have attacked vessels in the Mediterranean (Summer, p48), as they find them annoying?

Fred Bellamy via email

That's where the action is

In response to Geoff Wheeler and Mike Carr's letters in August's edition (Feedback, p13). BBC Science Focus keeps us up to date with science, without demanding that every reader has a vast knowledge of the specific topics. There's a lot going on in astronomy at present, which may seem to suggest a bias, but this could be said of other subjects from time to time, psychology for example.

Rodney Minns, Liphook

ALAMY, GETTY IMAGES

WRITE IN AND WIN!

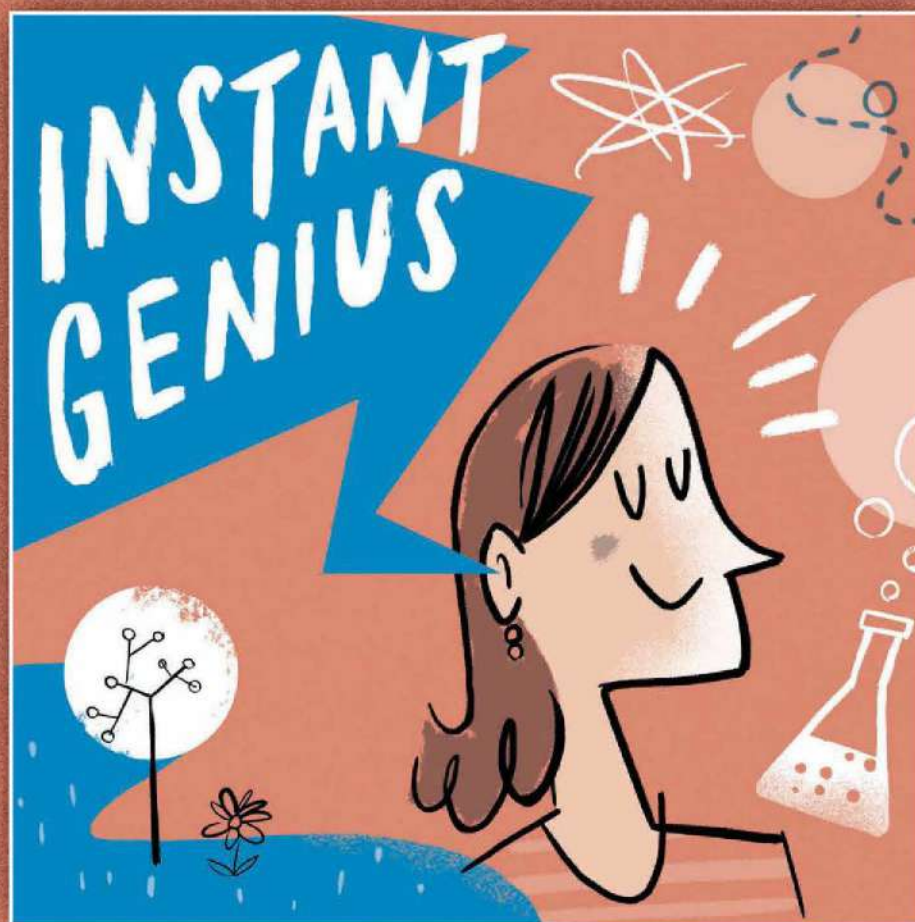
The writer of next issue's Letter of the Month wins a pair of paperback popular science books: *We Are Electric* and *Supersy Science*.



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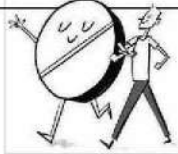
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SPORTS

with

Dr Madeleine Orr



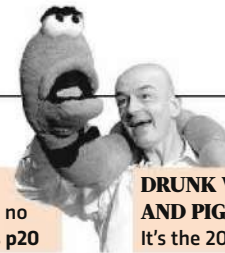
A NEW RIVAL TO OZEMPIC

The weight-loss drug's makers have a more effective version, in pill form p18



DESIGNER-DOG HEALTH

Labradoodles and cockapoos may be no healthier than their pedigree parents p20



DRUNK WORMS AND PIGEON BOMBS

It's the 2024 Ig Nobel Awards p22

NEWS FROM THE FRONTIERS OF SCIENCE

SPACE

Satellite collisions are a disaster waiting to happen, experts warn

With satellites old and new orbiting alongside each other, serious crashes are inevitable

In the first half of 2024, satellites belonging to SpaceX's Starlink fleet performed almost 50,000 collision-avoidance manoeuvres. This reflects the number of satellites orbiting Earth and raises fears about satellite collisions if we continue to launch more in an unchecked fashion. Considering how much of our telecommunications and navigation now comes from space, not to mention the observation data that informs us about climate change, fears of a catastrophic crash – triggering a loss of such essential services – are understandable.

But according to Andy Lawrence, Regius Professor of Astronomy at University of Edinburgh, it's more insidious than that. "This idea that eventually there will be some sort of catastrophe is not quite →

DISCOVERIES



With more satellites in orbit, there are more chances of collisions

RIGHT Satellite collisions can produce thousands of pieces of debris that litter orbital space around Earth

→ right. It's more like the infamous 'boiling the frog' problem," he says.

Essentially, the idea is that if a frog were dropped into boiling water, it would instantly leap out. But if it were placed into cold water to which heat was gradually applied, it wouldn't perceive the danger and be boiled alive. "It's exactly like climate change. You know it's getting gradually worse, but where do you say 'stop', and how do you manage to make it stop?" says Lawrence.

To circle the Earth, a satellite has to move at a minimum of 7.8km/s (4.8 miles/s). At this velocity, collisions would release an enormous amount of energy, shattering the spacecraft involved and producing large clouds of debris that could destroy other satellites.

Such crashes have already been happening: in 2009, the functioning US satellite Iridium 33 and the inoperable Russian Cosmos 2251 collided at 11.7km/s (7.3 miles/s), producing more than 2,000 pieces of trackable debris and many smaller pieces.

There are now more than 13,000 satellites in orbit, of which around 10,000 are functioning. In January 2023, the decommissioned US/UK/Netherlands' IRAS (Infrared Astronomical Satellite) space telescope came within 15–30m (49–98ft) of America's Gravity Gradient Stabilization Experiment (GGSE-4) satellite, which has been inoperable since 1972. A month later, NASA's scientific TIMED (Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics) satellite passed just



"It's exactly like climate change. You know it's getting gradually worse, but where do you say 'stop'?"

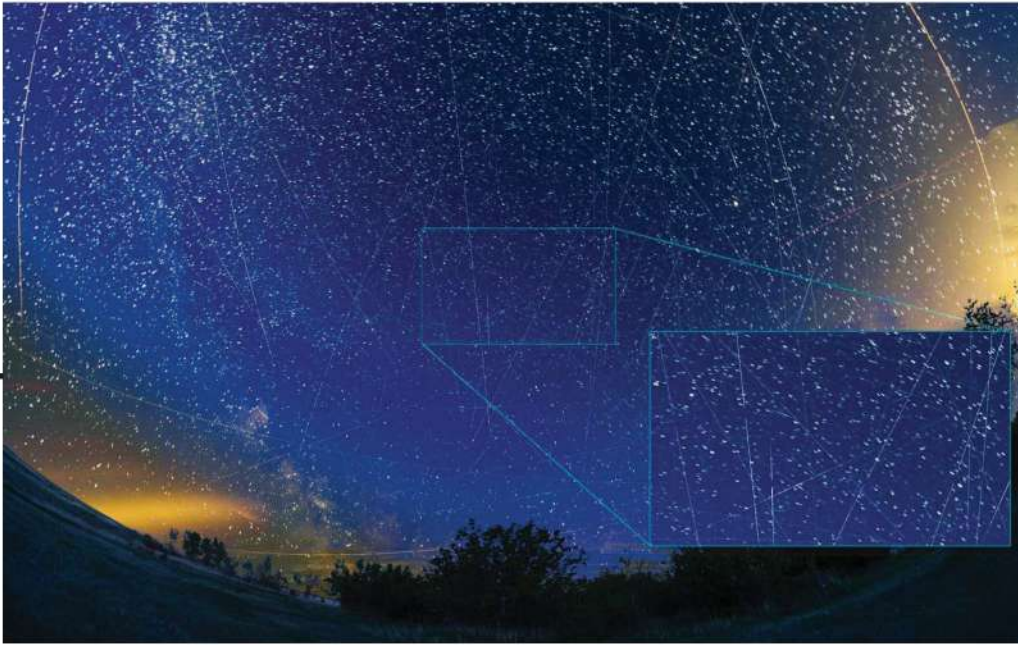
10–20m (33–66ft) from a defunct Russian satellite, Cosmos 2221. Although functioning, TIMED is a non-maneuvrable spacecraft, meaning that operators on Earth could simply watch and hope.

Commenting on the conjunction, as these close passes are called, the space tracking company LeoLabs posted on X: "Too close for comfort." In the subsequent message thread, it was pointed out that if these two satellites had collided, it would have produced 2,000–7,000 fragments big enough to track from Earth. Since there are currently around 12,000 pieces of trackable space debris, such an event would

have significantly added to it. While Lawrence doesn't believe a single catastrophic event is what will happen, he says one day a collision could take out something important to many people. "If suddenly you can't see the Super Bowl game, or an important military asset gets damaged, people will realise something's got to be done."

Satellites have been a feature of our world since 1957 when the Soviet Union launched Sputnik 1 to the astonishment of all. But the huge increase in the number of satellites in orbit in recent years means the risk of these fast-moving objects colliding has never been higher.





The dramatic rise in satellites has been driven by companies seeking to establish space-based internet services. To provide acceptable response times, the satellites have to be in low-Earth orbits, where they speed around the world every 90 minutes. So, to ensure unbreakable coverage and sufficient bandwidth, hundreds, thousands, if not tens of thousands of satellites are needed.

Starlink is the largest of the satellite constellations, having placed more than 7,000 satellites in orbit since 2019. To lower the risk of collisions, its satellites are manoeuvrable: onboard software executes a manoeuvre if it calculates

TOP Thousands of satellites are crowding the night sky

ABOVE Sputnik 1, launched by the Soviet Union in 1957, was the first satellite to orbit Earth

the probability of a collision is higher than 1 in 100,000. This is helpful, but some experts worry that the increasing number of satellites will overwhelm the software's ability to cope. (Starlink did not respond to *BBC Science Focus's* requests for comment on this.)

In 2023, Dr Jonathan McDowell, an astrophysicist at the Harvard-Smithsonian Center for Astrophysics, expressed this concern to the news website *space.com*, saying "we are operating at the edge of what is safe."

And it's not just orbital space that could be at risk from the increasing number of satellites. In an early effort to combat space junk, a decade or two ago NASA and ESA issued guidelines saying that at the end of a satellite's working life or after 25 years (whichever comes sooner) an operator must remove it. Mostly this means burning it up in Earth's atmosphere, but this could just be shifting the problem.

"You're filling the atmosphere with aluminium and nitrous oxide, so it's about atmospheric pollution as well," says Lawrence.

In April, NASA confirmed that a piece of discarded cargo from the International Space Station had survived re-entry and fallen to Earth, leaving a large hole in the ceiling and floor of a Florida house. Thankfully no one was hurt.

Obscuring our view of the Universe

As the number of satellites around Earth grows, so does the interference that astronomers experience when studying the sky. At visual wavelengths, satellites can leave streaks across images.

At radio wavelengths, satellites can emit signals that drown out the precious whispers from the distant Universe.

"As we industrialise space, which is a good thing, there will be challenges to astronomy," Prof Brian Cox recently told *BBC Science Focus*. "How you balance those things is the challenge in the next decades." (Read more from Prof Cox on p66).

A study with the LOFAR (Low Frequency Array) radio telescope, below, in the Netherlands showed that the most recent V2-mini Starlink satellites emit unintended radio waves that are up to 32 times brighter than the previous generation. That's 10 million times brighter than the faintest objects that LOFAR is capable of detecting.



HEALTH

New Ozempic-like pill cuts weight by 13 per cent

A new weight-loss drug's effects could rival the current injection-only medication

Weight-loss drugs like Ozempic and Wegovy are a hot topic, but new research suggests there could be a more effective alternative: Amycretin.

In the first human trial of Amycretin, its creator Novo Nordisk A/S (the pharmaceutical company behind Ozempic) recorded promising results. In fact, the trial found that people taking Amycretin lost an average of 13.1 per cent of their body weight over a period of 12 weeks. But unlike Ozempic and Wegovy, which require injections, Amycretin comes in pill form.

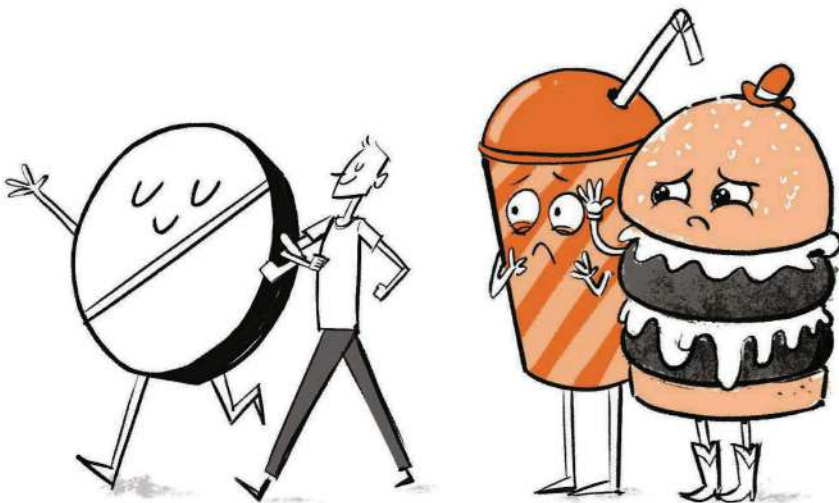
So how does this new pill work? Well, Amycretin is a kind of two-for-one deal, in that it mimics the actions of two hormones involved in weight loss: amylin and glucagon-like peptide (known as GLP-1). They both help to decrease hunger sensations and control appetite.

Published in the journal *Diabetologia*, the research compared

average weight loss across three groups of people. At the end of the 12-week period, scientists found that people taking a pill containing a double shot of 50mg Amycretin lost 13.1 per cent of their body weight, while those taking a single 50mg pill lost 10.4 per cent. In comparison, people who took a daily placebo only lost an average of 1.1 per cent of their body weight over the trial period.

For comparison, a recent study published in *JAMA Internal Medicine* found that people taking another weight-loss drug, Mounjaro, lost 5.9 per cent of their body fat across three months, while those taking Ozempic lost 3.6 per cent.

“Novo Nordisk has perhaps been lagging behind when it comes to developing competitive multi-acting single molecules, but Amycretin appears to be a promising advancement,” obesity expert Dr Christoffer Clemmensen of the University of Copenhagen, Denmark, who was not involved in the study, told *BBC Science Focus*.



NATURE

Tiny bug sets record for the fastest backflips on Earth

The insect somersaults so quickly that it seems to disappear

In a year already filled with incredible sports achievements, one athlete has now pulled off a truly astonishing feat: the fastest backflip on Earth. The record goes to a tiny bug known as a globular springtail, which performs the manoeuvre so quickly it appears to vanish entirely to the naked eye.

The globular springtail (*Dicyrtomina minuta*) is very small at only 1mm tall and a hexapod, meaning it has six legs. Researchers have discovered that it rapidly

ILLUSTRATIONS: ADAM CALE

PSYCHOLOGY

Being mentally resilient could help you live a much longer life, study finds

Coping well in the face of hardship may benefit your body as well as your brain

somersaults backwards to propel itself to over 60 times its body height – in the blink of an eye.

To learn more about the bugs, the researchers used a camera that shoots 40,000 frames per second. They started by provoking the bugs to jump by shining a light on them or tickling them with a small paintbrush. Then, using the super-fast video footage, they studied how the bugs take off, how fast they move, how far they go and how they land.

They discovered that the bugs take off with the same acceleration rate as a flea, moving at one-thousandth of a second to backflip off the ground. But then globular springtails do something unusual: they spin. Reaching 368 rotations per

“They started by provoking the bugs to jump by shining a light on them or tickling them with a small paintbrush”

second, this action is what makes them disappear.

This motion, the researchers think, is like putting on a vanishing act to escape predators: the globular springtail’s only superpower, given that it doesn’t fly, bite or sting.

“This is the first time anyone has done a complete description of the globular springtail’s jumping performance measures, and what they do is almost impossibly spectacular,” said Dr Adrian Smith, corresponding author of the paper published in the journal *Integrative Organismal Biology*.

If you feel that there is more to cope with as you get older, you’re not alone. But new research suggests that those who bounce back better from tough times could enjoy longer lifespans.

The new study, Published in *BMJ Mental Health*, showed that adults with the highest levels of mental resilience in older age had the lowest chance of dying, cutting their risk of death from all causes by a whopping 53 per cent.

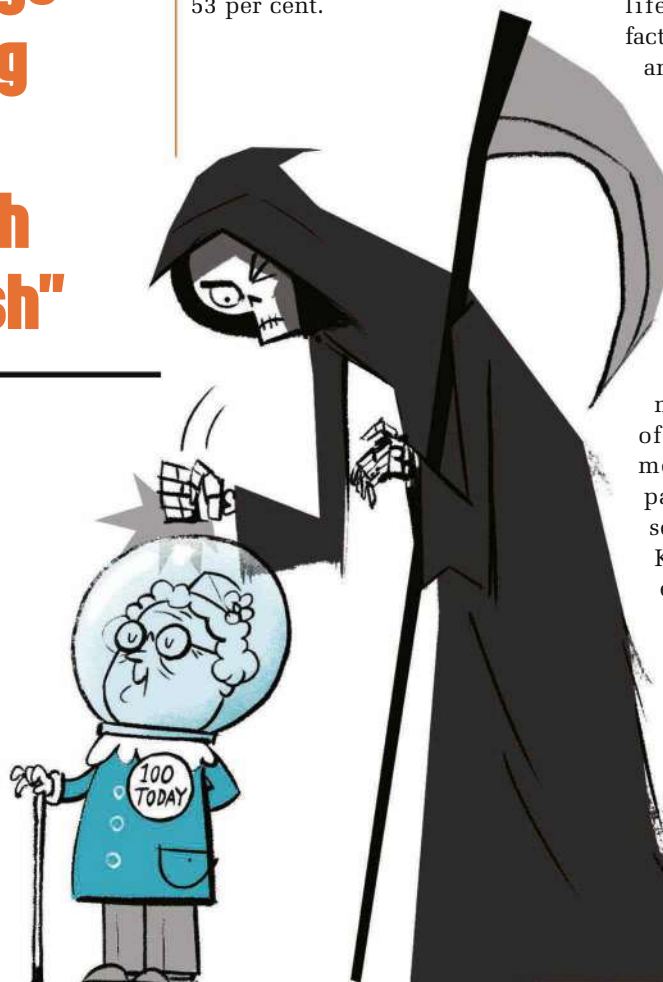
The study collected information about mental resilience and health from a large study of US adults aged 50 years and above. Over time, the scientists followed 10,569 adults for around 12 years or until they died (whichever happened soonest).

First, they measured their mental resilience and scored them on a scale of 0–12 based on their answers to a questionnaire. The questions established their perceived calmness, perseverance, self-reliance and sense that certain experiences must be faced alone. Then the researchers split the participants into four groups depending on this score. They discovered that, compared to the group with the least resilience, the most resilient older adults were 53-per-cent less likely to die in the next 10 years.

According to the scientists, mental resilience is an active process that changes across your lifespan and is influenced by factors such as your sex, hormones and genes that regulate the body’s stress response. But having meaning in life, positive emotions and satisfaction with social support can all also impact your resilience, they explain.

“Triggering these positive emotions may enhance the protective effects of psychological resilience and mitigate the negative impact of accumulated adversity on mental health in adults,” the paper’s authors, from Sun Yat-sen University, China, and the Karolinska Institutet, Sweden, explained.

In fact, the researchers think that mental resilience could have similar effects to bouncing back physically after illness and trauma, as good coping skills may offset the negative impacts of tough times.



ANIMALS

Crossbreed dogs might not be as healthy as you think, says study

The largest-ever study into the health of crossbreeds busts myths about what makes a healthy dog

If you've ever considered getting a dog, you've probably been given the same advice as every other potential owner: get a crossbreed. With longer lives and healthier bodies, these dogs are the obvious choice... or so we thought.

A new study from the Royal Veterinary College (RVC), London suggests otherwise, finding that

the overall health of designer crossbreeds (crossbreeds from two purebred dogs) is largely similar to their parents. "The popularity of designer crossbreeds has boomed over the past decade in the UK," said Dr Rowena Packer, senior author of the study and lecturer at the RVC. "However, our previous research discovered that many are purchased based on assumed characteristics that are not well-evidenced, such as

ANTHROPOLOGY

New research reveals Ice Age hunters tricked mammoths into impaling themselves

Rather than tracking and killing prey, ancient humans may have tricked animals to make them run into spears

Thirteen thousand years ago, human existence depended on our ability to find ways to survive in the snow and ice. Now, scientists think the solutions we found were even more ingenious – and brutal – than we initially thought. Research has found that Ice Age hunters probably crafted

a specialised weapon to make animals impale themselves.

Previously, researchers thought that hunters would throw spears topped with razor-sharp rocks (palm-sized tools known as Clovis points) at their giant prey. These included mammoths, mastodons (similar to mammoths, but more closely resembling modern-day

elephants) and bison. That, or the humans used the sharpened rocks to kill and butcher any wounded animals they scavenged.

But the new study, published in the journal *PLoS ONE*, suggests we may have got it wrong. The authors, archaeologists from the University of California, Berkeley in the US, think the weapons were used to trap and maim charging animals – and in some cases as a defence against sabre-toothed cats.

The theory is that the hunters would plant the bases of Clovis point-topped spears into the ground, with the spike facing upwards at an angle. Then, when a charging animal ran at them, its own force would drive the spear deep into its body. Given a mammoth could weigh as much as nine tonnes, this is likely to have been more damaging than even the strongest of hunters thrusting a spear into the animal.

"This ancient Native American design was an amazing innovation in hunting strategies," said Dr Scott Byram, first author of the paper. "This distinctive indigenous technology is providing a window into hunting and survival techniques used for millennia throughout the world."

Confirming this theory required several bizarre methods, including a simulation of this hunting technique. Essentially, the researchers built a test platform to see how much force a replica spear system could withstand before breaking. Next, Byram and his team plan to build a fake mammoth to further test their theory, using a slide or pendulum to thrust it down onto a replica Clovis point.



ILLUSTRATIONS: ADAM GALE

perceptions they are hypoallergenic, good with children and have good health.”

The study, the largest ever on the health of designer crossbreeds, surveyed 9,402 UK owners of three common crossbreeds (cockapoos, labradoodles and cavapoos) and their parent breeds (cocker spaniels, labrador retrievers, cavalier king charles spaniels and poodles). The researchers used owner-reported

information to compare the likelihood of each breed having one of 57 common disorders in dogs.

They discovered that there was no difference between the designer crossbred and purebred dogs in the likelihood of getting 86.8 per cent of these disorders. For the other 13.2 per cent, there was a difference between breeds, but no link between whether they were crossbred or purebred: each type

was equally likely to have these disorders. Among the disorders that designer crossbreeds were more likely to have, ear infections came top. Cockapoos also had a higher chance of itchy skin. However, both labradoodles and cockapoos had a lower risk of slipping kneecaps compared to their parent breeds.

“Our foremost priority should be overall dog welfare,” said Gina Bryson, lead author of the paper.

HEALTH

‘Too much of a good thing’: Fasting has many health benefits, but there’s a snag

Researchers warn of unseen risks

Intermittent fasting can lengthen your lifespan and aid weight loss – but according to a new MIT study, there could be a dark side to the regenerative powers of fasting.

The researchers behind the study, published in *Nature*, discovered that eating again after fasting activates a pathway that’s crucial for boosting regeneration in stem cells – an important process for healing injuries. But they also found a downside: cancerous mutations caused by this regeneration were more likely to develop into early-stage tumours. “Having more stem cell activity is good for regeneration, but too much of a good thing over time can have less favourable consequences,” said Prof Ömer Yilmaz, senior author of the study.

Observing mice eating again after a 24-hour fast, the researchers discovered that stem cells proliferated most at the end of the ‘refeeding’ period (much more than in mice who hadn’t fasted at all). This intense regeneration is caused by nutrients becoming available again, which enables stem cells to divide and grow – and therefore build

more specialised cells. But they discovered that the mice were much more likely to develop cancerous polyps during refeeding.

“I want to emphasise that this was all done in mice, using well-defined cancer mutations. In humans, it’s going to be a much more complex state,” Yilmaz said. “But it does lead us to the following notion: fasting is

very healthy, but if you’re unlucky and you’re refeeding after a fasting, and you get exposed to a mutagen, like a charred steak or something, you might actually be increasing your chances of developing a lesion that can go on to give rise to cancer.”

The researchers emphasise that human trials are needed to confirm the results in people.



“They discovered that the mice were much more likely to develop cancerous polyps during refeeding”

THE IG NOBEL AWARDS

The annual spoof-Nobel prizes celebrate the weird and wonderful side of science. Here are some of 2024's winners



Peace

Awarded to the late Prof BF Skinner for his experiments on live pigeons. In the paper 'Pigeons in a Pelican', he details tests on the feasibility of housing the birds inside World War II bombs to guide them to their targets. Skinner himself called it a "crackpot idea."

Physiology

Won by a team of Japanese and American researchers, the physiology Ig Nobel Prize solved a crucial question: Can mammals breathe out of their anuses? Turns out they can. The discovery could also help treat respiratory failure in humans.

Botany

Jacob White, from the US, and Felipe Yamashita, of the University of Bonn, won the botany prize for finding evidence that the South American plant *Boquila trifoliolata* can mimic the leaves of plastic plants nearby, indicating some form of plant vision.

Medicine

Fake medicine that causes painful side effects can be more effective in treating patients than fake medicine with no side effects, according to the Swiss, German and Belgian winners of the medicine prize.

Physics

It's not all fun and games: Prof James Liao from the University of Florida won the physics award for his investigation into the swimming abilities of a dead trout. Why? To demonstrate passive propulsion in fluid dynamics, of course.

Probability

A mostly Dutch team of 50 researchers won this category by setting out with a simple idea: to test the hypothesis that coin tosses are more likely to land the same way up as they started. To test it, they flipped 350,757 coins, confirming their theory, but only by a small margin.

Chemistry

In another fairly simple, but bizarre study, a team from the Netherlands used chromatography to separate drunk and sober worms. It's not entirely clear why, other than trying to advance polymer science.

Biology

Fordyce Ely and William E Petersen were posthumously awarded this prize for their 1940s research into factors affecting milk production in dairy herds. They placed a cat on the back of a cow, and repeatedly burst inflated paper bags next to it to see if the milk flow changed. Turns out a scared cow produces less milk.



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1

1. Paramotorists Márcio Aita Júnior and Senderson Laurido fly over crescent dunes near Lomas de Amara in Peru. Together, the ground and air teams have been able to survey over 150km² (37,066 acres) of Peru's deserts.

2. Aita Júnior (left) with botanists Oliver Whaley (middle) and Alfonso Orellana-Garcia (right), conducting fieldwork to collect specimens and establish the distribution of rare plants threatened with extinction.

3. The Sechura and Atacama hyper-arid belt is a rare ecosystem that stretches about 3,000km (1,864 miles) along the coasts of Peru and Chile. With virtually no rainfall, the plants that live here have adapted to survive on moisture from the fog sweeping in from the Pacific.

4. The scientists discovered that the paramotor pilots completed their missions 4.5 times faster than the ground crews and were also able to identify lomases that drones were unable to distinguish from the surrounding desert.



2

OLIVER WHALEY, JUSTIN MOAT/RBG KEW, MIKE CAMPBELL-JONES X2



3

BOTANY

The botanists studying plants from the sky

Scientists are working with paramotorists to find rare flowers in the desert

Finding tiny flowers in the middle of the desert is hard, but it's far easier if you can search from above. Desert ecosystems are generally delicate and inaccessible, and off-road vehicles can damage the fragile habitats. That's why scientists from the Royal Botanic Gardens, Kew, turned to paramotorists (paragliders powered by motors) to help in their conservation efforts in the deserts of Peru.

4

Scientists from Kew have been studying plants in parts of the desert known as lomases (oases fed not by rain, but by fog) for almost a century. There are over 1,700 plant species in the lomases, but they remain incredibly hard to map – some only flower once a decade – and the areas are extremely vulnerable to climate change and human activity.

Working with Peruvian scientists from Huarango Nature, RBG Kew helped train paramotorists to identify, collect, geo-reference and preserve plants for taxonomic study.

“Our study shows that through an exciting collaboration, today's extreme sports enthusiasts can work alongside scientists to help monitor ecosystems and gather crucial environmental data, protect species and aid conservation efforts,” said Oliver Whaley, Honorary Research Associate at RBG Kew.

The collaboration has led the Peruvian Government to protect a 63km² (15,689 acre) area of desert on the coast of Peru and designate it a conservation reserve.





COMMENT

Don't try to solve your partner's problems

You may think you're trying to help, but you'll both be better off if you keep your advice to yourself

If your romantic partner is ranting about a problem they have, you'd logically feel compelled to help. Why wouldn't you? You don't want someone you love to be upset, so you try to resolve the issue, to remove the source of their upset by offering advice and suggestions for how to fix it.

But if you do that, you may find your partner gets even more annoyed and frustrated – angry, even. It's not exactly a logical reaction.

If you've experienced this, you're not alone. The key term used so far is 'logical'. But real human relationships have never been purely logical. They're shaped by emotions and emotional connection.

Emotional processing is sort of a mental equivalent to digestion. Much like how food enters our bodies and is gradually broken down into useful components by the digestive system, when an emotional experience

becoming very important to our emotional processing. They become an emotional 'modulator'; someone we depend on to accept and validate us, but also help define and refine our emotions through their responses and interactions with us.

We usually don't know we're doing this with our partners, though. Like most of our emotional development and processing, it happens subconsciously. But that doesn't mean it's any less important.

What it does mean is that we regularly depend on our romantic partners to validate our emotions. Particularly those we've had to suppress, even temporarily, due to experiencing them in situations or groups where expressing them would have negative consequences – the anger at being unfairly blamed for something in a workplace meeting when the higher-ups are present, for example.

This means we're even keener to have our legitimate feelings validated, so we express them, enthusiastically, to our romantic partner.

Then they proceed to ignore our emotions and instead focus on the objective source of them, before making suggestions and offering advice, about a situation that they weren't involved with and have no experience of. What's this, if not a rejection of emotional expression and communication, a denial of much-needed validation?

On top of that, it can also be perceived as a loss of status. Because your partner's effectively saying: "I will offer solutions that I don't believe you will have thought of – ergo, I'm smarter than you."

Loss of status and rejection of emotional connection? Both are guaranteed ways to cause stress and upset in the human brain, both experienced when your romantic partner ignores your emotions and tries to fix your problems.

Let's be clear: no one who genuinely wants to fix their partner's problems is a bad person. It's an understandable and reasonable behaviour. But it's one that causes negative outcomes, due to unawareness of the emotional factors at work.

That's not necessarily a failing. Nobody understands exactly what another person is feeling, and what they want, 100 per cent of the time. Not even long-term partners. Heck, much of the time, we don't really understand what we're feeling ourselves, and what we want, until long after the event.

But it's important to put the effort into improving understanding of these tricky emotional factors, for your partner's wellbeing, and the wellbeing of your relationship.

Ultimately, if you ignore or dismiss your partner's negative emotions for long enough, unintentionally or otherwise, they'll eventually be left with nothing but negative emotions. And then you'll have an emotionally stressful problem to deal with all over again. So, just shut up and listen.

"We regularly depend on our romantic partners to validate our emotions"

occurs within our brains, various neuropsychological systems gradually convert it into something that can be safely added to and integrated into our existing memories, psyche and understanding.

And just like how a disruption to your digestion causes unpleasant physical consequences, prevention of emotional processing is bad for your wellbeing, both mental and physical.

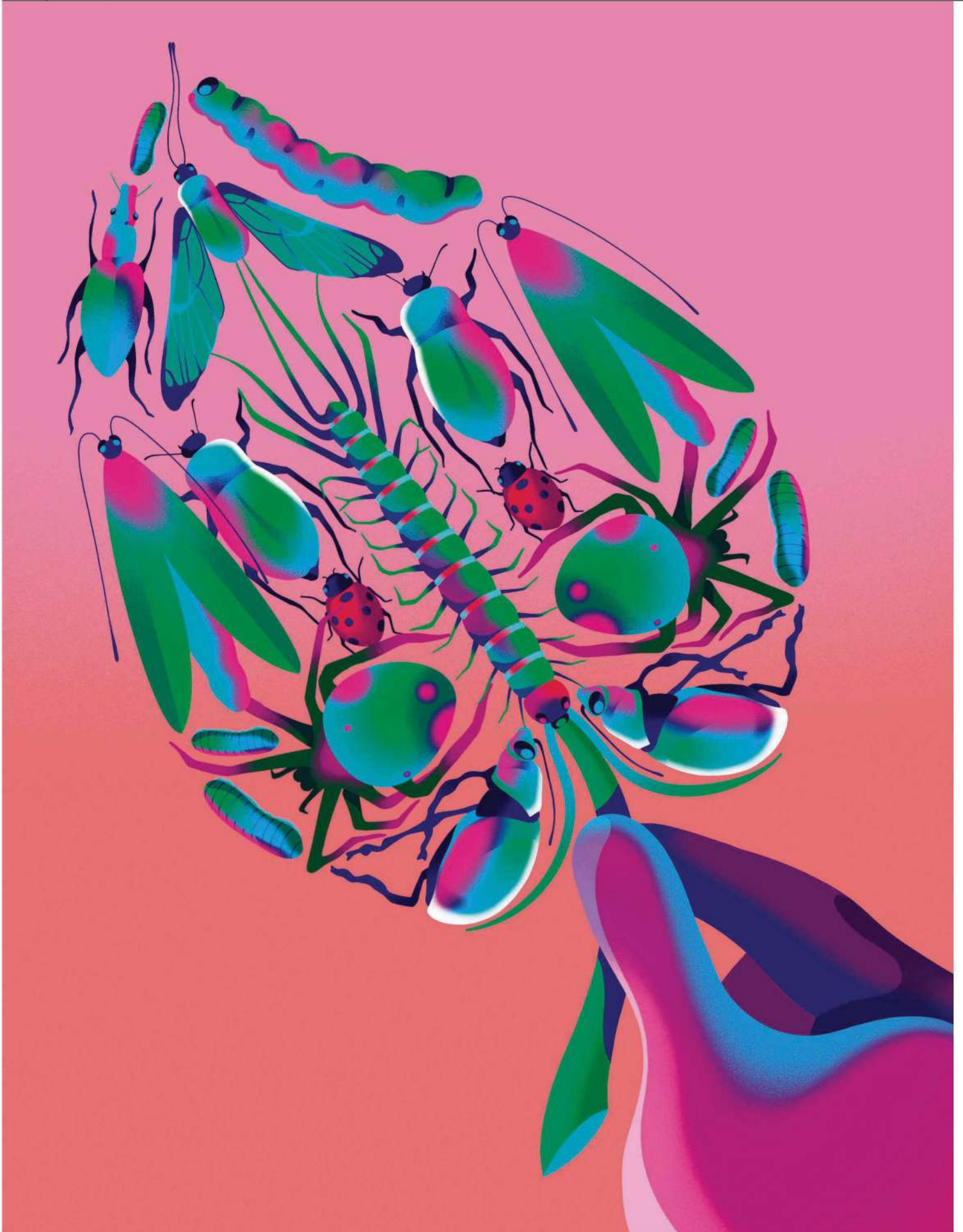
However, we humans are incredibly social creatures, and much of how we develop and learn is based on our interactions with other people and the social feedback they provide.

This has many consequences, one of which is that processing an emotion often means it needs to be communicated, shared, acknowledged and validated by others. But while emotional validation can theoretically come from anyone, we prefer it to come from those closest to us. Evidence shows that a long-term romantic partner often ends up



DR DEAN BURNETT

Dean is a neuroscientist and author. His new book *Why Your Parents Are Hung-Up On Your Phone And What To Do About It*, is out now (Penguin, 2024)



COMMENT

Unseen engineers have been secretly shaping life on Earth, says new research

Recently published studies suggest insects play a much larger role in seed dispersal than previously thought

Plants produce fleshy, juicy, sweet fruit with seeds inside so that birds and fruit-eating mammals, from toucans to fruit bats to orangutans, are lured into taking a bite. Then, these animals fly or roam far and wide and, once they've digested their meal, excrete the seeds together with the rest of their waste.

In doing so, these hungry animals help plants, which can't move, to travel and disperse their seeds across a wider range.

This is at the base of how hundreds of ecosystems work and has been since the dawn of time. However, a growing body of research is starting to suggest that mammals and birds are far from the only ones shaping how seeds travel and spread plant life to new parts of the world. Tiny insects and invertebrates play a crucial role, too.

Ants are perhaps the most well-known seed-dispersing insects. But the seeds they spread aren't from fruit.

Then, they excrete over 30 per cent of the dust-like seeds still intact enough to take root in the soil and grow, according to research published in the journal *People, Plants, Planet* earlier this year. These tiny invertebrates set a new record for the smallest and lightest animals to partake in seed dispersal after ingestion. The seedlings still need the help of fungi to successfully germinate, however.

It doesn't end there, though. Researchers in New Zealand discovered that the Wētā cricket, a flightless native insect the size of a hamster, eats the seeds of plants such as mountain snowberries and then disperses them by excretion as they wander over large distances.

"I was amazed," says Prof Kevin Burns, a biologist from the Victoria University of Wellington, whose work helped discover the phenomenon. "In fact, it was contentious. It still is contentious."

The humongous cricket likely stepped in to fill this unusual, surprising role in the ecosystem because the isolated island nation isn't home to any of the ground-dwelling, fruit-eating mammals that take care of seed dispersal elsewhere in the world.

Similarly, Japanese camel crickets eat and excrete the seeds of a leafy Asian shrub called *Rhynchoetichum discolor*, according to a new study published last month. The plant, found along moist, shaded forests, swamps, and thickets, has small, rounded, translucent and fleshy fruits containing thousands of tiny seeds. Once the fruits plop to the ground, the crickets chomp away and then excrete pellets with more than 78 per cent of the seeds intact and ready to germinate.

This is the first evidence of insects acting as seed dispersers for a light-harvesting, green plants in regions where land-dwelling mammals are also present to do the job.

It's "quite groundbreaking" and "opens up a whole new world of possibilities," says Prof Kenji Suetsugu, a botany researcher at Kobe University in Japan and lead author of the study.

This challenges the long-held notion that seed dispersal by insects is a special case – their role may be much more widespread and ecologically important than previously understood.

Insects could be just as important as the more traditionally recognised dispersers, says Suetsugu. Because they're incredibly diverse, abundant and small they can access a wider variety of areas than larger animals. What's more, plants might have evolved specific traits not just to attract birds or mammals, but also insects.

While some experts think it's important not to get ahead of ourselves, as it might still be a rare phenomenon on a global scale, more research could upend everything we've known about seed dispersal.

It may well be the case that small insects are the unsung heroes and tiny engineers of many of the world's ecosystems.

"More research could upend everything we've known about seed dispersal"



SOFIA QUAGLIA

Sofia is a freelance journalist who specialises in writing about biology and nature.

ILLUSTRATION: OLLIE HIRST

They spread seeds from particular plants that have special, ant-friendly oil bodies attached to the seed, known as elaiosomes. The ants carry the seed to their nest, eat the elaiosome and discard the seed, either by carrying it to the surface or placing it into 'rubbish piles' deep underground, according to Prof Ellen Simms, an integrative biologist at the University of California, Berkeley.

Other insects are thought to help disperse seeds by excreting them, like mammals and birds, but only for a special subset of plants. These are non-green plants that don't harvest light, but instead parasitise other plants or consume underground fungi to harvest the nutrients and energy they need.

For example, minute, centimetre-long woodlice eat the small fruits of a ghostly, parasitic bell-shaped Asian plant called *Monotropastrum humile*.



COMMENT

Lab-grown meat may be better for livestock, but not necessarily for the environment

The move to put alternative protein on our plates is gathering pace, but there are still questions to answer

On my morning walk with the dog, my path takes me past a field where a small herd of cattle grazes. I usually pause there, partly because my dog is utterly fascinated by cows, and partly because it's a pleasingly bucolic scene.

This is what I picture when I think of livestock farming: cows or sheep wandering around munching grass in a field. Then, like a lot of us who don't work in farming or meat production, I probably don't dwell as much as I should on what happens between the grazing animals and the meat we see on the supermarket shelves.

But there's a burgeoning meat-production industry that looks very different from this, which is set to offer us an innovative alternative using science: meat grown not in an animal, but cultured from a single cell, in a vessel inside an industrial production facility.

I'm curious to try it. And if there's a way I can indulge my appetite for meatballs and sausages without the need for an animal to be slaughtered, I'm keen to explore it.

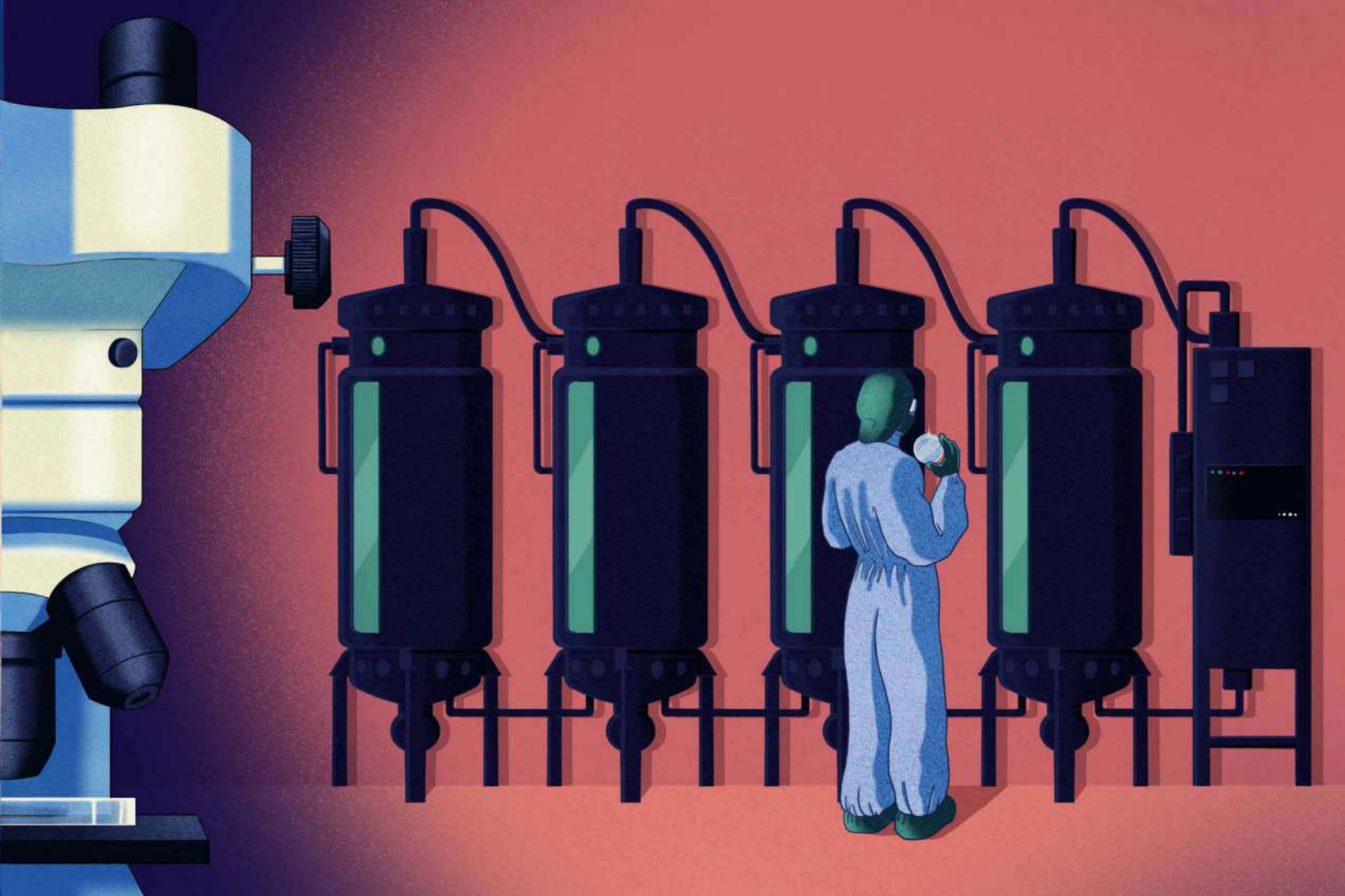
But lab-grown-meat companies are already making environmental claims that have yet to be borne out by evidence.

The production of meat from livestock is estimated to be responsible for over a tenth of our global greenhouse gas emissions, according to the UN, and that's only set to increase as the global population, and its demand for protein, rises.

UK Research and Innovation – the government body that directs the country's scientific research funding – recently launched a National Alternative Protein Innovation Centre, announcing that lab-grown meat “could soon be a sustainable and nutritious part of our diets.”

Because lab-grown meat doesn't need herds of livestock and land for grazing, advocates say it's an alternative with a much lighter environmental footprint. But not all grazing is equal. A recent study published in the journal *Nature Climate Change* revealed that, if properly managed, grazing can actually help sequester carbon from the air into the ground. But over-grazing, and the resulting loss of carbon from the soil due to soil erosion, is much more widespread.

ILLUSTRATION: SARA GIRONI CARNEVALE



“The carbon footprint of lab-grown beef could, in fact, be higher than beef farmed from an animal”

One widely reported preliminary study by researchers at the University of California, Davis, (yet to be peer reviewed) involved what’s known as a life-cycle analysis and concluded that the carbon footprint of lab-grown beef could, in fact, be much higher than beef farmed from an animal. The study tried to unpick the emissions costs of running these facilities and heating the culture media that the cells grow in. The ingredients for this nutrient-rich media, which feeds the cells, have to be grown somewhere. And extra energy is needed to stir and heat the cultured animal cells as they grow, because the cows or sheep aren’t doing that part of the job.

Dr John Lynch from the University of Oxford explained to me recently that it’s too soon to compare the climate costs of the lab-grown

meat sector with traditional agriculture. The industry is too young and there will be economies of scale as it develops. Lab-grown meat companies may also boost their environmental credentials by using renewable energy sources to power their production facilities.

But some of these companies are already declaring that their product is more sustainable. We’ll need data to back up those assertions. And it does our environment no favours to claim that lab-grown meat will be a silver bullet for the problems it faces.

There’s good reason to believe that lab-grown meat will have a lighter environmental footprint than rearing and slaughtering cows and sheep. But as Lynch pointed out to me, it won’t be intrinsically good for the planet, just better than conventional agricultural production.

And this is only if people actually want to eat lab-grown meat. Brits aren’t always hungry for scientific innovation. Take the backlash and alarmist coverage about genetically modified foods, for example.

In a very non-scientific exercise of gathering some vox pops on the streets of Cardiff while making a radio programme about lab-grown meat, I heard a lot of suspicion. “It doesn’t sound natural” and “it’s not real meat.” I also visited a lab-grown meat company in Oxford, where I saw how the product was made. On that day, a batch of Aberdeen Angus beef was being processed, all cultured from one specially selected, particularly “meaty” cell.

I wasn’t allowed to taste the result – it hasn’t been approved for human consumption here yet. When it is, I’ll be keen to try it. But I won’t pretend I’ll be saving the planet.



VICTORIA GILL

Victoria is an award-winning science correspondent. Her reporting can be found on television, radio and online.

REALITY

THE SCIENCE BEHIND THE HEADLINES

CHECK



REVIEW

Olive mill wastewater: a health-boosting tonic hiding in the leftovers

A by-product of the olive oil production process is packed with compounds that lower your cholesterol and reduce your risk of developing cancer

BBC

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Olive oil is well known for its health benefits. The star of the Mediterranean diet, it's rich in good fats, packed with antioxidants that have anti-inflammatory properties, and linked to a variety of improved health outcomes. The olive oil production process does create a lot of waste products, though. Luckily, however, it seems one of them – olive mill wastewater – might be a potentially health-boosting product in its own right.

Admittedly, olive mill wastewater, or 'OMW' as it's typically called in the scientific literature, isn't a particularly appetising name for a trendy, new, nutrient-dense supplement. But, olive mill wastewater is exactly what the name suggests – the wastewater from olive oil production.

It's one of many byproducts created when olives are milled and the oil is separated and filtered. To reduce such byproducts and improve profits, the waste is 'valorised' – reused, recycled, composted or converted into more useful things that have value, including materials, chemicals or fuels.

The solid waste products from olive oil production – olive pomace, olive oil sediment, olive pit residue



“The high level of organic compounds has potential health benefits”

and spent olive cake – can all be used as animal feed, compost or biomass fuel.

The liquid waste from the extraction process, which includes water added as part of the processing, is the olive mill wastewater, a dark, cloudy, bitter and slightly acidic liquid – millions of litres of which are generated each year. As a byproduct, it's considered the most harmful waste from olive oil production – its high organic load and phenolic content are a significant environmental concern. If it's not properly managed and treated before release (which adds to the cost of production), it can contaminate waterways and soil, and be toxic to plants and animals.

But olive mill wastewater might be more useful than most producers realise. One family-run farm in Tuscany, Italy is already selling olive mill wastewater as a health supplement shot and as a biodynamic cosmetics range called OliPhenolia. The shots are available in natural bitter and sweetened flavours, based on the traditional health tonic known as 'aqua mora' (an old Italian name for olive mill wastewater that roughly translates as 'dark water').

Scientists have also been looking into the contents of olive mill wastewater and how it might be used.

The high level of organic compounds it contains, known as phytochemicals – the very thing that makes olive mill wastewater harmful to the environment – has potential health benefits for humans. Phytochemicals are chemical compounds produced by plants as natural defences against environmental stressors and predators. These compounds, although not essential nutrients needed for survival, can have a positive impact on human health, earning them the broader name of bioactives.

COSTS VERSUS BENEFITS

The bioactives in olive mill wastewater include 30 or more phenolic compounds such as tannins, flavanols, oleuropein, hydroxytyrosol and anthocyanins, plus soluble dietary fibres such as mucilage and pectin. These compounds have antioxidant, anti-inflammatory, immunomodulatory, antimicrobial, anticarcinogenic, anticholesterolemic, antihypertensive, antihyperglycemic, analgesic and other beneficial effects, including for gut health.

These compounds are thought to be part of the reason why plant foods are health-promoting, above and beyond the essential nutrients they contain. High consumption is linked to reducing risk of cardiovascular diseases, metabolic disease, diabetes, cancer and more.

Because many of these phenolic compounds are water soluble, the concentration can be up to 10 times higher in olive mill wastewater than in olive oil, with levels varying depending on pressing methods, storage and olive type.

This health-giving wastewater could be consumed as a drink, tonic or elixir, and there are extraction techniques that can concentrate the bioactives and nutrients to allow them to be used in other products. For the valorisation to be successful, these →

ABOVE Vast quantities of wastewater are produced during the production of olive oil

LEFT Olives and olive oil are packed with beneficial compounds. So, it seems, is one of the leftovers from the olive oil production process

“History is littered with examples that prove how much we love a food trend, especially one with purported health benefits and a great origin story”

→ techniques need to be cheap enough to produce products of sufficient value to outweigh the costs associated with the treatment and discharge of waste.

Most of the research on olive mill wastewater is centred around its potential use as a nutraceutical. Nutraceutical is a portmanteau of the words ‘nutrient’ and ‘pharmaceutical’, and is used to describe products derived from food and plant sources with significant health benefits. Nutraceuticals are complex mixes of nutrients and bioactives, which can have synergistic effects. They can be used as supplements or added to foods to give them bioactive health benefits, or they can be used in food production as natural preservatives. In 2021, at least five companies were known to be recovering phenolic compounds from olive mill wastewater for use as a natural preservative or bioactive to add to food products and supplements.

So, can we expect olive mill wastewater to become the next wheatgrass or apple cider vinegar shot? Maybe.

BELOW The health benefits of olive oil are well documented

History is littered with examples that prove how much we love a food trend, especially one with purported health benefits and a great origin story. We also love the idea of ‘silver bullet’ supplements that claim to help protect us from a range of conditions.

WEIGHING UP THE OPTIONS

It’s important to note that while multiple studies have been conducted with olive mill wastewater, they’ve all been carried out on cell cultures or microbes. No studies have yet been conducted on actual humans to assess if drinking olive mill wastewater, or consuming foods into which it’s been added, has any direct health benefits. There have been multiple studies conducted on humans to investigate the health benefits of olive oil, however.

So why not just eat the whole unprocessed olive? After all, they contain all the nutrients and bioactives found in both olive oil and olive oil wastewater, not to mention the dietary fibre that’s lost during the olive oil production process.

The problem is olives can’t actually be eaten fresh – they need to be processed via pickling or curing to make them edible. This means they’re soaked for a long time and can lose many of the beneficial compounds. Olives can also be very high in salt due to this process. But processing olives into oil and wastewater can help release the phytochemical compounds they contain, making them more available for absorption into the human body. Compared to olive oil, the health benefits of olives as a food aren’t actually very well studied.

Phytochemicals are plentiful in all plant foods, so can be readily accessed in a diet high in fruits, vegetables and wholegrains. Bioactive compounds are also many and varied – over 10,000 have so far been identified. This means consuming a specific bitter drink or extracting the bioactives for use in foods or other nutraceutical products for repeat consumption isn’t likely to be more beneficial alone than the combinations found in a healthy balanced diet. Eating whole plant foods also has the added benefit of displacing less healthful foods from a person’s diet, which doesn’t happen with tonics and supplements, as, typically, these are simply added to someone’s existing diet.

But, since most people aren’t eating plant foods at the levels recommended by national dietary guidelines and the World Health Organization, novel products may encourage the consumption of bioactives and nutrients, while simultaneously creating a valuable use for a common waste product.



by **DR EMMA BECKETT**
(@DrEmmaBeckett)

Emma is a senior lecturer in Food Science & Human Nutrition at the University of Newcastle, Australia and a senior scientist at Nutrition Research Australia.



ANALYSIS

Could Ozempic ever be an over-the-counter drug?

The hunger for this new generation of weight-loss drugs is seemingly insatiable. Would making them available without the need for a prescription save people from turning to the black market?

Since its launch in 2019, the hype and demand for Ozempic has grown rapidly, owing to its effectiveness not only at treating type 2 diabetes, but also its ability to help people lose weight. Given its popularity, could we ever see Ozempic, and drugs like it, being available over the counter? And what would the implications of such easy access to powerful appetite suppressants be?

WHAT IS OZEMPIC AND HOW DOES IT WORK?

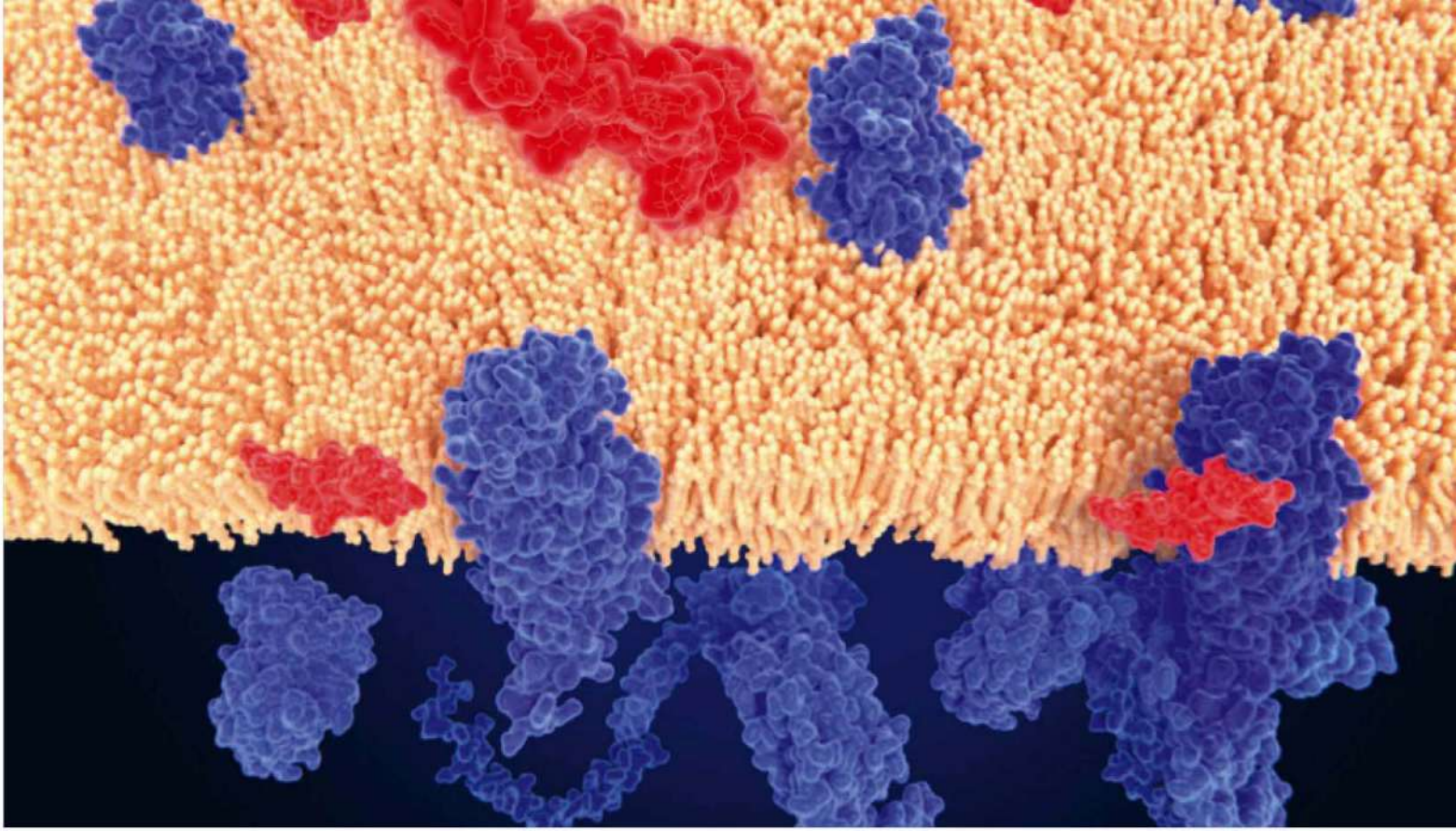
The active ingredient in Ozempic is semaglutide, a drug that mimics the actions of a naturally occurring hormone called glucagon-like peptide-1 (GLP-1). When we eat a meal, GLP-1 is released from cells in the intestines and does a few key things. Firstly, it signals the pancreas to release insulin, helping our bodies keep our blood sugar levels under control. Secondly, GLP-1 works on our nervous systems to reduce both the feeling of hunger and the desire to eat. This combination of actions places GLP-1 analogues in a unique position to treat both type 2 diabetes and obesity.

Clinical studies have shown that semaglutide can maintain weight loss of on average 10 per cent over four years in patients with obesity, as well as reducing cardiovascular mortality. Newer GLP-1 analogues, such as Mounjaro (tirzepatide) show even greater weight-loss potential, averaging 22-per-cent weight loss over 72 weeks, and more are in development.

Considering the paucity of anti-obesity medications that are both effective and safe, along with people's desire for weight-loss solutions, it's little wonder these drugs have been highly sought after. Such has been the demand that the UK government's Department of Health and Social Care was forced to issue a National Patient Safety Alert in July 2023 preventing doctors from initiating new patients onto GLP-1 analogues, due to national shortages of the drugs.

It's worth noting that Ozempic has never been licensed for the treatment of obesity. Instead, Wegovy, which also contains the active ingredient semaglutide (albeit at a higher dose), was made available specifically for the treatment of obesity in September 2023. However, →

ABOVE Drugs containing semaglutide have the potential to help people lose weight



“There’s anecdotal evidence that the black market supply of Ozempic is booming, potentially putting people at significant risk”

→ given supply issues of Wegovy and stringent body mass index (BMI) criteria, many patients have looked to off-licence prescriptions of the relatively more obtainable Ozempic for help with their weight loss. Concerningly, there’s anecdotal evidence that the black market supply of Ozempic is booming, potentially putting people at significant risk.

HOW DANGEROUS IS BLACK MARKET OZEMPIC?

GLP-1 analogues themselves are a relatively safe class of drugs. Clinical trial evidence shows that the majority of patients who suffer side effects experience nausea, vomiting, diarrhoea or constipation, with few patients suffering more significant responses, such as gallstones or acute pancreatitis. That being said, monitoring of patients on these drugs is vital, since their doses need to be carefully formulated to increase tolerability.

There are a growing number of reports about people buying Ozempic through non-legitimate routes (social media websites, for example), only to find out that the products they receive often contain potentially harmful substances.

Between January and October 2023, the Medicines and Healthcare products Regulatory Agency (MHRA) seized 369 potentially fake Ozempic pens in the UK, with reports of patients being hospitalised with

dangerously low blood sugar levels, suggesting the pens may have contained insulin instead.

Given the difficulty that many people experience when trying to lose weight, the shortages associated with this new generation of weight-loss medication, and the stringent criteria applied to their prescription on the NHS, it’s perhaps unsurprising that many people have turned to illegal routes to obtain them. But could Ozempic, Wegovy or any future GLP-1-based analogue ever be bought over the counter?

WHAT DETERMINES LEGITIMATE ACCESS TO A DRUG?

Medication in the UK can generally be obtained through two main routes: via a prescription typically given by a healthcare provider, or over the counter, where members of the public can buy what they need without a prescription at a pharmacy or chemist. Whether a drug is available as a prescription or over the counter depends on certain factors, such as the risk of serious side effects and the potential for misuse.

Some medications do transition from being prescription-only to available over the counter. For example, the antihistamine fexofenadine was originally only available on prescription. In 2020, however, after many years of clinical data demonstrating its safety and non-drowsiness, it was reclassified and made available without the need for a prescription.

ABOVE An illustration of how semaglutide (red), the active ingredient in drugs like Ozempic, binds to GLP-1 receptors in the body (blue) to improve blood sugar control and make us feel full

ABOVE RIGHT Demand for drugs like Ozempic and Wegovy is high

GETTY IMAGES X2



COULD OZEMPIC EVER BE AVAILABLE OVER THE COUNTER?

Whether Ozempic, Wegovy or any other GLP-1-based weight-loss drug could ever be available over the counter depends on it meeting the criteria outlined: is it safe and does it have the potential to be misused?

The safety of GLP-1-based analogues is generally very good, however there's still the risk for potentially serious side effects to develop, so patients on these drugs do still require careful monitoring.

Case studies have demonstrated examples of patients taking GLP-1-based medications who have developed potentially life-threatening acidosis (where blood levels become too acidic) due to significant nausea and diarrhoea, highlighting the need for careful monitoring of how patients react to the drugs.

Given the scarcity of these drugs and their significance for many patients with type 2 diabetes in controlling their sugar levels, it's also important for clinicians to restrict these drugs to those who have the potential to gain the most benefit, as well as monitoring how well patients are responding to them.

But perhaps the biggest barrier to these drugs being made available over the counter is the risk associated with misuse. The strict criteria for their prescription on the NHS (typically requiring a BMI over 35kg/m² plus conditions associated with obesity, such as cardiovascular disease) means that for those who

are prescribed GLP-1-based medications, the benefits of weight loss typically outweigh any risks and their effectiveness has the potential to significantly and positively transform people's lives.

If it becomes available over the counter, such stringent rules on who can access these drugs are removed. Given their powerful appetite-suppressive actions, the effect that these drugs could have on people who suffer from body dysmorphia or eating disorders has the potential to be incredibly dangerous.

WHAT IS THE FUTURE FOR WEIGHT-LOSS MEDICATION?

Given the scale of the obesity crisis, multiple drug companies are busy developing GLP-1-based anti-obesity medications to add to those already available. Currently, medications such as Ozempic, Wegovy and Mounjaro are taken as once-weekly injections, a method that's not favourable with all patients.

Many of the medications currently in development are oral formulations, which have the potential to dramatically reduce the costs and make it simpler for patients to use. New medications entering the market should also help address the shortages of existing drugs, which will hopefully enable more patients to take advantage of their benefits. Will we one day see any of them readily available to the public without the need for medical supervision? That seems a long way off.

by **DR SIMON CORK**
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 Simon is a senior lecturer in physiology at Anglia Ruskin University's school of medicine.

INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

INNOVATIONS

COULD ARTIFICIAL INTELLIGENCE BE THE CURE FOR LONELINESS?

Rates of loneliness are increasing worldwide.
But big-tech companies think they have the solution...

Despite being more connected than ever, we're pretty lonely right now. So lonely, in fact, that in 2023, the World Health Organization declared the 'loneliness epidemic' a global public health concern.

Roughly a quarter of the world reported feeling lonely, with young people making up the brunt of that figure.

In other words, we're facing a crisis. So, what's the solution? Social clubs are springing up in cities everywhere, Japan has pushed support groups and the Dutch have found success in flatshares that mix elderly and younger residents.

But while these measures have all been shown to help, they're a drop in a rather big, lonely ocean. Rates of loneliness are increasing and a global solution isn't easy to come by... Or is it?

Tech companies are jumping at the opportunity to fight loneliness with all sorts of hard- and software. But while they've gotten off to a surprisingly good start, the tech has a long way to go if it wants to actually cure loneliness.

LONELINESS (OVER)SIMPLIFIED

In its rush to design a solution, big tech has over-simplified its idea of loneliness, conflating it with a need for conversation. But that's not necessarily big tech's fault; few of us understand loneliness fully.

"There are three types of loneliness. The psychological type is what we know best – [the] 'do you have someone to talk to about your problems?' [type]. If you don't, your cortisol levels are up, causing serious stress," says Dr Jeremy Nobel, author of the book *Project UnLonely*. "Systematic exclusion is the second, whether that be due to race, gender, disability or something else. The third is spiritual loneliness. [The] 'does my life have meaning, does it have consequences?' [type] – it's the feeling that we're alone in a big world."

The solutions currently being offered by the tech world are geared towards dealing with psychological loneliness. Take Replika, for example. It's an AI chatbot program in the form of a virtual companion that you create. The more you chat with it, the more the companion adapts its vocabulary, tone and emotion to become a friend you'd trust. It even remembers details about previous conversations you've had with it.

It all seemed like a decent option for boosting people's social confidence and reducing loneliness... until the data breaches happened. In addition, the companions began to offer sexually charged responses, while changes to the AI algorithm suddenly and drastically altered the companions' 'personalities'.

Then, there's 'Friend', an AI in the form of a microphone you wear around your neck. Say a few things into the mic and the AI sends you texts based on your utterances and converses with you about your day's events. The idea is well-meaning, but it feels like a somewhat meagre solution to such a large problem.



"BIG TECH HAS OVER-SIMPLIFIED ITS IDEA OF LONELINESS, CONFLATING IT WITH A NEED FOR CONVERSATION"

Elsewhere, miniature robots have found their way into retirement homes, offering a futuristic take on companionship with surprisingly promising results. Take ElliQ for example (see left). As well as offering video calls and chats with trusted contacts, the table-top AI sidekick also initiates interactions by suggesting games and conversation topics to help keep elderly people engaged and active.

ADDRESSING LONELINESS WITH TECH

While there are plenty of tech-based attempts to address loneliness available, they're all relatively primitive in their approach, designed to be temporary fixes to the symptoms of loneliness, rather than a solution to the causes of it.

That said, Nobel believes that tech is perfectly positioned to play a greater role in addressing the problem of loneliness, but in order to do so the people behind it need to take a different approach.

"We need to perceive loneliness for what it is, an emotional signal. When we feel thirsty, it's a sign to drink water. When we feel lonely, it's a sign that we need social engagement or support. We wouldn't feel embarrassed about feeling thirsty," says Nobel.

"There's a cultural narrative around loneliness that suggests we're flawed for feeling lonely. That comes with guilt

that sends us into a self-perpetuating spiral."

The occasional pang of loneliness is perfectly normal, but these spirals can be where loneliness becomes challenging. Nobel highlights the cycle of loneliness where someone doesn't want to burden others so they withdraw. From the outside, this can be perceived as cutting other people out, causing people who might be able to offer help to back away too.

Nobel sees a future where wearables could incorporate loneliness sensors, tracking indicators of a period of loneliness.

"The wearable could be paired with an app. When it notices the signs, it could offer suggestions. Maybe to meet up with a friend or something as simple as going out in public to feel more connected to society," he says.

Alternatively, Nobel sees potential for the use of AI-powered chatbots in solving all types of loneliness. Psychological loneliness could be aided by having social contact, even in the form of an AI companion.

Equally, in social exclusion loneliness, or a more existential type, chatbots can help people unravel these concerns, acting as a sounding board and advisor. It could even be as simple as apps that help people make new friends with shared hobbies – a trend that's growing in popularity.

We're not there yet, but tech could soon be a crucial tool to deal with the loneliness epidemic. A variety of apps, wearables and gadgets are emerging that, when combined, are able to address the variety of types of loneliness we're facing today.

THE BEST SMART SPEAKERS FOR AN AUTOMATED HOUSE



SPEAKERS ARE GETTING SMARTER. THEY CAN ADJUST THEIR AUDIO TO SPECIFIC ROOMS, CHAT TO YOU AND CONTROL OTHER GADGETS IN YOUR HOUSE. VERITY BURNS CHECKS OUT FIVE OF THE BEST

...THE BEST-SOUNDING SMART SPEAKER

The Sonos Era 100 takes audio quality seriously. It's really a music speaker first and a smart speaker second, delivering detailed and powerful stereo sound from a compact and stylish design that also happens to have all of Alexa's talents built in. As well as superb sound quality, it also has Sonos's TruePlay, a feature that automatically optimises the speaker's performance depending on its position in your room.

If you're looking to build a multi-room audio system (whether now or in the future), the Sonos Era 100 is perfectly

positioned to be the first part of the set-up, or to simply slot into an existing one. That means if you invest in Sonos speakers for different rooms, you can play music through all of them simultaneously over Wi-Fi, while controlling them via the Sonos app.

The Era 100 also has Bluetooth, which makes it easy for your guests to connect to the speaker and DJ your party, too.

Sonos Era 100
£199, [sonos.com](https://www.sonos.com)

...THE GOOGLE ASSISTANT SMART SPEAKER



The Google Nest Audio has better natural language understanding than the competition, so you can ask it several questions at once and it can handle them all. It supports over 50,000 devices and is a great option for controlling Nest products, like the smart thermostat and doorbell.

Its audio is pretty good, but has directional drivers so it sounds best when playing towards you, rather than from the middle of a room.

Google Nest Audio
£89.99, store.google.com

...THE SIRI SMART SPEAKER

We would recommend the HomePod Mini for most Apple fans due to it being £200 less than the HomePod 2 while having much of the same core functionality. Sound-wise it has an engaging and refined character that's great for all music genres. It's fair to say that Siri lacks some of the smarts of its rival assistants, but the seamless functionality it offers with the rest of Apple's ecosystem is a joy.

Apple HomePod Mini
£99, apple.com/uk



...THE PORTABLE SMART SPEAKER

The Beosound A1 2nd Gen is a premium Bluetooth speaker with IP67 waterproofing and Alexa capabilities. It has a circular aluminium grille, a leather carry strap and is perfectly sized for throwing into a picnic bag or backpack, or simply moving it between rooms as needed.

But how does a Bluetooth speaker use Alexa without Wi-Fi? There's the catch: it needs to be linked to a phone with an internet connection and the Alexa app. This limits some of its functionality, but it can still answer your questions, play songs from Amazon Music, manage your smart home and loads more.

It's by far the priciest speaker here, but for a small Bluetooth speaker, it sounds fantastic, delivering detailed, punchy and dynamic audio.

B&O A1 (2nd Gen)
£259, bang-olufsen.com



...THE BUDGET SMART SPEAKER

Amazon's Echo speakers are among the very best when it comes to smart capabilities and if you're looking to keep the cost down, the Echo Dot is a great option. With a neat and compact design, and all the power of Alexa, it's a great choice for anyone who has bought other Amazon smart-home products, like Ring's doorbells and security products.

That said, Alexa supports a wide range of third-party smart devices, plus it can answer questions, set timers, sound alarms, and do plenty of fun things like tell jokes and read bedtime stories.

You can play music and audiobooks from the likes of Amazon Music, Spotify and Audible, and, for its size, it's a pretty capable little speaker, with Bluetooth and Wi-Fi built-in. We particularly love having the ability to send announcements to other Echo speakers around the house, meaning telling everyone it's time for dinner has never been easier.

Amazon Echo Dot
£54.99, amazon.co.uk



IDEAS WE LIKE...

Our pick of
the month's
smartest tech

...A WI-FI BOOSTER TO GET ONLINE ANYWHERE

Elon Musk has been involved in some bizarre projects. But for every flamethrower, brain chip and social media takeover, there's the occasional useful project too. Starlink, a subsidiary of Musk's SpaceX company, specialises in making the internet more accessible. With the Roam, a backpack-sized router, it has made its most portable kit for getting online yet. Its size and ability make the Roam perfect for anyone who regularly finds themselves far off the beaten track, whether they be hikers or researchers deep in the field. It can withstand the elements and get access in some of the most remote parts of the world.

[Starlink Roam](#)
[£399, starlink.com](#)





↑...A HEARING AID WITH AI

Artificial intelligence is being crammed into just about every gadget these days. Sometimes it's great, and sometimes... it's not. Luckily, in the case of the Phonak Audéo Sphere, it's great. The hearing aid uses AI to separate speech from background noise to improve clarity and help you hear what's being said. The company claims that this technology can even work in busy environments like restaurants and bars, cutting background noise to help you focus on the chat. There is a catch, though: it comes at a price.

Phonak Audéo Infinio Sphere i90
Approx £3,000 per pair, phonak.com

↓...A SMALL COOKER WITH BIG CAPABILITIES

Ninja is seemingly on a mission to make a kitchen gadget that can do everything. Its latest attempt crams 12 different functions into an electric cooker. The 12-in-1 Multi Cooker will air fry, slow cook, bake, reheat, grill, cook multiple meals simultaneously at different temperatures, boil rice, sauté, prove bread and more. How your existing hob and oven will feel about being usurped by a comparatively tiny interloper, we can't say. But if Ninja start incorporating fridges, freezers and dishwashers into their cookers, kitchens may never be the same again.

Ninja Combi 12-in-1 Multi Cooker
£279.99, ninjakitchen.co.uk



↑...A DICTAPHONE WITH AI

Having some sort of wearable device equipped with artificial intelligence to record your every utterance is quite a trend at the moment. Plaud is jumping on that bandwagon with its NotePin, an AI-powered mic that you can wear as a necklace, bracelet or, as the name suggests, a pin. Press a button and it records your conversations, adding everything that's said to a document you can review later, if needed. It can even translate conversations in different languages and add names for speakers if they introduce themselves.

Plaud NotePin
\$169 (approx £125), plaud.ai

↓...A PAIR OF EARBUDS THAT PACK A PUNCH

Sony makes some of the world's best headphones, but they're normally found well beyond the £200 mark. The audio giant is making some of its high-end audio tech available at more affordable prices, however. The wireless WF-C510 earbuds might be cheap, but they have a 22-hour battery life, impressive audio quality and an ambient sound mode that filters out background noise so you can hear more of your music. They might not have active noise cancellation, but at this price, they're a potential market leader.

Sony WF-C510
£55, sony.co.uk



IDEAS WE DON'T LIKE...

...A ROBOT CHEF

After a long day of work, cooking is often the last thing you want to do. So why not let a robot handle it for you? Probably because they're not really up to the task yet, as the Nymble robot chef proves. You use an app to choose a recipe and schedule the cooking time, then you prep all the required ingredients and load them into the machine. Nymble then drops them in the pan when they're needed, and proceeds to heat and stir them. So it's all the same steps as actually cooking, just with slightly less stirring.

Nymble
\$1,500 (approx £1,120),
eatwithnymble.com



...AN ICE BATH WITH ADDED TECH

While the science behind ice baths is mixed, with a list of concerns as long as the supposed benefits, that hasn't stopped tech companies from diving in at the deep end. Monk is offering a smart bath that has a range of features to help you optimise the experience of bathing in ice-cold water (and take your mind off the fact you paid almost £6K for a bathtub). Its temperature can be set and adjusted via an app, it has "self-cleaning ozone sanitation" and it can help you embrace the cold using soundscapes and guided breathwork. Sounds impressive, but it's still a lot to pay for something you could recreate with a bag of ice and a smart speaker.

Monk Smart Ice Bath
£5,995, discovermonk.com

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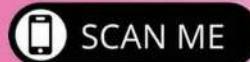
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SAVE THE SHARKS...

RUTHLESS PREDATORS, MINDLESS KILLERS, MAN-EATERS... SHARKS HAVE A FEARSOME REPUTATION THAT BEARS LITTLE RELATION TO REALITY. THE TRUTH IS, THESE REMARKABLE CREATURES ARE STRUGGLING TO SURVIVE. BUT OUR WATERS WON'T BE ANY SAFER WITHOUT THEM. IN FACT, THE PLANET'S SEAS WILL BE IN EVEN GREATER JEOPARDY THAN THEY ALREADY ARE

by JOE PHELAN

Each morning, hundreds of thousands of fishing vessels head into the waters around Indonesia. The country, comprising around 17,000 islands with a combined coastline of almost 100,000km (about 62,000 miles), is one of the world's fishing superpowers and, in recent decades, has grown in strength.

The country has established a reputation for providing quality tuna, shrimp and crab to high-end restaurants around the world. But behind this economic and culinary success story is an uncomfortable truth: Indonesia ranks among the world's top shark-killing nations, catching an estimated 100,000 metric tonnes (98,400 tons) of shark a year, which is contributing to an alarming global decline in shark numbers.

"The biggest threat to sharks currently is fishing," says Dr Colin Simpfendorfer of the University of Tasmania's Institute for Marine and Antarctic Studies. "Its impact dwarfs any of the other impacts for almost all species. Too many sharks are dying in fisheries."

The issue is by no means exclusive to Indonesian waters. Across the planet, an estimated 100 million sharks are killed annually either intentionally or as bycatch. That's one shark per 80 people – a colossal figure that's almost impossible to comprehend.

According to an article published in *Nature*, the global abundance of oceanic sharks and rays has declined by 71 per cent since 1970 and, as reported in a 2021 analysis in *Current Biology*, one-third of sharks and rays are now threatened with extinction. Historically, that decline has been largely attributed to overfishing, →

BRANDON COLE/NATUREPL.COM



...SAVE THE OCEANS

→ but it's not the only activity putting pressure on shark populations today. "New threats such as shipping, offshore wind farms and climate change are also affecting populations," says Dr James Sulikowski, director of the Coastal Oregon Marine Experiment Station in the US.

A KEYSTONE SPECIES

The decline of sharks is liable to be devastating – for the creatures themselves, but also for the marine ecosystems that depend on them and their behaviour. Behaviour that, generally speaking, is misunderstood. The creatures have gained a bad reputation – as ruthless predators at best, mindless killers at worst – but it bears little relation to reality.

In fact, as scientists are learning, sharks play a key role in regulating the populations of various marine species. Insights gained into shark behaviour are showing how they support the development of habitats such as coral reefs and seagrass beds, without which many marine organisms could not survive.

"Sharks are a diverse group of fish that vary in their respective roles across the oceans," says Dr Philip Matich, instructional associate professor in biology at Texas A&M University at Galveston. "They feed on a variety of species, but they don't only shape marine food webs by feeding on prey and altering their abundances. The presence and behaviour of sharks can lead to changes in the distribution, movement patterns and foraging of their prey.

"Healthy predator populations promote the health of the organisms responsible for creating the habitat itself, like seagrass and macroalgae." But a decrease in the number of sharks, adds Matich, means the creatures usually preyed on by sharks can swell in population, leading to the overgrazing of these organisms, thus throwing an ecosystem out of kilter. In oceans missing their most essential predators, the ripple effects are devastating and can trigger a trophic cascade – an ecological phenomenon that can result in sweeping changes to the food chain.

"Healthy shark populations promote healthy ecosystems and healthy ecosystems promote healthy shark populations. It's a reciprocal relationship," Matich says.

Urgent and sustainable steps need to be taken to prevent population collapse, preserve ecological functionality and ensure marine stability. Thankfully, crucial work is under way.

Shark rewilding organisation ReShark was formed in 2020. On its website, it's described as an international coalition of over 90 conservation organisations, aquariums, governments and experts dedicated to reintroducing sharks to the world's oceans by re-establishing healthy, genetically diverse and self-sustaining populations. As a mission statement, it's admirable, but easier said than done. "There's no 'one-size-fits-all' solution to shark and ray

RIGHT Maryrose Tapilatu, an aquarist at Raja Ampat Research and Conservation Centre, releases a zebra shark into a sea pen

BELOW Fishing in Indonesia is big business and the country is a major supplier of tuna

OPPOSITE TOP Millions of sharks, like this smooth hammerhead, are unintentionally caught as bycatch in fishing nets

OPPOSITE BOTTOM As part of the ReShark rewilding project StAR, juvenile zebra sharks are tagged so they can be monitored after release



rewilding," says Dr Erin Meyer, chief conservation officer at Seattle Aquarium and a founding member of the ReShark initiative. "Conservation efforts are only as strong and enduring as the people who lead and collaborate on them."

The Raja Ampat Islands, in the Indonesian province of West Papua, were chosen as the location for ReShark's first repopulation initiative, which launched in 2022. The *Stegostoma tigrinum* Augmentation and Recovery (StAR) project was devised with the aim of re-establishing healthy, →



→ resilient populations of zebra sharks (*Stegostoma tigrinum*) within their known ranges.

To date, two ReShark nurseries have been established in Raja Ampat – the Raja Ampat Research and Conservation Centre (RARCC) on Kri Island, and the Misool Foundation nursery. Both are equipped with advanced facilities to rear shark eggs and pups, and include sea pens where young sharks acclimatise before release. Since receiving the first zebra shark eggs from Sea Life Sydney Aquarium, Australia in August 2022, the nurseries have successfully released five sharks into protected waters. “We’ve spent the last two years scaling up and now have 20 pups ready for release this fall, with another 20 eggs ready to ship to Indonesia,” says Meyer.

The location of the nurseries was carefully considered. The Misool Foundation has almost 20 years of experience looking after the Misool Marine Reserve, which surrounds the nursery and release site. Its team of full-time rangers currently protect an area of around 1,214km² (469 sq miles) from poaching.

Reintroducing sharks requires patience, diligence and a great deal of collaboration. First, appropriate shark eggs need to be laid in partnering public aquariums before being shipped to the specialised nurseries, where they hatch. The young sharks are then reared until they reach around 70–80cm (27–30in) in length, tagged with RFID and acoustic trackers and moved to the specially designed sea pens. Once their health and behaviour have been deemed normal, the sharks can be released into designated marine protected areas. Post-release, the sharks are monitored regularly, with detailed data on their movements collected every six months to gain further insights into their behaviour.

Nathaniel Soon, media and communications coordinator for ReShark, is confident the StAR Project is on course to be successful not only in terms of bolstering shark numbers in Raja Ampat, but also with regards to raising awareness of the shark’s plight. “Our population viability analysis suggests that releasing 500 individuals over 10 years will establish a healthy, self-sustaining local zebra shark population. Therefore, increasing the number of eggs from our aquarium partners to our nurseries remains our top priority. Currently, we receive eggs periodically and in small batches, but we must scale up the number of available breeders and eggs in the coming months and years.”

SHARK SANCTUARIES

While resharking is arguably the most compelling initiative, it’s not the only one aimed at saving sharks. Dwindling shark populations have encouraged a handful of progressive, conservation-focused nations to create sanctuaries where sharks can roam and hunt without risk of being killed. “[In 2011], the Bahamas enacted legislation that protects all sharks across



“THE FACT IS, WE’RE NOT ON THEIR MENU. IF WE WERE, THERE WOULD BE A LOT MORE HUMANS MISSING”

its 630,000km² (243,000 sq mile) national waters so that sharks can’t be targeted or caught,” Matich says. “The economic benefits derived from sharks being alive far outweighs those from sharks being harvested, because of the more than \$100m (£76m) shark diving brings to the Bahamas annually, and also the value sharks have in keeping Bahamian ecosystems healthy.”

A 2021 study by non-profit research group Beneath the Waves concluded that efforts in the Bahamas were working. Not only is its healthy shark population encouraging more people to visit the country, but the initiative provides a tangible example of how action can make an impact in just over a decade.

Similar protective measures are also in place around Micronesia in the western Pacific. The Micronesia Regional Shark Sanctuary, launched in 2015, prohibits the commercial fishing and trade of sharks and rays. It encompasses the waters of several island nations and territories, including Palau, the Federated States of Micronesia, the Marshall Islands, and the Northern Mariana Islands. It covers over 6.5 million km² (2.5 million square miles), making it one of the largest shark sanctuaries in the world.

Given the top threat to sharks remains overfishing, the best chance of conserving them internationally must be to make fisheries, and fishing practices, more sustainable. It’s perhaps unrealistic to expect all countries to pass legislation that excludes the fishing of sharks from its waters, but it’s clear that effort needs to be made to understand how the introduction of protected areas and shark-friendly regulations can lead to effective conservation.

“Many communities around the world rely on sharks for subsistence or income, and past bans have proven ineffective because enforcement was too expensive,” says Dr Daniel C Abel, professor of marine science at Coastal Carolina University, in the US. “It’s therefore preferable to work with shark-fishing interests to devise management strategies.” Effective strategies, Abel suggests, could be to implement strict catch quotas or to prohibit shark fishing in critical habitats at specific times, such as breeding season.

Simpfendorfer adds: “Because of the large number of shark species [around 530] and the fact they occur throughout our oceans, the conservation measures required are going to be diverse.”

Sulikowski agrees: “We need to look at a holistic approach. Understanding migration patterns –

and the drivers of them – as well as where sharks spend critical time during key life stages (pregnancy, for example) could help conserve shark populations.”

Without approval from governments and the public, however, bringing sharks back from the brink will be difficult.

A REPUTATIONAL REBRAND

Thanks to the efforts of organisations like ReShark, governments and the public are, slowly, beginning to appreciate the value of sharks thriving in their natural habitats. But experts agree that more needs to be done to highlight how endangered they are.

“Scientists are aware of historic and continued declines in shark populations, but the public is often uninformed,” Matich says. “The conservation of any species is inherently linked to garnering support from the public.”

Sharks are polarising. While some people are fascinated by the animals, many more are fearful of them. Indeed, galeophobia (a fear of sharks) is one of the world’s top phobias. “One of the biggest misconceptions about sharks is that every time we enter the ocean, they’re going to eat us, or want to eat us,” Sulikowski says. “The fact is, we’re not on their menu. If we were, there would be a lot more humans missing, as we’re slow and make noises that sound like injured prey.”

Typically, around 100 unprovoked shark attacks are reported and confirmed each year, meaning that for every shark attack recorded annually, humans kill close to one million sharks. If anything, sharks should be scared of us.

Matich believes that, while changing the narrative about sharks isn’t an easy proposition, it’s something that can be done in increments. “Work to share this knowledge through media is valuable, along with reducing, and ideally eliminating, media that creates a false idea around the inherent danger sharks pose to humans. Such an approach, coupled with improving the public’s understanding of why sharks are important, should increase the number of ocean stewards and improve shark conservation efforts.” **SF**

by **JOE PHELAN** (@acedece)

Joe is a freelance journalist whose work has appeared in *Scientific American*, *The Observer*, *Vice* and *National Geographic*.

ABOVE Scientists say an overhaul of global fishing practices is needed to protect sharks

LEFT Prof James Sulikowski has spent 25 years studying sharks, skates and rays

D A M A G E

A S S E S S

Could we deflect an asteroid to stop it from hitting Earth? The success of NASA's DART mission suggests so, but only after ESA's soon-to-launch Hera mission has checked the results will we know if this approach to planetary defence is a viable possibility



M E N T

by DR STUART CLARK

A

nother day, another rocket launch. So many, in fact, it's easy to get blasé. In 2023, almost 200 rockets lifted off from Earth, carrying satellites and other spacecraft into orbit. By early September this year, the number for 2024 had already reached 158, most of them from Elon Musk's SpaceX company,

which has launched 89 rockets and is aiming for around 150 by year's end.

In October, one of those additional SpaceX launches will carry the European Space Agency's (ESA) Hera mission into space. Although one more launch may seem almost insignificant, Hera could prove to be one of the most important missions ever launched, because it'll tell us how capable we are of deflecting asteroids.

In November 2021, NASA launched the Double Asteroid Redirection Test (DART) mission. It targeted Dimorphos, a small asteroid with a diameter of 177m (580ft) in orbit around a larger one called Didymos. The DART spacecraft would collide with Dimorphos on purpose to see if it could alter its orbit around Didymos. Any change would be reflected in a shift in the small moonlet's orbital period.

The mission was designed to test a deflection technique known as the kinetic impactor – essentially smashing one thing into another – and it succeeded spectacularly. The spacecraft impacted Dimorphos at a speed of approximately 6.6km/s (over 14,750mph) in September 2022, changing its orbital period around Didymos by 33 minutes – far more than had been expected. It was a historic moment, marking the first →

→ time we had intentionally altered the trajectory of a celestial body.

“DART has really shown how effective a kinetic impactor can be in moving and diverting small asteroids. It was a complete and utter success of a mission,” says Prof Alan Fitzsimmons, an astronomer from Queen’s University Belfast, Northern Ireland, who specialises in asteroid research.

To really make use of DART’s success, however, astronomers need to know a number of crucial facts about its target – for example, the internal structure of Dimorphos and exactly how it responded to being hit.

This is where Hera comes in. Arriving at the Didymos-Dimorphos system in 2026, Hera will perform a detailed post-impact survey of both asteroids, carrying out high-resolution imaging, measuring the asteroids’ masses and studying the full aftermath of DART’s impact.

“DART succeeded so well that we have no clue what Dimorphos now looks like,” says Dr Patrick Michel of the Université Côte d’Azur, in France, and Hera’s principal investigator. “We have different kinds of predictions that all work, but are all very different.”

One of the predictions says there will be a well-defined crater on the surface, while another says that the asteroid could have been completely reshaped and that boulders might have been thrown from it onto the surface of the larger Didymos. Astronomers will find out by comparing the images from DART’s Draco camera to those from Hera. “It’ll be like the discovery of a new world,” says Michel.

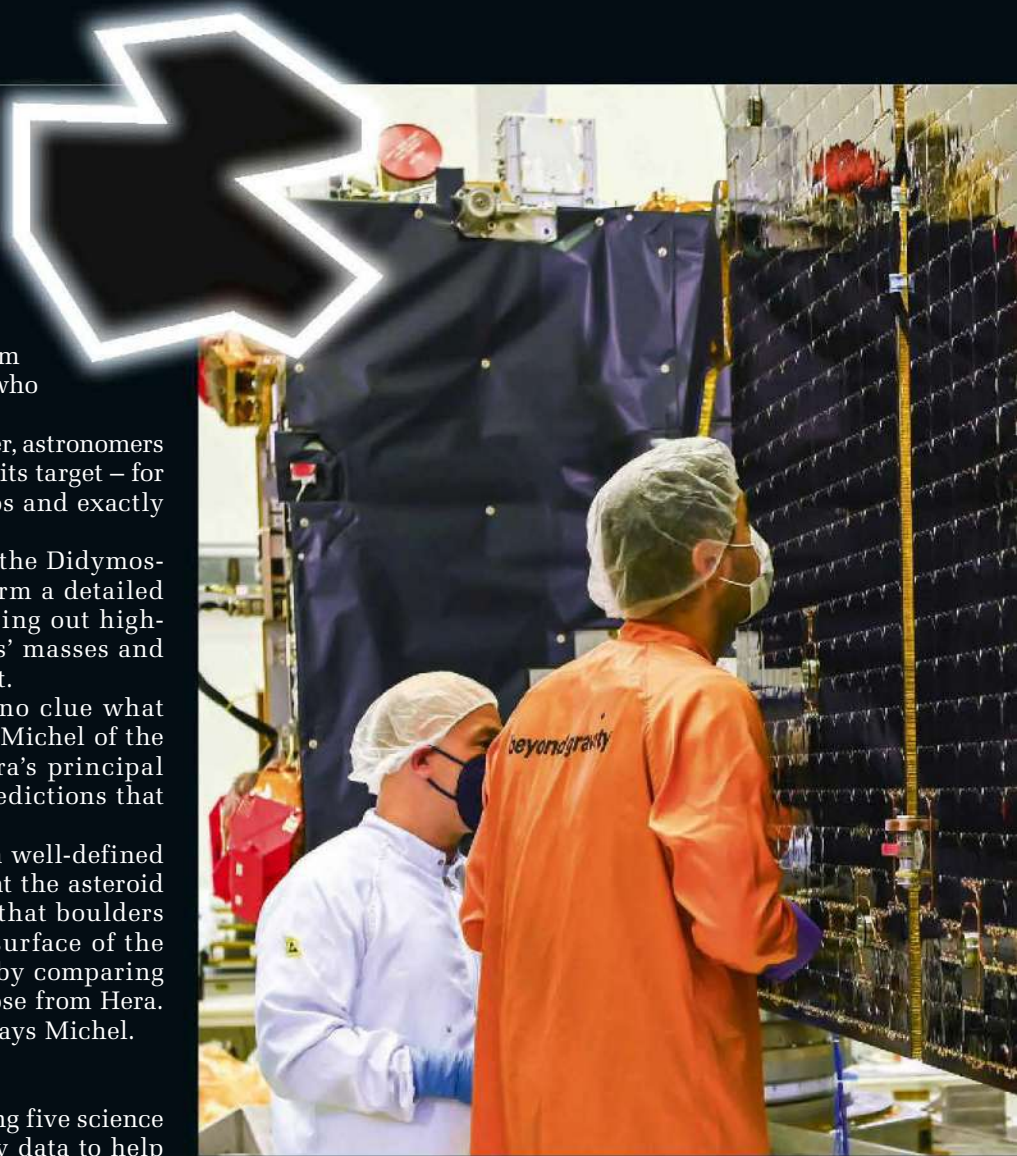
THE HERA SPACECRAFT

Hera is a 1.2-tonne (2,645lb) spacecraft carrying five science instruments that will gather complementary data to help characterise Dimorphos. There are two cameras, one working at visible wavelengths and another in the infrared; a hyperspectral imager that allows light to be split into small bands to aid geological and compositional investigations; a laser altimeter to gauge how far Hera is from the asteroid’s surface; and a radio experiment that helps determine the asteroids’ masses and gravitational fields.

In addition, Hera will also deploy two CubeSats, nanosatellites named Milani and Juventas. These small, secondary spacecraft will carry out additional investigations, including radar and spectroscopic analyses. Milani will allow the mineralogy of the asteroids’ surfaces to be detected, whereas Juventas carries a radar that will allow the scientists to look inside the asteroids to help determine their internal structure and composition.

Taken together, the data will prove essential in our understanding of asteroid deflection techniques and their potential applications in future planetary defence efforts.

“PLANETARY DEFENCE HAS BECOME A MAJOR FOCUS FOR SPACE AGENCIES AROUND THE WORLD”



ABOVE Solar wings will power the Hera asteroid mission as it ventures out to meet the Dimorphos and Didymos asteroids

RIGHT The Hera spacecraft’s antenna will transmit back the close-up images of the asteroids

This is because asteroids can come in two broad types: monolithic and rubble piles.

Monolithic asteroids are single slabs of rock that were once molten. Rubble piles are conglomerations of pieces of debris with no real solid structure to them. Each would react to a kinetic impactor in a different way. Dimorphos is thought to be a rubble pile asteroid.

“When we get those first images back from Hera at the end of 2026, we’ll know very quickly what the internal structure of Dimorphos is, how it reacts and its physical characteristics,” says Fitzsimmons.

GLOBAL EFFORTS

During the past 20 years, planetary defence has become a major focus for space agencies around the world, reflecting the growing recognition of the threat asteroids pose. It’s not just NASA and ESA that are involved in protecting the planet from dangerous asteroids.



China is also working on a deflection test similar to DART and Hera. Although unnamed at present, the mission is due for launch sometime around 2027 and the current target is asteroid 2015 XF261. This is a small asteroid that's estimated to be between 17–78m (55–255ft) wide.

“China plans to combine the DART and Hera missions into one launch. So they would have a single launch sending two probes. One would go on a course to intercept this asteroid and, at the same time, the other probe would take a different trajectory and be able to do follow-up observations,” says Andrew Jones, a space journalist who specialises in covering China's space industry.

Reversing the DART and Hera process, the Chinese observer spacecraft would arrive first so that it could spend months studying the unblemished target asteroid. It would also watch the impact in real-time and begin scrutinising the aftermath instantly.

As well as advancing our understanding of planetary defence, there's a lot of pure science to come from these missions. Asteroids are the leftover remnants from the beginning of the Solar System. They hold crucial clues about the formation of Earth and other planets. Any mission that studies an asteroid's structure and composition is adding to our knowledge of our origins, as well as to our future survival as a species.

There's also a geopolitical angle to China's interest. “China aims to demonstrate leadership in space and generate prestige, similar to NASA,” says Jones. “So national security and strategic implications are also motivating factors.”

This may not lead to competition, however. Instead, the global nature of asteroid threat could bring similar nations together in collaboration, according to Jones.

Fitzsimmons agrees: “Asteroids don't care about boundaries or geopolitics, so perhaps having a little bit more openness and being able to work with each other would be quite nice.”

EARLY WARNING SYSTEMS

While it's the deflection tests that capture the headlines, the true cornerstone of planetary defence is detection.

Former Army officer Jonathan Tate established Spaceguard UK in 1997. It's an independent observatory and visitor centre in Powys, Wales, that supplies information to schools, universities and tourist parties about the asteroid threat and what's being done to detect and prepare for them.

For Tate, the message is clear. “There's absolutely no reason that a proper, well-organised, reasonably well-funded planetary defence organisation can't protect Earth,” he says.

While The Spaceguard Centre is modest in global terms, it continues to perform essential follow-up work of tracking known asteroids to refine the knowledge of their orbits. Tate is also just coming to the end of a long project to install a discovery camera to help in the search.

Of the larger government-funded initiatives, ground-based telescopes and radar systems, such as those operated by NASA's Planetary Defence Coordination Office (PDCO) and the International Asteroid Warning Network (IAWN), now continuously scan the skies for objects that could come →



ESA/SJM PHOTOGRAPHY X2



→ dangerously close to Earth. There are dozens of facilities around the world that contribute to this effort, and two stand out. They are the Pan-STARRS (Panoramic Survey Telescope and Rapid Response System) telescopes at the Haleakalā Observatory on Maui, Hawai'i, and the Catalina Sky Survey (CSS) in the Santa Catalina Mountains, Arizona in the US. Together they've discovered more than 17,000 near-Earth asteroids, or near-Earth objects (NEOs) as they tend to be called.

A particular success for the CSS was the discovery of asteroid 2024 RW1, a one-metre-wide (3ft) space rock that was detected by the system on 4 September 2024. ESA instantly analysed the data and realised that it was heading for Earth, posting the prediction on X (formerly Twitter), stating: "A roughly 1 metre asteroid will strike Earth's atmosphere over the Philippines near Luzon Island at 17:08 UTC today, 4 September. The object is harmless, but people in the area may see a spectacular fireball! Discovered this morning by the Catalina Sky Survey, this is just the ninth asteroid that humankind has ever spotted before impact."

And, indeed, the disintegrating space rock produced a super-bright meteor that was caught on numerous cameras and videos. Although the time between detection and impact was around eight hours, it proves to Fitzsimmons the progress that's being made in impact prediction.

"The important thing is that it was actually found," he says. "The orbit was calculated, it was tracked, and we knew it was going to hit; the impact time was calculated and the impact position was calculated very accurately before it entered Earth's atmosphere. Go back 20 or 30 years and that wouldn't have happened."

In other words, the telescope survey systems and the associated follow-up calculations are now sensitive and quick enough that they can predict impacts. And if we can do it for a small, one-metre-wide object found only a few hours before it enters Earth's atmosphere, we should be able to discover incoming 50m objects a week before impact, or objects the size of Dimorphos around a month or longer before they hit.

This is crucial because early detection is the key to success when deflecting asteroids. The sooner a dangerous asteroid can be detected, the smaller the nudge it'll need to move it out of harm's way.

INTENSE OBSERVATION

To bolster our ability to detect NEOs, there are a number of new facilities being planned and built. ESA is working on a ground-based telescope called Flyeye, which uses specially constructed optics inspired by the compound eyes of insects to view a large area of the night sky all at once. It's currently scheduled to be built on the Italian island of Sicily.

In 2025, the Vera C Rubin Observatory, located on Cerro Pachón in Chile, will begin operation. Housing a giant survey telescope with a diameter of 8.4m (27.5ft), it's expected to prove an amazing discovery machine for finding NEOs.

There are a number of space-based telescopes in the offing, too. NASA is funding the NEO Surveyor space telescope for launch in around 2027–28. This 50cm-diameter (20in) space telescope is designed to discover and characterise most of the potentially hazardous asteroids and comets that come within 30 million miles of Earth's orbit. Working at two infrared

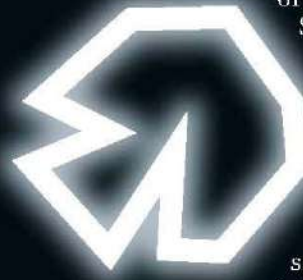
wavelengths, the telescope will provide good size estimates for the asteroids that it finds and provide information on their compositions, shapes and rotation rates. The mission is expected to work for at least five years.

Meanwhile, ESA is planning NEOMIR (Near-Earth Object Mission in the Infrared) that, if approved, would provide early warning of asteroids approaching Earth from the direction of the Sun. These can't be detected by ground-based observatories, as they are hidden in its glare. A prime example of an asteroid 'coming out of the Sun' was the Chelyabinsk meteor of 13 February 2013 that hit Earth's atmosphere close to the city in the Ural Mountains in Russia without warning that morning.

Chinese researchers have also proposed an early warning system for Chelyabinsk-like objects. Known as CROWN, instead of NEOMIR's single space telescope, the ambitious Chinese concept proposes six space telescopes in Venus-like orbits to keep a close watch on this difficult-to-survey region of space.

THE GREAT SERPENT

Even before Hera has launched, ESA is already setting its sights on its next asteroid target. In 2029, asteroid Apophis will make a historic close flyby to Earth. With a diameter of 370m (1,213ft), Apophis caused concern upon its discovery in December 2004, when initial orbital calculations gave it a 2.7-per-cent chance of hitting Earth on 13 April 2029 (ironically a Friday). Somewhat melodramatically, it was



A

BELOW Dr Patrick Michel of the Université Côte d'Azur, France, is Hera's principal investigator





“THE ASTEROID WILL COME SO CLOSE TO EARTH THAT OUR PLANET’S GRAVITATIONAL FIELD HAS THE POTENTIAL TO ALTER ITS ROTATION AXIS AND ORBIT”

named after the ancient Egyptian mythological serpent who was said to attack the Sun god Ra each night to stop sunrise.

Subsequent observations refined the orbit of Apophis to the point that the collision was ruled out, but it’ll pass Earth just 32,000km (19,880 miles) above its surface – lower than the ring of geostationary communications satellites at 36,000km (22,370 miles), and bright enough to be seen by the naked eye. More than two billion people in Africa, Europe and Asia could have the opportunity to see it pass across the sky. Calculations suggest that such a sight is a once-in-every-7,000-years event.

The asteroid will come so close to Earth that our planet’s gravitational field has the potential to alter its rotation axis and orbit, and may even create ‘quakes’ on its surface. So, Michel and others from the Hera team are proposing a new mission to ESA, to be built and launched fast enough to rendezvous with Apophis and follow it through its closest approach, gaining valuable scientific data. The mission, dubbed Ramses, is currently in the design phase, and will need to be approved by ESA at its Ministerial Council meeting next year if it’s to proceed. It’ll then need to be built and launched within three years. “This is challenging,” says Michel. He insists,

ABOVE The Milani CubeSat, built at Tyvak International in Turin, Italy, will investigate the minerals of the Didymos and Dimorphos asteroids

by **DR STUART CLARK**

(@DrStuClark)
Stuart is an astronomer, science journalist and author. His latest book is, *Beneath the Night: How the Stars have shaped the History of Humankind* (Guardian Faber, 2020).

however, that not only is it possible, but also that launching asteroid missions as quickly as possible will be a necessary component of planetary defence. After all, as soon as we detect an asteroid on a collision course, we’ll want to take a good look at it – and fast.

“We’ll want to send a reconnaissance probe to tell us the properties so that we can design the best deflection mission possible,” Michel adds.

It’s an extraordinary turnaround. Rewind the clock a few decades and the threat from asteroids was largely swept under the carpet. Now we’re on the cusp of having a fully tested and understood deflection mechanism.

“I couldn’t have imagined we’d be where we are now 20 years ago, so imagine where we’ll be 20 years from now. It’s going to be an interesting journey,” says Fitzsimmons. **SF**

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KEEP
YOUR



ON

**MORE THAN HALF OF MEN AND MILLIONS OF WOMEN ARE AFFECTED BY HAIR LOSS.
IT CAUSES LOW SELF-ESTEEM IN SOME AND ANXIETY IN OTHERS.
THANKFULLY, SCIENTISTS AROUND THE WORLD ARE GETTING TO THE
ROOTS OF THE PROBLEM WITH PIONEERING NEW TREATMENTS**

by HAYLEY BENNETT

As the partner of a 40-something male, I'm acutely aware of the hair-loss horizon looming large in our house. With the first signs of a receding hairline come furtive glances in the bathroom mirror, then throwaway remarks about shaving it all off. Pretty soon, we'll be stocking up on scalp cream and hats.

Going bald is no joke, though, as the now-retired American body-image expert, Prof Thomas Cash, showed in a 2001 study. Cash convinced 145 customers of Virginian barber shops and hair salons to visit his lab, where he checked the extent of each man's hair loss and asked them how they felt about it. Men who had more severe balding were less satisfied with their hair, but also with their overall appearance, admitting to feeling self-conscious and unattractive, while actively coping by restyling their hair, trying to dress better and embracing the aforementioned hats.

And while Cash's study focused on men's hair hang-ups, plenty of women have to confront hair loss too. In fact, according to Dr Christina Weng, a dermatologist in Boston, Massachusetts, and chief medical officer at Los Angeles-based company Pelage, which is developing a new drug to treat the condition, the majority of patients she sees for hair loss are women. "Hair is obviously a big part of identity so it's really distressing and the treatments are very limited for female patients," she says. In contrast to men, who lose their hair in the classic pattern we've come to expect (the receding hairline and bald spot) women are more likely to have thinning across the whole scalp.

Either way, the widespread psychological impact of hair loss makes it a condition deserving of better solutions. Existing hair-

loss medications have been around for years and don't benefit everyone who tries them. Meanwhile, hair transplants may be a great solution for the celebrities of the world, but they're not affordable for most of us. All of this means that scientists are still seeking new ways of saving our scalps.

IN THE GENES

As with many conditions, treating balding depends on knowing what causes it. That's something scientists are still working on. What we do know is that it's a complex picture involving ageing hair follicles, hormones and stress – as well as whatever genes our parents passed on.

More than 380 sites in the human genome are known to play a part, although this large collection doubtless boils down to fewer mechanisms that could be targeted to develop new treatments. "That will somehow merge into a number of pathways and maybe a number of main regulators and switches," says Dr Stefanie Heilmann-Heimbach from the University of Bonn in Germany, whose work focuses on the genetics of hair loss. Since the human genome was sequenced, scientists have uncovered strong links between balding and genes on the X chromosome that influence the body's response to testosterone. Evidence for a hormonal link emerged much earlier, however. In 1960, the anatomist Prof James Hamilton noticed that mentally disabled men castrated in American prisons (a shockingly common practice associated with the eugenics movement) didn't go bald. Moreover, those who had a family history of balding started to lose their hair if they were given testosterone.

The role of testosterone became even more intriguing in the 1970s when a rare 'gender-switching' condition was discovered in families in the village of Las Salinas in →

**"IT'S A
COMPLEX PICTURE
INVOLVING AGEING
HAIR FOLLICLES,
HORMONES
AND STRESS"**

→ the Dominican Republic. Children with the condition are initially brought up as girls, but develop male genitalia during puberty. As adults, however, their prostate glands remain small and they don't lose their hair like other men.

When US scientists studied how these people metabolise testosterone, they appeared to have normal testosterone levels while, crucially, lacking the enzyme needed to convert the hormone into its more potent form: dihydrotestosterone (DHT). It's DHT that's responsible for the development of male sex characteristics in the womb and, later, acne and hair loss. Both DHT and testosterone stick to receptor molecules, called androgen receptors, whose production we now know is housed in the same region of the X chromosome that links to balding.

The triggering of these receptors all over the body (including in those associated with hair follicles) mediates the hormones' effects. DHT binds more tightly to the receptors than ordinary testosterone and people whose genes make them more sensitive to DHT, or who convert more of their testosterone into it, face a greater risk of going bald.

DHT accumulating in hair follicles is considered key to the chain of events that eventually leads to a bare scalp. This process centres on the 'shrinking' of hair follicles, as they spend less time actively growing and more time in the resting phase between one cycle of hair growth and the next (see 'The hair growth cycle', p64).

"Usually the new hair cycle is switched on and there's a regrowth of the hair," says Heilmann-Heimbach. Whereas in balding, she says, the follicles spend more and more time resting between cycles, becoming shorter and shorter, until eventually they fail to breach the scalp at all.

A few decades back, the enzyme that converts testosterone to DHT – 5-alpha-reductase (5AR) – became a target for pharma companies as it was presumed that suppressing it could treat men with conditions like an enlarged prostate and hair loss. In 1992, these efforts led to the approval of the first 5AR blocker, finasteride, which remains one of only two widely approved hair-loss treatments – the other being minoxidil, a drug whose action isn't fully understood.

Both offer limited benefits and neither come without side effects. In finasteride's case, the side effects can't be glossed over: erectile dysfunction, depression and



suicidal thoughts. The drug is also not prescribed for women, largely due to risks to unborn babies (though benefits for post-menopausal women are being explored).

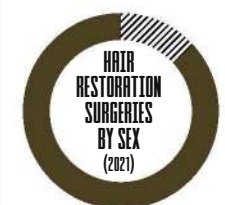
NEW APPROACHES

Testosterone may be essential to the balding process, but as Heilmann-Heimbach notes, interfering with testosterone is "not the ideal option" for treating the condition, precisely because of the hormone's widespread effects. So, alternative solutions targeting other, or multiple, biological pathways are in demand.

One increasingly popular experimental treatment is platelet-rich plasma (PRP) therapy, in which a whole bunch of components with restorative potential are concentrated from the patient's own blood and then injected into their scalp. But while the therapy has shown promising results and is safe for men and women, it's not clear exactly how it works or what the standard treatment regimen should be. Plus, it's impossible to predict who it's going to work for – a problem for such an expensive

703,183

The number of hair transplants performed globally in 2021



12.7% on women
87.3% on men



“THESE THERAPIES CAN ESSENTIALLY USE FAT FROM YOUR BOTTOM TO REGROW HAIRS ON YOUR HEAD”

treatment. As Weng points out, “[You might pay] \$800-plus (around £600) a pop for a series of six injections and then maintenance injections thereafter. So the cost really adds up and you don’t know if you’re going to be one of the folks who respond until six treatments in.”

PRP therapy is one of a growing number of new ‘regenerative’ treatment approaches intended to stimulate hair regrowth through growth factors and other components, which experts think may tackle inflammation, reduced blood supply and the altered hair growth cycle in thinning hair.

Many regenerative approaches use stem cells, either in an attempt to freshen up ageing hair follicles’ stores of stem cells, which are supposed to generate new hairs, or as a source of molecules with the desired regenerative effects.

“We think that by providing stem cells we could restore the population that has been diminished,” says dermatology chief Dr Eduardo López Bran from the Hospital Clínico San Carlos in Madrid, Spain, who believes that stem cells could

offer longer-lasting benefits than existing medications. In August, López Bran and colleagues at Complutense University of Madrid published a study outlining the latest advances in regenerative hair-loss therapies, highlighting several examples where stem cells were collected from patients’ excess fat tissues, which offer more accessible stores than sources like bone marrow and teeth. These therapies can essentially use fat from your bottom to regrow the hairs on your head.

In 2020, plastic surgeons and dermatologists in the US treated a group of 71 men and women with stem cell-enriched fat, collecting the fat via liposuction, processing it to concentrate the stem cells and then injecting it back into the participants’ scalps. The treatment increased hair growth over 24 weeks (albeit with a possible need for repeat treatment after a year) and is now being developed by US company Bimini Health Tech under the name Kerastem.

SIMPLER METHODS, BETTER RESULTS

However, it’s becoming clear that what stem cells produce when they’re cultured in the lab – their so-called ‘secretome’ – may be more practical for treatment purposes than whole stem cells, which have to be kept alive. Recent trials suggest such secretions can increase both hair density and thickness, with better results the longer treatments last. In one trial, patients receiving laser therapy for hair loss also got a preparation made from stem cells (or a placebo) applied to their heads. Those who received the rejuvenating elixir grew an extra 14 hairs per cm² compared to two per cm² with the placebo.

So what’s the secret of the secretome? Essentially, it’s a collection of molecules that scientists hope can manipulate key biological pathways involved in hair growth. One such pathway is the ‘Wnt’ pathway, which Heilmann-Heimbach’s genetic studies have linked to hair loss.

“Wnt signalling is an important regulator of the hair growth cycle,” she says. “And what genetic studies show is that men who are balding more frequently have particular genetic variants in or near genes involved in Wnt-signalling.”

Intriguingly, it’s thought the Wnt pathway may also interact with testosterone-related pathways. As well as individual molecules, many cells (including stem cells) also release bigger bubbles of molecules, seemingly to communicate →

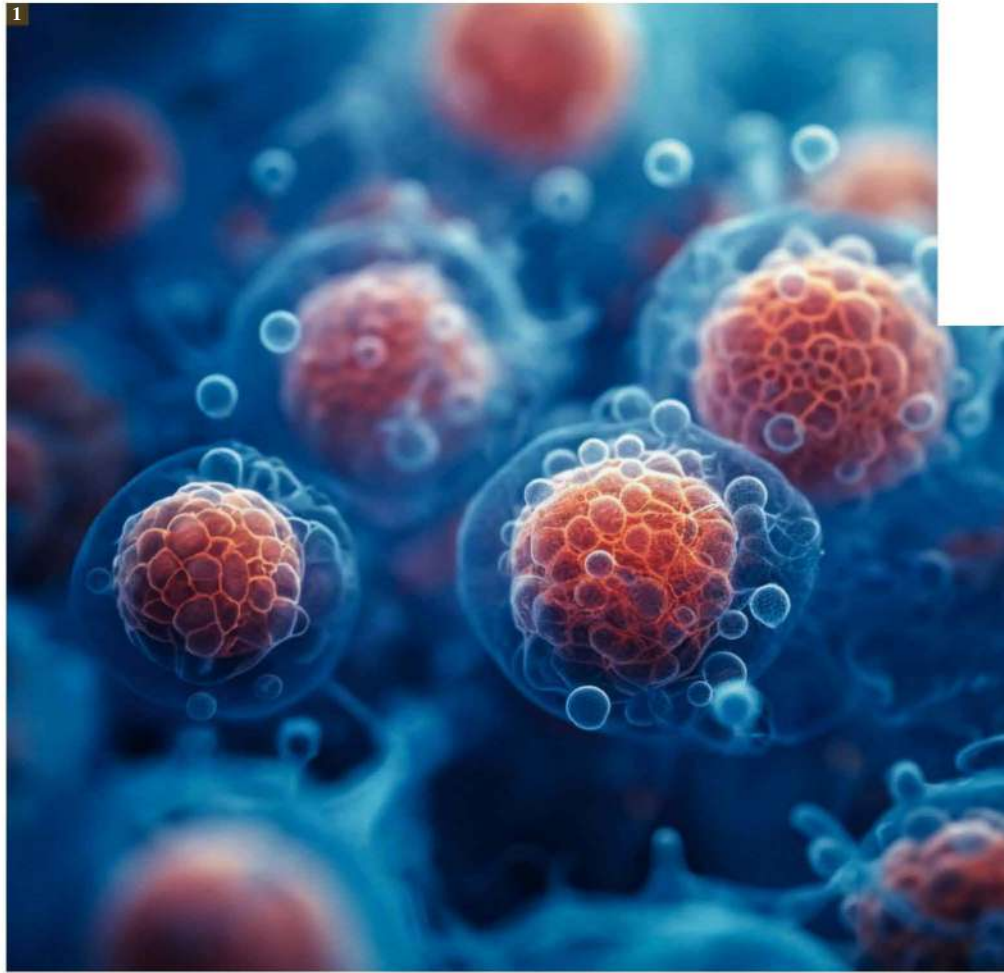
TOP More and more people are seeking hair transplants, which cost anything from £1,000 to £30,000 (approx \$1,300–\$40,000)

→ with cells elsewhere in the body and to transfer useful cargoes to them. These ‘exosomes’ were only discovered around 40 years ago and thought of as cellular ‘garbage’, but some scientists now see them as potential treatments for everything from Alzheimer’s disease to bone cancer.

Exosomes from the stem cells of healthy human hair follicles have been shown to alter the hair regeneration cycle in mice by teasing follicles out of their growth phase and delaying the shedding phase, a neat trick apparently accomplished by hair-growth-regulating molecules – including those in the Wnt pathway. Dr Mert Ersan, a plastic surgeon at Yeditepe University Hospitals in Istanbul, Turkey, has just completed a trial aiming to treat baldness using exosomes from stem cells in foreskins. While Ersan couldn’t divulge anything more about the trial before the results are published, he confirmed that it’s “one of the first in a clinical context.”

NEW AWAKENINGS

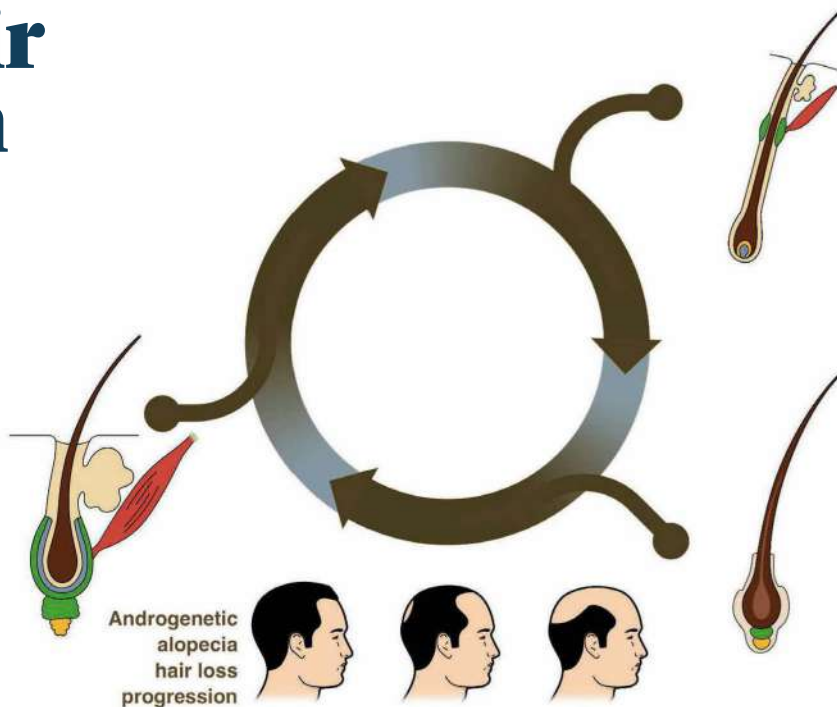
If you don’t fancy fixing your hair with your own fat or other people’s foreskins, however, there may one day be regenerative options that resemble more traditional medications. Pelage recently attracted investment to continue clinical trials of its topical treatment for hair loss, PP405, which Weng says delivered “fantastic”



The hair growth cycle

TELOGEN PHASE
Resting

The follicle rests for a few months in preparation to grow again. In balding, this phase becomes increasingly long.



Androgenetic alopecia hair loss progression

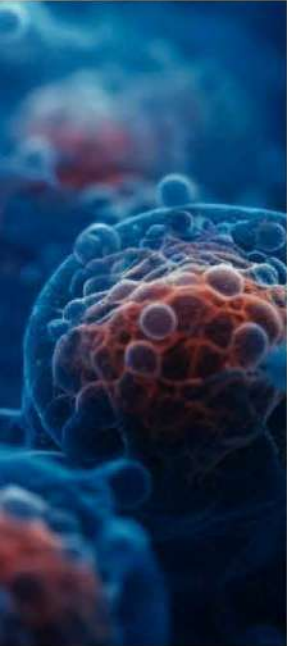
ANAGEN PHASE
Growing

Healthy hair follicles may grow for up to six years, but in balding, the anagen phase of follicles gets shorter so that hairs don’t grow as long.

CATAGEN PHASE
Hair loss

The hair detaches and falls out over a matter of weeks.

SCIENCE PHOTO LIBRARY X3 ILLUSTRATION: ACUTE GRAPHICS



results in initial safety trials in humans. The drug works by targeting stem cells already living in the hair follicles. In healthy hair follicles, these stem cells maintain a “mysterious lifestyle”, says Dr William Lowry, Pelage co-founder and stem cell expert at the University of California in Los Angeles. “They wake up at the start of a new hair cycle to produce very rapidly dividing cells that go on to make a new hair and then they return to quiescence a couple of days later.” In ailing follicles, however, they can get stuck in the resting phase of the cycle and carry on sleeping.

What Lowry’s team discovered is that the sudden awakening of hair follicle stem cells is associated with metabolic quirks that seem to be particular to stem cells, which can be manipulated by the right drug molecules to shake the cells out of their slumber. While such drug molecules could also be used to activate stem cells in other areas of the body, Weng says PP405 has been specially engineered to penetrate the hair follicle. The drug can be incorporated into easy-to-apply gels or creams for home use – an advantage over injections that can only be given at a clinic. Reviving the hair’s indigenous stem cells is easier than relying on stem cells that have to be cultured outside the body. “Cell-based therapy is just much more complicated logistically,” says Lowry. “Maybe, one day it could be a way to restore follicles if you’ve lost all your follicles, but for most

[regular male or female pattern baldness] the stem cells are still there and so our approach is just to wake them up.”

Meanwhile, tissue regeneration experts from other fields are exploring solutions that don’t focus on stem cells at all. At the COMSATS University Islamabad in Pakistan, Dr Muhammad Yar has devoted much of his career to finding better treatments for burns and ulcers. One of the problems he has been trying to solve is poor blood supply to wounds,

which can impair healing. Poor blood supply affects ageing hair follicles, too. So, when he came across a natural molecule that appeared to help restore blood supply, it occurred to him it might also be a good bet for hair regrowth.

This 2-deoxy-D-ribose (2dDR) molecule is a sugar that forms part of our DNA and is already available from companies stocking scientific supplies. “We were very happy to see that we could buy this at kilogram scale from various companies,” says Yar. “So it was really easy for us to buy and use it.” The implication being that it could provide a quick, and possibly cheap, option for a new treatment.

Working with researchers at the University of Sheffield in the UK, Yar made a gel containing 2dDR that they tested on mice. It turned out to be as effective as minoxidil and Yar suggests it should have fewer side effects, since it’s “already in our bodies anyway, so it’s not something strange.” Still, it’ll have to undergo testing in humans before making its way on to pharmacy shelves.

The question is, then, can today’s 40-somethings feel any more hopeful about saving their 50-something hairlines? Well, López Bran expects some new stem cell-based therapies to reach the latter stages of clinical trials in the near future, while PRP, he says, is likely to be approved soon. Meanwhile, women’s options look to be expanding with companies like Pelage testing their products in both sexes.

For Heilmann-Heimbach though, the chances of finding a cure for balding increase along with each new gene and biological pathway we can link up in the chain of events that causes it. “Balding is something we see every day,” she says. “Yet in biological and genetic terms, we’re still a bit in the dark – we have some clues, but it’s not the full picture.” In other words, if we’re going to stop hair loss, we’re going to have to get to the root of it. **SF**

1. Human cells secrete bubbles of molecules known as exosomes, which can be used in a hair-loss treatment to stimulate hair follicles and encourage new hair growth

2. Minoxidil is one of only two widely approved hair-loss treatments currently available, but it doesn’t work for everyone and comes with side effects

3. When balding occurs, hair isn’t being lost, rather the hair follicles are shrinking

by HAYLEY BENNETT (@gingerbreadlady)

Hayley is a science writer based in Bristol, UK.

Thanks to Lorena Pozo Pérez for interpreting the interview with Eduardo López Bran.



SOPHIA SPRING/EVÉVINE ILLUSTRATION ANDY POTTS

WATCH

Look out for *Solar System*, a brand-new series with Prof Brian Cox, coming this autumn



THE GOLDEN AGE
OF SPACE
EXPLORATION
WITH
**PROFESSOR
BRIAN COX**

The biggest space missions yet are making their way to new parts of the Universe. In his new BBC Two series *Solar System*, Prof Brian Cox reveals what these explorations are discovering about life in our galactic neighbourhood. **Noa Leach** sat down with him to talk about the most exciting new missions, life in the Universe and his top behind-the-scenes moments of filming

A

s you read this, five of the eight planets in the Solar System have spacecraft orbiting them or landers on their surfaces – and more are on the way. In his new series *Solar System*, Prof Brian Cox reveals the freshest insights coming from these spacecraft and landers, and which of the planets they're studying holds the most promise for finding signs of life.

So, naturally, we had to ask him all about it: from filming in the most alien-like places on Earth

to his hope that aliens might explore the vast expanses of the Universe after we humans (possibly) extinguish ourselves.

As a show, *Solar System* sounds familiar, but this series is very current and looks behind the scenes of the biggest space missions right now. What were your hopes for the show?

That was one of the central ones: to show that there are over 40 spacecraft currently active in the →

→ Solar System, so the amount of knowledge that we have of our neighbourhood is increasing all the time. With that increase – that huge amount of data that’s raining down on us every second from these probes – we find that there are more questions than answers quite a lot of the time.

So, as with a lot of science, one of the things I hope that the audience takes away is that in no sense do we know everything about our neighbourhood in space.

In particular, [in the show] we talk about life – and life is a central part of any exploration of the Solar System. We say that the Solar System is a giant chemistry set and life is chemistry – complex carbon chemistry.

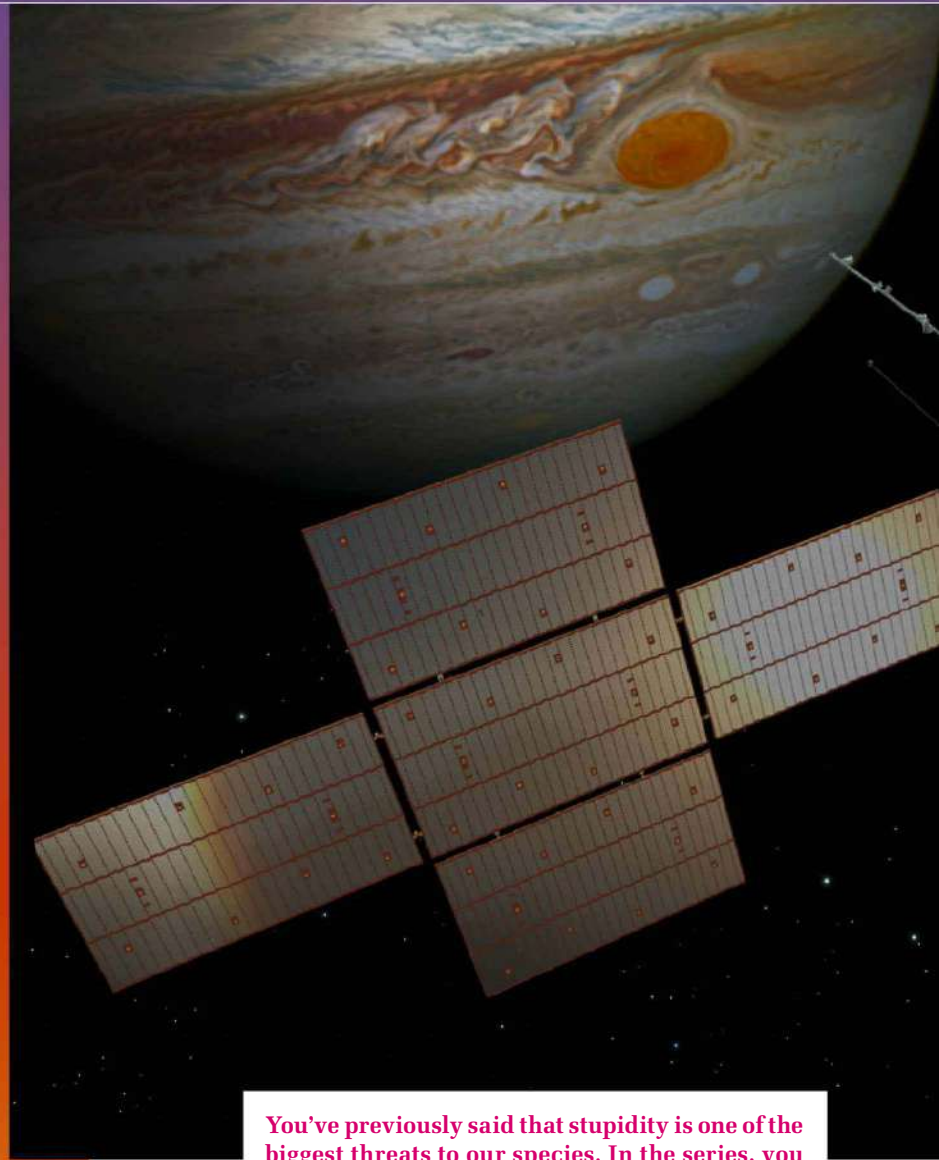
I think it’s fair to say that we’re finding more potential habitats than we ever would have guessed, in stranger places than we ever would have guessed. Ceres, the minor planet, is a good example. The fact that it appears, because of data from a spacecraft called Dawn, to have liquid water below its surface is a tremendous surprise.

Even the fact that the moon Enceladus around Saturn seems to have liquid water, an ocean perhaps, going all the way around it was a surprise. We would never have guessed that before the Cassini spacecraft got there. So we’re finding more and more places where the possibility for complex chemistry, and therefore possibly life, exists – and that’s, I think, one of the messages.

There are lots of behind-the-scenes moments: I loved the bloopers you’ve integrated into the series. Why did you decide to keep these in?

That stuff always happens – I’m always messing around! But the decision to put them in was, I think, a really good one because it shows you that not everything’s perfect all the time when you’re trying to do experiments and demonstrate things.

But I think [it also shows] there’s joy in doing science – even the apparently silly experiments that actually illustrate deep properties of nature. I like that we decided we would just put in some of the fun stuff as well, and not take ourselves too seriously.



You’ve previously said that stupidity is one of the biggest threats to our species. In the series, you also talk about our responsibility not to destroy ourselves, given how rare we seem to be. What do you think: are we special?

As with many profound questions, the answer is: we don’t know. But what I can do is look at what we do know and make a guess – my guess would be that civilisations are very rare in a galaxy like the Milky Way.

What [the evidence] suggests, if you look just at Earth, is that single-celled life may potentially be quite common (although we don’t know). But complex multicellular life might be less common, and something as complex as a human being in a civilisation might be extremely uncommon.

My guess is that, and I wouldn’t be surprised if, there are no other civilisations in the Milky Way. But in the entire observable Universe, where there are over a trillion other galaxies, I would be very surprised if there weren’t any other civilisations. It’s a big place!

Someone asked me once what I would feel if I saw an alien spaceship. I wouldn’t be surprised if an alien

“ I ’ M O P T I M I S T I C A B O U T
T H E F U T U R E O F S P A C E
E X P L O R A T I O N ”



spaceship came floating down and landed in Hyde Park. I'd go: "Okay, well, that solves a big puzzle here."

But what I'd *feel* would be relief. We're such idiots, I fear, that I think the chances of us surviving long enough to get out there to the stars are perhaps quite low. I'm not entirely convinced that we're going to do it; that we're going to solve the problems that we have here sufficiently well so that we can start to move out and become a multiplanetary and interstellar civilisation.

I'm quite miserable in the sense that if we don't do it, I think maybe nobody will. So there'll be nothing; the whole Galaxy will be meaningless, potentially, forever, because there's nothing out there that thinks, other than us. So if it turns out there [are aliens], then at least it's a weight off my shoulders. Then I'll think, "Well, at least somebody's done it."

I'd be utterly delighted if I was wrong. And that's really important because the foundation of science is to be delighted that you're wrong – that's when you find stuff out. The job is not to be right, but to find out more.

Let's talk about some of the missions and the research. The timescales involved are long: Europa Clipper is launching now, due to arrive at Jupiter's moon in 2030; the Jupiter Icy Moons Explorer (JUICE) will arrive in 2031; and the Perseverance rover is due to return its rock samples from Mars in the mid 2030s. How do you stay patient while we wait for these results? What about the people who are working on them? Can you imagine? You build these things, then have to wait 10 years, 15 years, 20 years for the data. It's a remarkable way of life for space

scientists. The thing is, the distances are so big. We could get things there more quickly, but it would make them a lot more expensive at the moment. That's part of the reason rocket technology, like what SpaceX and Blue Origin are working on, is really important.

Getting things into orbit and sending them off to the planets is really expensive. So the cheaper that gets, the easier it'll be to get more there, more quickly – and the easier it'll be to learn more. So, although I'm sometimes pessimistic, I'm optimistic about the future of space exploration just because it's getting easier and cheaper to do.

What were your top highs and lows of filming?

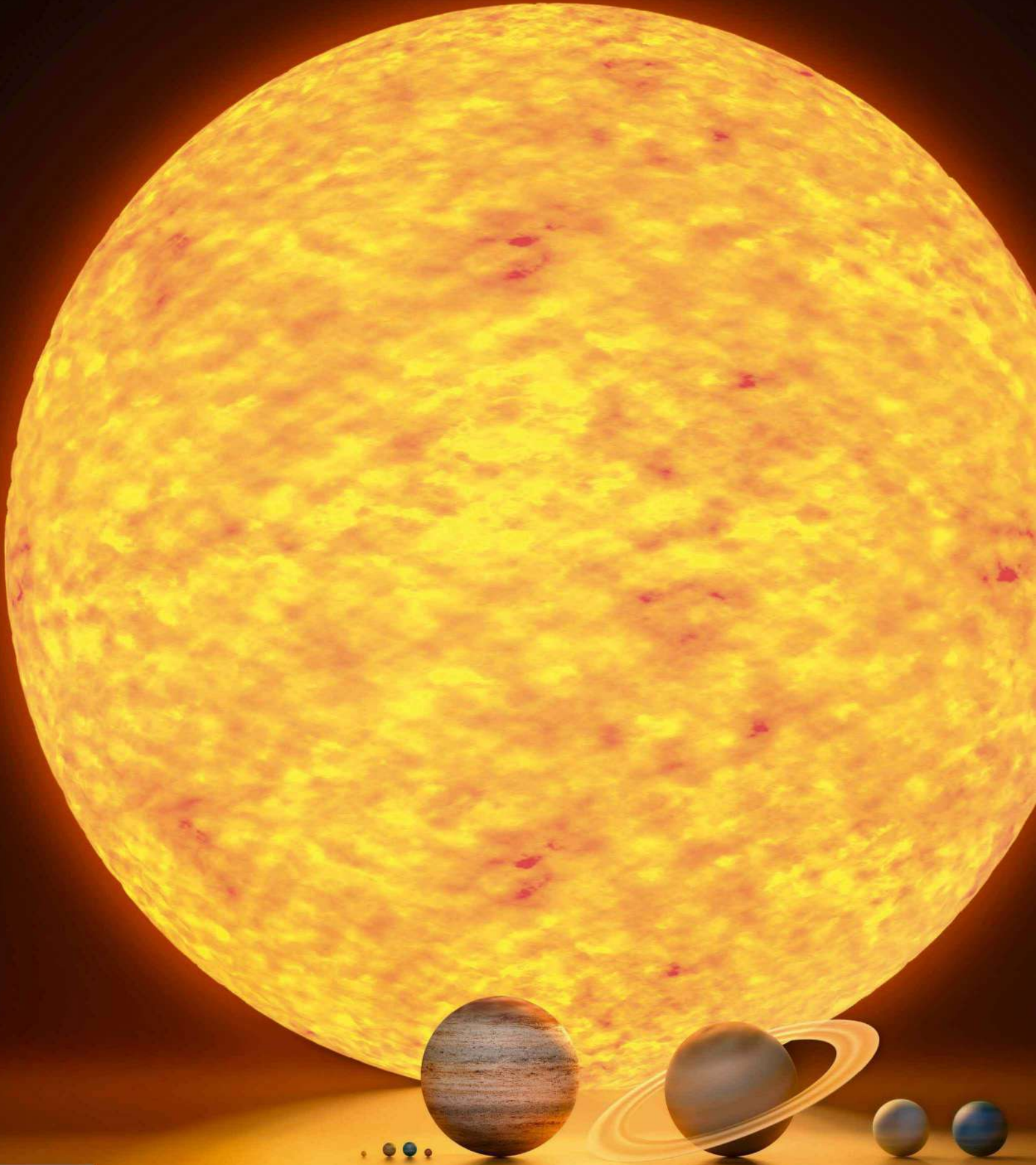
We filmed in Spain, a beautiful location that really delivered for us. But [we forgot that] it was the place that Terry Gilliam tried to film the *Don Quixote* film, which failed because of the location.

The thing is, it's a Spanish Air Force bombing range, which immediately should tell you it's not the easiest place to film because they've got jet aircraft practising bombing runs in it. And then it's also full of mosquitoes like you wouldn't believe – just clouds of these insects. It turned out very beautifully, but it wasn't very nice to film there!

And also Alaska: it was freezing cold. I always enjoy Alaska, but it's never easy. They told me to take a lot of protective clothing cause it's zero degrees, and I thought "Oh, that's fine." But it was zero *Fahrenheit* (-18°C) they were talking about! [When filming] my nose would go white, which is a sign of the start of frostbite, so then I'd have to put hand warmers on my nose and sit there for 10 minutes [before starting again]. **SF**

ABOVE ESA's JUICE spacecraft, launched in April 2023, will investigate Jupiter and three of the gas giant's moons

ABOVE RIGHT Prof Brian Cox filming on location by the Thrihnukagigur volcanic chamber in Iceland



WATCH

Look out for Solar System, a brand-new series with Prof Brian Cox, coming this autumn



THE ORIGIN OF THE SOLAR SYSTEM

by COLIN STUART

There are key details missing from the story of how our Solar System formed. But recent discoveries are helping scientists fill in the blanks and understand how rare it is

Origin stories have a special way of capturing our imaginations. Whether it's a particular species of plant or animal, or a favourite fictional character, knowing how they came to be makes for captivating stories. It's no different in space. Especially the small corner of it we live in: the Solar System.

How did it form and why does it look the way it does today? How does it compare to other solar systems and is the one we're part of special or just like all the others? In recent years, astronomers have got closer to answering these important questions and uncovering the story of our Solar System.

How they're doing it is a story in itself. Humans may not have been around to see and record how the Solar System began, but there were witnesses, of a sort, who can relate that part of the tale. The rocky asteroids and icy comets that silently patrol the Solar System date back to its earliest days. Many are older than Earth.

"Their chemical composition and the distribution of their orbits contain clues as to what happened in the Solar System's past," says Prof Alan Fitzsimmons, an expert on asteroids and comets at Queen's University Belfast.

ONCE UPON A TIME...

The story starts around 4.6 billion years ago, when a cloud of interstellar gas and dust buckled under

its own weight and collapsed until newborn stars lit up inside. The Sun was one of those stars.

Leftover material was hurled around these fledglings, forming flat bands known as protoplanetary discs. Gravity then took over, pulling and sculpting debris until it snowballed into objects, each one about a kilometre (just over half a mile) or so across. These 'planetesimals' then collided, smashing into each other and bulking up until the planets finally emerged.

But, where we find the Solar System's eight planets today isn't where they started their →

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→ lives. They've jostled and jockeyed for position, migrating from their birthplaces to settle into a more stable configuration. At least that's according to the Nice model, a popular version of the Solar System's origin story named after the city in France where it was devised.

As the largest planet, Jupiter had a particularly big role to play. Today, Jupiter shares its orbit around the Sun with a population of ancient rocks known as the Trojan asteroids. These asteroids appear to be quite diverse, with varying compositions. This means it's unlikely that they all formed together in the same spot. If the planets did shuffle around, they would have scattered asteroids and comets far and wide, from many different places, in the process. Jupiter's intense gravity could have vacuumed up many of the stragglers. "We know very little about the Trojans," Fitzsimmons says.

That may soon change, though, thanks to NASA's Lucy mission, which is en route to the outer Solar System. The spacecraft is named after the 3.2 million-year-old fossils of a hominin found in Ethiopia, which, when they were discovered in 1974, were the oldest-known, human-like remains. The choice of name underscores the fact that asteroids and comets are the fossils of the Solar System.



Astronomers, like archaeologists, pore over ancient fragments in search of answers. Lucy launched in 2021 and should arrive at the Trojans in 2027. With the data that Lucy collects, “we should be able to work out where the Trojans have been,” Fitzsimmons says. In turn, that could tell us how the Solar System’s early evolution forced them into their current position.

STELLAR SIBLINGS

According to the Nice model, Jupiter moved slightly inwards towards the Sun, whereas the other three giant planets (Saturn, Uranus and Neptune) moved outwards. The outer trio then encroached upon the Kuiper Belt, an icy band of objects that includes dwarf planet Pluto. The outward migrating planets, particularly Neptune, scattered smaller objects from the Kuiper Belt further out and off the main plane of planets, creating what’s known as the Scattered Disc.

This distant region is thought to be the source of short-period comets – those that tumble around the Sun every few decades or centuries (Halley’s Comet being the most famous example). Except there’s a problem: “The predictions and the observations don’t match,” says Fitzsimmons. In other words,

ABOVE
Planetesimals, rocks that form from the dust and gas around newborn stars, collide and fuse together, eventually creating new worlds

LEFT ESA’s Comet Interceptor will be the first mission to visit a comet coming from the outer reaches of the Solar System in a bid to get a snapshot of its earliest days

the Nice model alone can’t account for the way the Scattered Disc looks today.

A relatively new idea – one that’s gaining popularity – could yet save the day. Astronomers are confident that the Sun wasn’t born alone. They think it had many siblings that have since drifted away. Just as our siblings help shape the people we become, so the Sun’s brothers and sisters may have contributed to the way the Solar System looks today.

The infant Solar System could have experienced one or more stellar fly-bys as the Sun’s siblings drifted away – other stars buzzing past us at thousands or maybe even only hundreds of times Earth’s current distance from the Sun. The gravitational pull of these stars could have upset the astronomical apple cart. “If the nascent Solar System got a little push with a close fly-by, that gives a much better fit to what we see now,” Fitzsimmons says.

In this way, the distribution of comets may hold the key to unlocking the secrets of the early Solar System. They may also be responsible for making it a suitable place for life, delivering the chemicals necessary for life to evolve on this planet. For many years, comets were thought to have delivered water to the early Earth once it had cooled sufficiently after its fiery formation from colliding planetesimals.

Astronomers are starting to change their minds, however. “The consensus is swinging towards asteroids,” Fitzsimmons says.

One of the major catalysts for the change of heart came when the European Space Agency’s (ESA) Rosetta mission visited the comet 67P/Churyumov-Gerasimenko a decade ago. Rosetta’s study of the comet found it contained a ratio of deuterium to ordinary hydrogen that’s three times higher than the ratio found on Earth. The result suggests comets like 67P may not have been responsible for delivering such chemicals to Earth.

But it’s not as clear-cut as that. Comet 67P has spent a long time in the inner Solar System. Interactions with the Sun have eroded its surface and could have changed its chemistry. If we’re to really see what comets were like back when the Solar System formed, we need to study one that has never entered the inner Solar System.

That’s exactly the plan behind ESA’s Comet Interceptor mission, slated for launch in 2029. Its target hasn’t even been discovered yet. Astronomers are waiting to spot a pristine, incoming comet before they pounce. “We’d see an object in a →

“ IT TURNS OUT
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→ deep freeze from the time the giant planets formed,” says Fitzsimmons. As the pieces of our Solar System’s story begin to fall into place, attention is turning to how it compares to other planetary systems.

STRANGE AND EXOTIC SYSTEMS

The last 25 years have seen an explosion of discoveries of exoplanets. The number of these planets orbiting other stars is fast approaching 6,000 and many are giving astronomers big surprises. Before detecting these exoplanets, they expected to find solar systems that were broadly identical to ours, confirming their suspicion that ours is an average, or typical, solar system.

The emerging reality couldn’t be more different. Astronomers have found a celestial zoo of strange and exotic systems that wouldn’t look out of place in a science-fiction saga. Systems with planets that orbit two stars, instead of one, or systems with planets orbiting so close to their central star that it

probably rains liquid metal or jewels. Many of these other solar systems contain types of planets that we simply don’t have. “The typical exoplanetary system has lots of in-between planets larger than Earth, but smaller than Neptune,” says Prof Karin Öberg, an astrochemist at Harvard University in the US. Then there are hot Jupiters – giant planets that have migrated so far inwards that they orbit their stars in days, sometimes even hours.

Astronomers have now discovered so many exoplanetary systems that they can begin to classify them, like biologists placing animals and plants into different species groups. Last year, a team of Swiss astronomers identified four types of solar system: ordered, anti-ordered, mixed and similar.

All the planets in a similar solar system have masses that are, unsurprisingly, similar, while in a mixed system, the masses vary from one planet to another. Ordered solar systems (like ours) have planets that generally increase in mass the further out you go. In anti-ordered systems it’s the other way around, with mass decreasing as you head outwards.

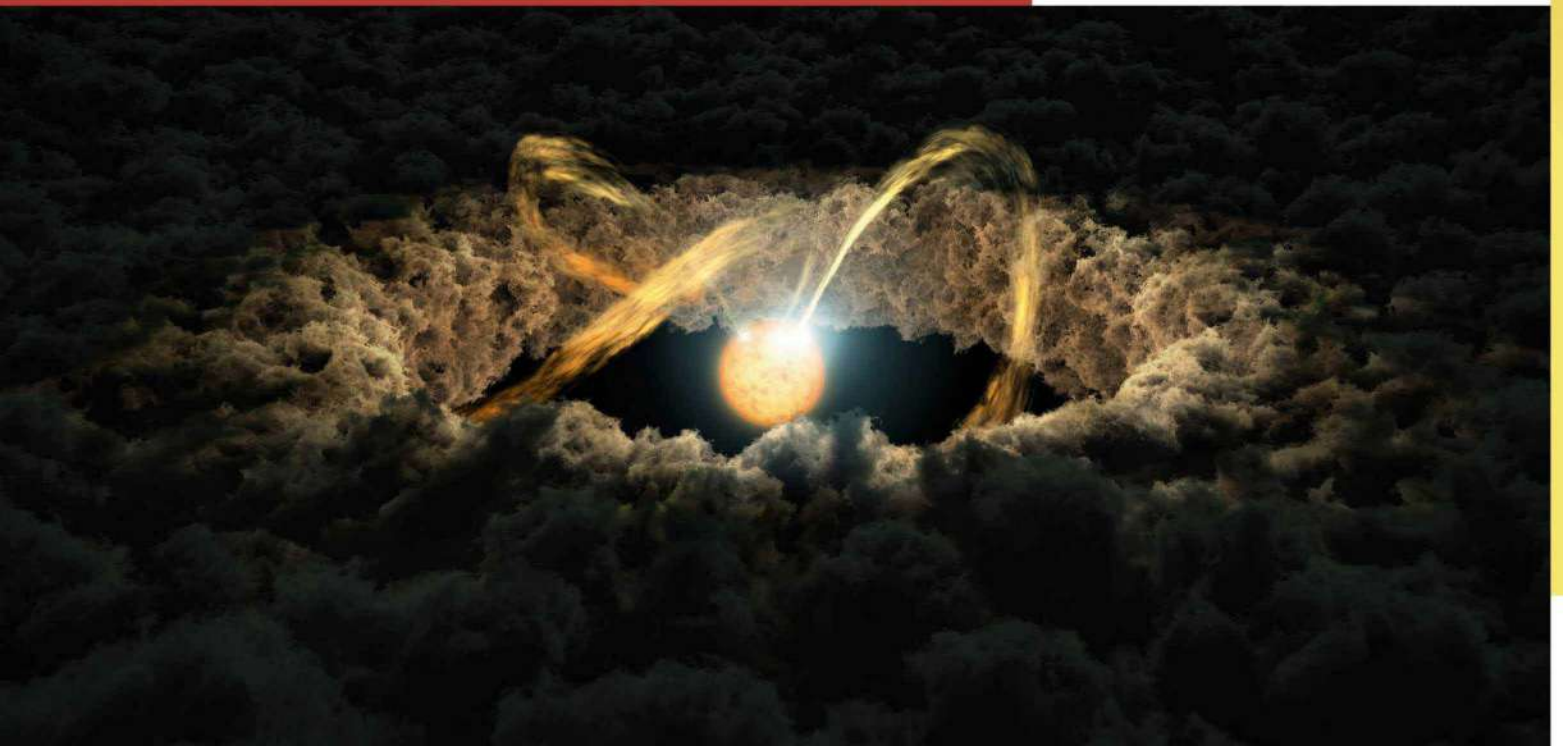
So which type of system is the most common? To date, no examples of anti-ordered systems have been found, but according to the Swiss study that came up with the classifications, around 80 per cent of systems can be classified as similar. But just 1.5 per cent can be classified as ordered solar systems, like ours. It turns out our Solar System may very much be the exception, not the rule.

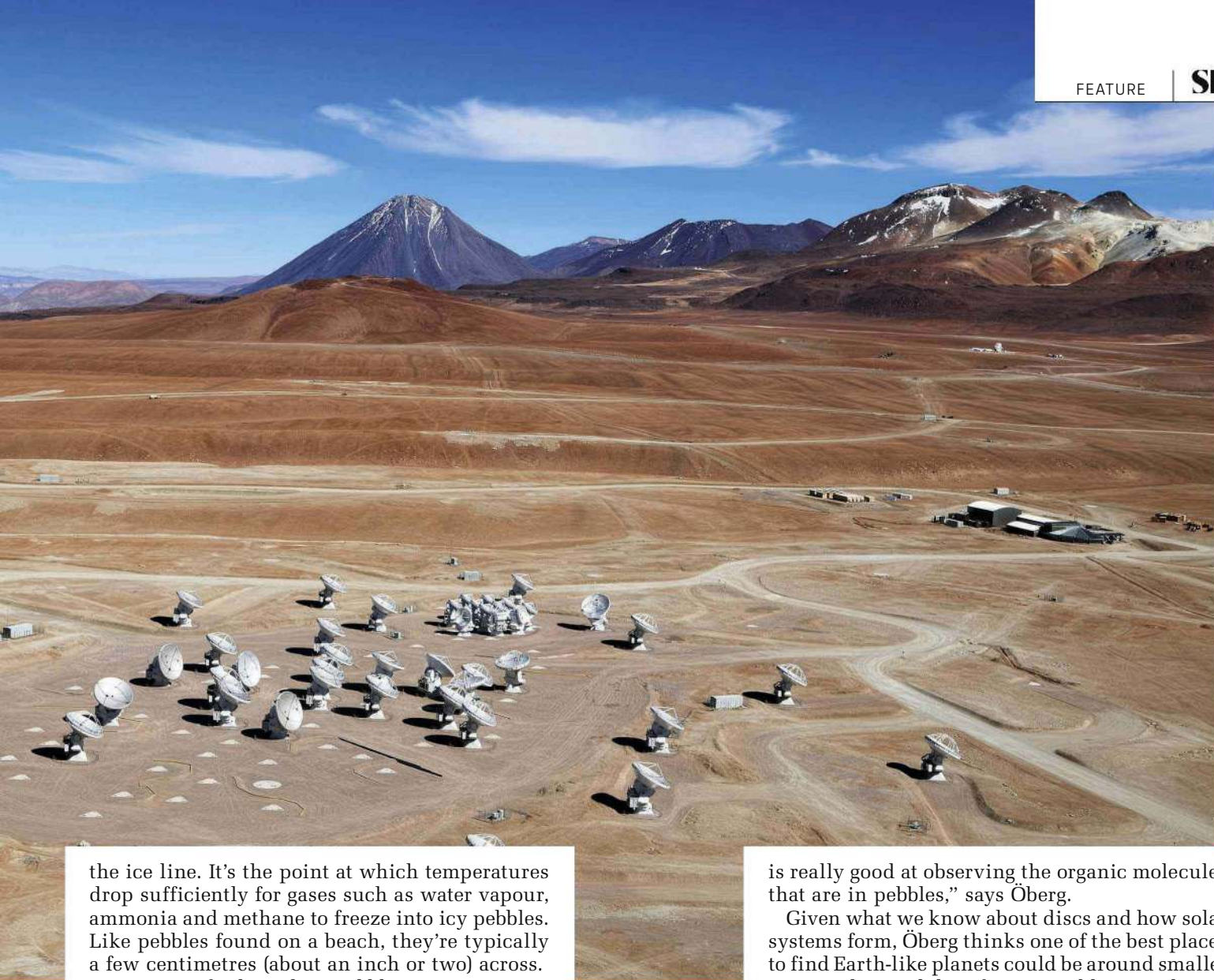
What’s more, it seems the seeds of our relative uniqueness were sown long ago, before there was even a collection of planets to orbit the Sun. It all comes down to the order in which the planets emerged from the disc of gas and dust. Once again, it’s Jupiter that appears to be the key.

THE RIGHT KIND OF JUPITER

“One idea is that Jupiter formed early enough to stop the inflow of material into the innermost part of the Solar System,” says Öberg.

To play this role effectively, Jupiter also had to form in the perfect spot, close to a region astronomers refer to as





the ice line. It's the point at which temperatures drop sufficiently for gases such as water vapour, ammonia and methane to freeze into icy pebbles. Like pebbles found on a beach, they're typically a few centimetres (about an inch or two) across.

"As Jupiter feeds on those pebbles it creates a gap," Öberg says. "It's very difficult for other pebbles to cross that gap." With the remaining pebbles stranded in the outer Solar System, the inner Solar System was starved of material from which to build large planets. This potentially explains why we have an unusually ordered solar system apparently carved in two, with small planets close to the Sun and giant planets further out. Not many systems have the right kind of Jupiter.

Intriguingly, new observations by the James Webb Space Telescope (JWST) of the protoplanetary discs from which a system's planets form, lend credence to this idea. In discs with large planets forming, there's very little water vapour close to the star where an Earth-like planet could be forming. The opposite is also true. "In discs where there are no gaps carved out by giant planets, we do see a huge amount of water in the innermost disc," Öberg says.

Along with JWST, the other telescope improving our understanding of protoplanetary discs is the Atacama Large Millimeter Array (ALMA). A collection of 66 radio dishes scattered in the Chilean desert, it's best suited for looking at the outer, cooler parts of protoplanetary discs. "ALMA

is really good at observing the organic molecules that are in pebbles," says Öberg.

Given what we know about discs and how solar systems form, Öberg thinks one of the best places to find Earth-like planets could be around smaller stars such as red dwarfs. But could asteroids and comets have delivered water and the building blocks of life from elsewhere in their discs? "The jury is still out," Öberg says. "I'm optimistic, but I do think we have a few more years of gathering data before that optimism is completely rewarded." For one thing, the chemistry around these low-mass stars might be different from the chemistry we observe in our Solar System.

So, for now we must wait. But continuing our work to understand how the Solar System formed will lead to more answers. "If we manage to decipher what happened in our Solar System, those lessons might be applicable to other solar systems," says Fitzsimmons. "Mother Nature is clearly very adept at making all sorts of planets," he says.

Slowly, chapter by chapter, astronomers are piecing together the origin story of the Solar System, and with each new chapter we're learning more about how we came to be in a position to wonder about it. **SF**

ABOVE The ALMA antennas on the Chajnantor Plateau in the Chilean Andes

LEFT Protoplanetary discs are providing evidence for why the planets in our Solar System increase in size the further out they are from the Sun

by COLIN STUART

(@skyponderer)

Colin is an astronomy author and speaker, and a fellow of the Royal Astronomical Society.

×

THE BIG QUESTION

What tipping point are climate scientists most worried about?

Collapsing ice sheets, loss of the Amazon rainforest, melting permafrost... Key parts of Earth's climate system are in trouble. Which could trigger disaster first?

—
by PROF BILL MCGUIRE

If you want to make a climate scientist uncomfortable, just sidle up to them and whisper “tipping points” in their ear. Climate breakdown driven by global heating is scary enough, but so-called climate tipping points send a shiver down the spine. So, what are they and why do they have us all running scared?

We're in the middle of a unique experiment that's driving up the global average temperature at least 10 times faster than at any time in the geological record. The consequences are all around us: explosions of extreme weather, collapsing ice sheets and accelerating sea-level rise.

But as greenhouse gas emissions continue to climb as fast as ever and the global temperature rise (compared to pre-industrial times) for the last 12 months touches 1.64°C (a rise of almost 3°F), so the

“The AMOC is now weaker than at any time probably since the end of the last Ice Age, more than 11,500 years ago”

likelihood of sudden, permanent switches in dangerous elements of the climate system is becoming increasingly possible. Because a critical threshold needs to be reached before a switch can occur, and because – like a tilting seesaw – once a

switch starts, there's no going back, they're called tipping points.

There are plenty of definitions out there, but the one that really hits the nail on the head comes from *The American Heritage Dictionary of the English Language*, which describes a tipping point as: “A critical moment in a complex situation in which a small influence or development produces a sudden large or irreversible change.” Where the climate is concerned, for large, read disastrous.

How things could tip

Scientists who work to model where global heating is taking our climate struggle with tipping points for two reasons. Firstly, they're not easy to pin down in terms of timing and impact. Secondly, how tipping points are treated within climate models can dramatically



The Amazon rainforest plays a vital role in regulating Earth's climate. If too much of it is lost, it could set off a chain of events with disastrous results

influence the output, thereby increasing uncertainty in terms of forecasting how climate breakdown will unfold in years to come.

Such is the complexity of the climate system, that there are likely to be countless tipping points, most having local or regional influences. Nine, however, are recognised as having the potential to trigger massive environmental changes at the global scale. These include the collapse of the Greenland and West Antarctic ice sheets (GIS and WAIS respectively), the dieback of the Amazon rainforest and the release of colossal volumes of methane from thawing Arctic permafrost.

GIS and WAIS collapse would eventually result in a 12m (almost 40ft) sea-level rise that would flood all coastal cities. The replacement of white ice with dark rock

would also mean that more heat was absorbed, pushing up Earth's temperature further. The loss of the Amazon rainforest and thawing of Arctic permafrost would add massively to carbon levels in the atmosphere, driving up the heat even more. And we aren't talking of the distant future here. Irreversible collapse of the GIS and WAIS will likely be triggered by a global average temperature rise of just 1.5°C, which we'll see by the early 2030s. And the same goes for an abrupt thaw of Arctic permafrost.

The tipping point that keeps members of the climate science community awake at night, however, is the collapse of the Gulf Stream and associated oceanic currents, which help to keep the UK and northern Europe warmer than they would otherwise be. Go back a decade or so and this was thought to be highly unlikely, something

which would only happen given a global temperature rise of several degrees. But all that has changed.

The Atlantic Meridional Overturning Circulation (AMOC) is now weaker than at any time probably since the end of the last Ice Age, more than 11,500 years ago, and the authors of an analysis published in 2021 suggest that it may already have suffered an "almost complete loss of stability."

A study published earlier this year reports that the AMOC has gone through a "noticeable reduction in strength" in the last couple of decades, and recent estimates of when shutdown might happen are getting ever closer to our time. A 2023 study forecast sometime between 2025 and 2095, with a central estimate of 2050. Another analysis, revealed in August this year, points to collapse sometime →

→ between 2037 and 2064. Even more concerning (if not downright terrifying): up to almost half of high-quality climate models suggest that serious weakening of Atlantic currents will see cooling across the North Atlantic region begin as early as the 2030s.

Earth's great engine

To understand why collapse would be a big deal requires some understanding of what the AMOC does. In a nutshell, it's a critical component of the worldwide system of currents known as The Global Conveyor Belt, carrying heat from the tropics northwards into the Arctic.

The numbers associated with the AMOC are mind-boggling. Every second it shifts 17 million cubic metres of water – equivalent to nearly 7,000 Olympic-sized swimming pools. At the same time, the AMOC carries around 1.2 million gigawatts of heat, equivalent to more than 150 times the energy capacity of the global electricity network, which amounts to one-quarter of all the heat transported into the northern hemisphere.

The tropical waters carried northwards by the AMOC are warm, shallow and salty. As they approach the Arctic, they cool and become more dense, causing them to sink into the deep ocean, where they feed a cold current that returns south. This explains the 'overturning' part of its name. But this process is becoming harder all the time, as the shallow, northward-flowing waters are retaining more of their heat.

On top of this, water from melting Greenland ice is pouring into the North Atlantic in increasing volumes, freshening the waters and reducing salinity. Because warmer, less saline waters have relatively low densities, this hinders sinking, slows the whole system down and threatens to bring everything to a grinding halt.

So what can we expect if and when the AMOC stalls? Are we talking *The Day After Tomorrow*? Well, not quite. But make no mistake, it would still be a catastrophe for Earth and humankind.

The AMOC is one of nature's great engines, which helps to drive not only the climate, but also global weather patterns. Knock-on effects of shutdown will extend across the planet, weakening the Asian and African monsoons, and playing havoc with weather patterns

"Are we talking *The Day After Tomorrow*? Well, not quite. But it would still be a catastrophe"



by **PROF BILL MCGUIRE**
Bill is Professor Emeritus of Geophysical & Climate Hazards at University College London and the author of Hothouse Earth: An Inhabitant's Guide (Icon Books, 2022).

across the Amazon. But the biggest and most severe impacts are reserved for the North Atlantic region. Average temperatures will plunge across the UK and Europe by at least 10°C, while winter sea ice could reach almost as far south as the southernmost point of the UK. Meanwhile, on the other side of the Atlantic, the eastern seaboard of North America would see a rapid hike in sea level as the northward-flowing waters backed up, leading to inundation or flooding of coastal communities.

The bottom line is that AMOC collapse would be a cataclysmic event that could result in crop yields being slashed across the planet, bringing widespread starvation and spawning civil conflict and war. And don't expect this to be short-lived. Once a tipping point tips, it stays tipped, at least on the scale of a human lifetime.

The question is: can we stop it happening? Reducing emissions to zero as soon as possible could help, but the problem with tipping points is that we might not know we've passed one until it's too late. Fingers crossed that this isn't the case with the AMOC. **SF**



Recent research suggests the Antarctic ice sheet may be melting faster than existing models predict

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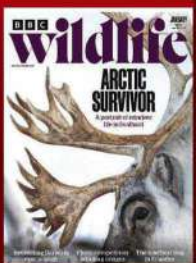
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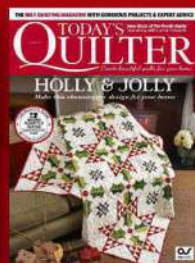
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Q & A

YOUR QUESTIONS ANSWERED

OWEN BARRETT, CAMBRIDGESHIRE

CAN SCIENCE EXPLAIN HAUNTED HOUSES?

Paranormal phenomena, including supernatural 'hauntings', have been the subject of serious scientific investigation since the emergence of spiritualism during Victorian times. Unfortunately, the vast majority of paranormal investigations have been of the pseudoscientific variety – based on incorrect, incomplete or misrepresented science, or invalid due to bias, manipulation, assumption or omission. In these cases, the presented 'evidence' doesn't satisfy scientific rigour, or can also be interpreted in ways that don't require the paranormal. Other cases can be shown to be fraudulent. So, the conclusions (and methods) of such studies can be safely ignored from a strictly scientific perspective.

Of course, there are some cases of 'hauntings' for which there is evidence of some physical phenomena: magnetic, pressure or temperature variations, recorded images, video or audio, for example. These phenomena don't prove the existence of the supernatural though, as



there's no logical connection between the evidence and the conclusion. There may well be other, as yet unknown, phenomena that can explain the observations.

The problem is akin to the UFO, or UAP (Unidentified Anomalous Phenomena), issue. While there are undoubtedly numerous cases of unidentified aerial objects, some even with documentary or physical evidence, there's no scientific

reason to conclude that these are associated with extraterrestrial craft or ancient alien civilisations. It's an unscientific leap of faith to believe in alien visitation based solely on unexplained sightings. The same is true for the belief in ghosts; there's no scientific rationale for it.

Science does offer some potential explanations for hauntings. Most are environmental or psychological in nature.



PETE LAWRENCE
Astronomy



DR HELEN PILCHER
Nature



DR ALASTAIR GUNN
Physics



IAN TAYLOR
Human body



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Mysteries



LUIS VILLAZON
Planet Earth



PROF PETER BENTLEY
Biotech

"CARBON MONOXIDE HAS BEEN SHOWN TO BE THE CAUSE OF HAUNTINGS"

Perhaps the most obvious is the simple misperception of perfectly normal experiences. Sleep paralysis (when the body is paralysed, as during sleep, but the mind is fully active) can create perceptions that can easily be misconstrued as paranormal. Hallucinations can also be brought on by sleep deprivation, high stress, electromagnetic variations, infrasound (low-frequency sound), or simply high-temperature environments.

Surprisingly, mould, often found in old houses, may play a part. Some species are known to cause inflammation of the optic nerve and subsequent hallucinations. Experiments have shown that *Stachybotrys* (black mould) induces a feeling of fear in laboratory mice. One study even found that houses with reported hauntings were statistically more likely to contain mould.

Other scientists have proposed that chemical intoxication can result in convincing 'supernatural' hallucinations or misperceptions. Suspect chemicals include some pesticides and formaldehyde (which can be found in treated wood as well as some paints and varnishes).

Also, carbon monoxide (CO) has been shown in several cases to be the cause of hauntings. In February 1921, the *American Journal of Ophthalmology* published a letter in which a haunting, including 'ghostly apparitions', was unequivocally associated with CO. So, not only is your home CO alarm preventing you from asphyxiation, it may also be guarding you against ghosts and demons!

In conclusion, there's no evidence that houses are haunted by the spirits of the departed. On the other hand, there are plenty of 'hauntings' that have been shown to have rational explanations. **AG**

DAN KNAPTON, VIA EMAIL

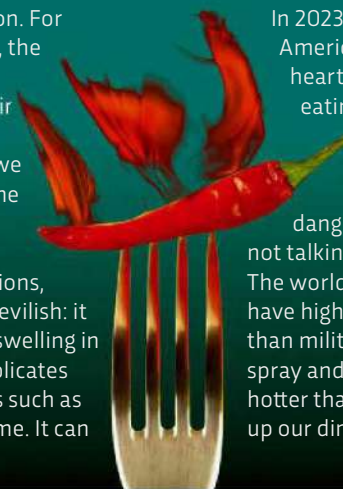
HOW SPICY IS TOO SPICY?

It depends on the pepper and it depends on the person. For most people, capsaicin, the active compound that gives chilli peppers their taste and heat, is harmless at the levels we typically consume. Some studies even suggest it improves our health.

At higher concentrations, however, capsaicin is devilish: it causes heartburn and swelling in the stomach, and complicates pre-existing conditions such as irritable bowel syndrome. It can

also be poisonous to children. In 2023, a 14-year-old American boy with underlying heart conditions died after eating a spicy tortilla chip as part of a social media challenge.

It's hard to say what a dangerous dose is, but we're not talking about Tabasco here. The world's hottest chilli peppers have higher Scoville Heat Units than military-grade pepper spray and can easily be 100 times hotter than the sauces we spice up our dinners with. **IT**



SAM TOOVEY, VIA EMAIL

WHAT HAPPENED TO EINSTEIN'S BRAIN?

Einstein died in 1955 at Princeton Hospital, New Jersey, in the US, and the autopsy was conducted by pathologist Dr Thomas Stoltz Harvey. Einstein's body was cremated the next day, but, unbeknown to his family, Harvey had removed Einstein's brain and eyes.

Although he later received permission to use the specimens for scientific study, Harvey's actions attracted great controversy. The brain was sliced into 240 pieces and 12 sets of 200 microscope slides. Some went to scientific and medical institutions, but he kept 170 pieces for himself, preserved in jars. He eventually handed them over to the University Medical Center of Princeton in 1998. **LV**



NATURE'S WEIRDEST



DEAD MAN'S FINGERS

Picture the scene. It's Halloween and you've gone for an ill-advised stroll through the graveyard on the edge of town. As the screams of trick-or-treaters fade into the distance, a shroud of dense fog rolls in, blanketing the tombstones. It already feels like an episode of *Scooby-Doo*, but things are about to get worse. You stumble and fall, face-planting into the detritus, where you spot a putrid-looking hand sticking out of the ground. Misshapen digits. Long, twisted nails. You try to scream, but the sound is stuck in your throat. Where is Velma Dinkley when you need her?

Then you look again closely and realise it's not a hand at all. Although dead man's fingers (*Xylaria polymorpha*) may look like it belongs on the end of a dead man's arm, it's actually a fungus.

A quick fungus primer: Fungi can't eat food, like animals, and they can't make food, like plants and algae. Instead, they secrete enzymes that break down nearby organic matter, releasing nutrients that they can then absorb. Disappointingly, given its zombie-like appearance, this fungus doesn't break down dead bodies, but dead wood. It can be found, sprouting from the rotting

base of broadleaved trees such as beech and oak. Hence the first part of its Latin name, '*xylaria*' means 'growing on wood.'

The second part of its Latin name, '*polymorpha*', means 'many shapes', reflecting the fact that this fungus changes in appearance over time. In spring, when it emerges, it sprouts in clusters of three to six 'fingers', which are pale to dark grey, each with a pale 'nail' at the top. But by winter, when it's mature, each finger is up to 10cm (4in) tall and dark brown to blue-black. For this reason, it has been described as looking like a putrid finger, a piece of burned wood,



"BY WINTER, WHEN IT'S MATURE, EACH FINGER IS UP TO 10CM (4IN) TALL"

and a mummified penis.

Fungi aren't mobile, so they spread by producing spores that they disperse from their fruiting bodies, which are the bits of the fungus that you can see above the ground. In this case, the fingers are the fruiting body. Like many fungi, *X. polymorpha* has two modes of reproduction, asexual and sexual. Asexual reproduction produces genetically identical copies of the fungus. It occurs in spring when the fungus releases spores, called conidia, from all over the surface of the finger. Meanwhile, sexual spores, called ascospores, are released through a hole at the top. When an ascospore from one parent fuses with an ascospore from another, a new, genetically different fungus is produced.

It may look bizarre and a little grotesque, but this fungus is good news for all the invertebrates that feast on the soft, nutrient-rich detritus it creates. But don't be tempted to eat it yourself. A 2018 study found that the macabre-looking fungus contains toxins that are similar to those found in the infamous death-cap mushroom. Tuck in and you could be the one who ends up in the graveyard! **HP**

MARLOW SMITH, VIA EMAIL

CAN ANIMALS BE RIGHT OR LEFT-PAWED?

Here's a fun experiment to try. If you have a cat or a dog, place a treat in a thin, empty container and see which paw they use to retrieve it. If the science is correct, most males will favour their left paw, while most females will favour their right. Many animals are ambilateral (the non-human equivalent of being ambidextrous), and sometimes there's a sex bias to these preferences.

Other times, differences exist at the species level. Around 85–90 per cent of us humans favour our right hands, and we're not alone. Among primates, most chimps, gorillas, baboons and ring-tailed lemurs also prefer to use their right hands, but Sichuan golden snub-nosed monkeys, de Brazza's monkeys and orangutans tend to use their left.

This plays to the idea that handedness is linked to lifestyle. Among those listed, the right-handers are predominantly ground dwellers, while the left-handers like to hang out in trees. According to the postural origin theory of handedness, early primates lived in trees and used their dominant left hand to grab food and branches, while holding the tree with their right. Then, as they adapted to life on the ground, they started to use their right

hand more, which then became dominant over time.

The theory has its critics, who point to the fact that some primates don't follow the rules. Slow lorises are arboreal yet favour their right hands, while Hanuman langurs live on the ground and are mainly left-handed.

Adding to the confusion, glossy black cockatoos hold seed cones with their left foot, walrus preferentially use their right flipper to forage for clams and red-necked wallabies prefer to use their right paw to reach for food.

For the record, my cat failed to comply with the experiment, with either right or left paw, and instead miaowed loudly until she was fed. **HP**





GEORGE GRAINGER, LONDON

WAS AMELIA EARHART OR HER PLANE EVER FOUND?

One of the most famous pioneers in aviation, Amelia Earhart is best known for becoming the first woman to fly solo across the Atlantic. But her story ended in tragedy in 1937, when her Lockheed 10-E Electra plane disappeared without a trace while she attempted an ambitious round-the-world flight.

Hoping to become the first person to circumnavigate the globe around the equator, Earhart planned a 46,670km (29,000-mile) journey from California across Central and South America, Africa, Australia and finally crossing the Pacific Ocean. Six weeks into the trip, Earhart and her navigator Fred Noonan, set off from New Guinea towards Howland Island, about 2,735km (1,700 miles) southwest of Honolulu. This 20-hour flight was the

JACK CHILDS, VIA EMAIL

COULD I REALLY LAND A PLANE IN AN EMERGENCY?

According to an utterly believable survey by YouGov in 2023, almost half of men think they could safely land a plane in an emergency. We're not here to ground anybody's confidence, but landing an aircraft – especially a large passenger plane – without experience is an extremely difficult thing to do.

There are documented cases of people landing smaller aircraft with the guidance of air traffic controllers and flight instructors on the ground, but remember that pilots of all kinds undergo hundreds of hours of training.

Some larger aircraft, like the Boeing 737, have an autoland function that allows the plane to land itself, even without power, and is sometimes used by pilots in low visibility.

Setting this up requires dozens of steps and knowledge of the instruments in the cockpit, but some pilots and instructors



believe a novice could manage it with the right help. Petter Hörnfeldt, a 737 instructor, details a 20-step procedure that a non-pilot could follow in an emergency on his YouTube channel. You'd still have to set the plane's speed, heading and altitude, and also engage the flaps and landing gear. More importantly, as Hörnfeldt points out, you'd also first have to find a way into the locked cockpit.

In a smaller plane, the odds improve a lot. It's more manual and familiar, with fewer controls. In 2022, a BBC journalist with no experience landed a two-seater plane, guided by instructors in a set-up scenario where the actual pilot only played dead.

Experts say that for small aircraft, flight simulator games give a good approximation of what's needed to make it back to Earth. **IT**

GETTY IMAGES ILLUSTRATIONS: PETE LAWRENCE, KYLE SMART

longest leg of the journey and close to the maximum range of the plane. Despite support from the US Coast Guard, they failed to locate the flat, 6.5km² (2.5 square mile) island in the vast Pacific Ocean and were never seen again.

The US government's investigation concluded that, after failing to find Howland Island, Earhart's plane ran out of fuel and crashed into the ocean. But the lack of definitive evidence has spurred wild speculation and there are many theories about what happened. One of the most popular is that Earhart and Noonan landed on the coral reef around Gardner Island, 650km (400 miles) southeast of their intended destination, where they ultimately died.

Navigational issues may have been to blame for why Earhart and Noonan failed to reach Howland Island. One explanation, known as the Date Line Theory, suggests that Noonan

"LACK OF DEFINITIVE EVIDENCE HAS SPURRED WILD SPECULATION"

didn't account for crossing the International Date Line in his calculations. He was using celestial navigation, which is based on the position of the Sun, stars and planets. Because the Earth simultaneously rotates on its axis and revolves around the Sun, the positioning of these celestial bodies, relative to the Earth, changes slightly each day. So, it's important to know the exact date and time to navigate accurately with this method. Noonan was aware of this effect, but the timing of the flight made the calculations particularly complex. During their flight, they passed midnight local time and Noonan would have needed to adjust his calculations accordingly. They then flew over the International Date Line, changing the date back again. If Noonan hadn't noted this second date change, he would have navigated the plane off course, ending up 110km (70 miles) east of Howland Island.

In January 2024, an ocean exploration team from the US, Deep Sea Vision, found wreckage on the seabed that might be Earhart's plane. They used an underwater drone to sonar scan more than 12,950km² (5,000 square miles) of the Pacific Ocean floor. The images revealed an object that resembles the shape of a Lockheed Electra, located roughly where the Date Line Theory predicts. The team plans to return to the site to investigate further. **CA**

ASTRONOMY FOR BEGINNERS



Looking east at midnight BST mid-October and 10pm GMT at the end of October

HOW TO SEE: JUPITER'S GALILEAN MOONS

WHEN: MID-LATE-OCTOBER INTO EARLY NOVEMBER 2024

Jupiter is currently prominent, a veritable beacon among the stars of Taurus. It's very bright to the naked eye, more so when the Moon appears close, as will be the case just before dawn on 21 October.

Binoculars make Jupiter look brighter, but don't show any detail. Hold them really still, however, and you may see some or all of its four brightest moons: Io, Europa, Ganymede and Callisto – also known as the Galilean Moons. These appear as star-like dots dancing slowly from one side of the planet to the other.

Gravity rules at Jupiter and the distances between the three innermost moons are such that orbital resonance occurs. Each moon exerts enough of a gravitational influence on its neighbour to roughly double its orbital period – Io's being 1.76 days, Europa's 3.53 and Ganymede's 7.16 (Callisto breaks form slightly at 16.69 days).

A small telescope will show Jupiter's disc. A vast gas giant with a diameter 11 times larger than Earth's, the planet

rotates in just under 10 hours (no wonder it appears to bulge at the equator). On the nights of 26 October and 3 November, Jupiter's largest moon, Ganymede, casts its giant shadow on Jupiter. A small telescope will show this as a black dot, a view that barely conveys the immensity of what it would be like up close.

Ganymede is the Solar System's largest moon. With a diameter of 5,268.2km (3,273.5 miles), it's larger than Mercury!

With a small telescope, you should be able to detect a couple of dark bands running parallel across Jupiter's disc. These are the North and South Equatorial Belts (NEB and SEB). The famous Great Red Spot sits in the southern edge of the SEB, a huge persistent storm system, which requires at least a 100mm telescope to see. **PL**



by **PETE LAWRENCE**
(@Avertedvision)

Pete is an astronomy expert and presenter on *The Sky at Night*.

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TANIA MATTHEWS, VIA EMAIL

WHY DOES TIME MOVE SO SLOWLY WHEN I'M AT THE GYM?

The answer to this one is a little more nuanced than simply wishing you hadn't booked a spin class for 6:30am. Our perception of time can be faster or slower than reality in different situations. When it's slower, the phenomenon is called time dilation. It can sometimes happen in scenarios that are boring, anxious or mindful – and exercise could be any of those things for different people.

They say a watched pot never boils. The same is true of a stopwatch if you're plodding away on a treadmill when you'd rather be somewhere else. The more aware you are of the passage of time, the more it can seem to drag. A small, recent study even quantified the effect. Researchers at Canterbury Christ Church University in the UK asked people to ride trials on a stationary bike and measure 30-second intervals as best they could. Participants were nine-per-cent faster, suggesting that time had passed slower for them than it had in reality.

The researchers suggest that "physical activity creates a heightened associative state of impulse awareness and causes a perceived slowing of time." In other words, your raised heart rate and other physical changes in your body could contribute to the feeling that time is moving slower than it actually is. Similar phenomena have been reported in dangerous situations, where a person's heightened state of anxiety makes an ordeal feel like it's occurring for longer.

Time perception is obviously important for professional runners or cyclists. Knowing that your perception of time could be slower than reality may help athletes pace themselves better. The team behind the study also think that further research could help to design exercise classes that are more enjoyable... But maybe don't mention this to your spin instructor. **IT**



LUKE PARKER, SOUTHAMPTON

COULD TECHNOLOGY GIVE US MORE THAN FIVE SENSES?

We already have more than five senses. Besides touch, taste, sight, sound and smell, we have a sense of pain (nociception), a sense of balance (equilibrioception) and a sense of body positioning (proprioception). But evolution moves at such a slow pace that it might be millions of years before we develop a new sensory organ, assuming there's sufficient need for us to have it.

Technology could provide us with extra senses much faster than evolution, though, and how artificial enhancements could be added to our bodies to achieve that is a popular trope of science fiction.

But, similarly, we're already using tech to augment our senses. Microscopes allow us to see very small objects, while telescopes make very distant ones visible. Then there are X-rays, positron emission tomography (PET) scans and other medical imaging techniques that enable us to see into our bodies. As the capabilities of virtual- and augmented-reality headsets improve, it might be possible to incorporate this sort of tech into wearable devices, making it more like an extension of ourselves. But could it ever become part of us? Potentially, and again, precedents for this already exist.

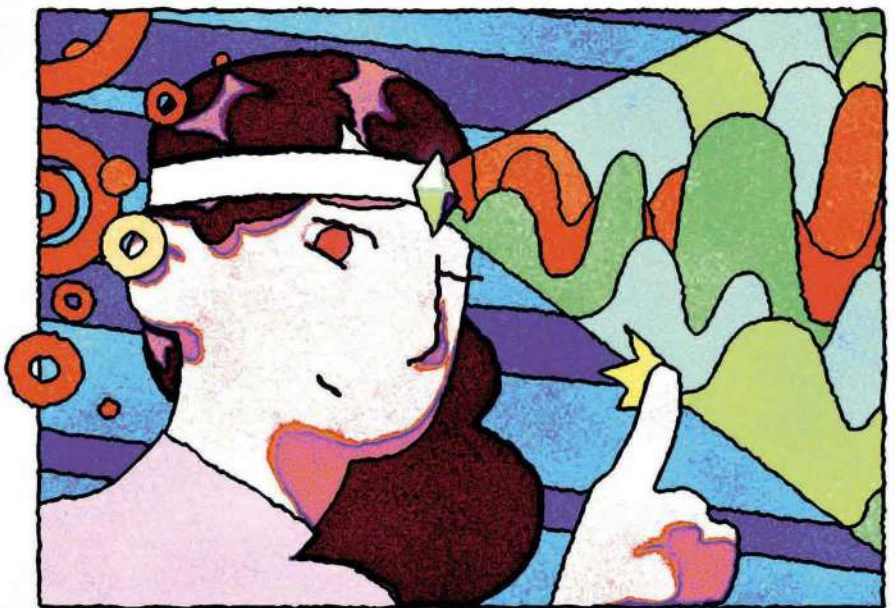
Developed to improve vision for visually impaired people, retinal implants are little light-sensitive chips embedded

into the retina of the eye. They stimulate the remaining light-sensitive cells to restore some level of vision, with degraded colour vision restored in some cases. In the future, it might be possible to have retinal implants that are sensitive to more than just the part of the electromagnetic spectrum that's visible to humans. In theory, you might one day be able to see into the infrared or ultraviolet ranges, maybe even beyond.

The same principle applies to cochlea implants, which have been developed to restore the hearing of people with auditory impairments.

While such devices exist, they're nowhere near that advanced yet, but one day they might be. Which leads us to the key question: not whether this could happen, but whether it *should*. Restoring sight and hearing to those without them is one thing, but implanting devices to enhance perfectly functioning senses could be problematic.

Already, some patients with retinal implants have found themselves using obsolete technology that's no longer supported. When the company that made your eyes goes out of business, what do you do? Or when the tech fails, as it inevitably will in some cases, will the work to repair, replace or remove it cause damage? Be careful what you wish for. **PB**





DAWN GREER, VIA EMAIL

WHAT IS HECTOR THE CONVECTOR? AND WHY DOES HE ALWAYS ARRIVE AT PRECISELY 3PM?

Meteorologists normally only name weather systems that threaten significant impacts over a large area – think hurricanes, or the massive winter ‘nor’easters’ that batter the Atlantic US and Canada. Hector is an exception: a simple thunderstorm, named not for his power, but for his dependability.

Hector forms over the Tiwi Islands, off the coast of Darwin in Australia’s Northern Territory, so reliably that you can set your watch by him. Nearly every afternoon during the build-up and rainy seasons, September through to March, Hector appears at 3pm.

His clockwork consistency is the result of a local microclimate, created by sea breezes and the Tiwis’ pyramid-like topography. The islands are surrounded by tropical marine air. In the morning sunshine, dry air over the land warms faster than the humid air over the sea. As the dry air heats up, it expands, creating a pocket of low pressure above the islands that sucks the marine air onshore as afternoon sea breezes.

These sea breezes rush in from all sides. When they converge at the peaks, they have

nowhere to go but up, carrying moisture from the seas with them. As the column of air rises, it cools and condenses, forming water droplets and clouds, and injecting instability into the atmosphere that quickly builds into a deep convective storm. Hence Hector’s nickname: Hector the Convector.

He was named by World War II pilots, who used his hulking cumulonimbus thundercloud as a navigation beacon when flying between Darwin and Papua New Guinea. According to the Australian Bureau of Meteorology, Hector is one of the most consistently large thunderstorms on the planet, regularly reaching over 19km (12 miles) high – and occasionally punching into the stratosphere.

He’s also one of the most well-studied. Thunderstorms tend to be unpredictable, short-lived beasts. It’s difficult to pinpoint just where they’ll pop up, but since the 1980s scientists have been exploiting Hector’s extraordinary reliability to probe the mechanics of storm formation and investigate phenomena including lightning and updrafts. **CP**

QUESTION OF THE MONTH

SEAN ROBERTS, VIA EMAIL

WHAT HAPPENS TO TIME AT THE EVENT HORIZON OF A BLACK HOLE?

In Einstein’s theory of gravity, mass warps space-time, creating an effect known as gravitational time dilation. This means that an elapsed span of time is measured differently for observers in different gravitational potentials. So, as you get closer to a black hole, the flow of time slows down, compared to the flow of time far from the black hole.

According to an observer far from the black hole, an object falling into a black hole freezes in time at what is known as the ‘event horizon’ (the edge of a black hole, the point of no return).

Nothing ever appears to cross the event horizon. However, the observer falling into the black hole doesn’t experience time stopping at the event horizon. They witness time passing normally, but will see time speeding up far from the black hole. The closer to the event horizon they approach, the faster time will appear to progress far from the black hole.

Gravitational time dilation can actually be measured. In 1976, NASA launched an atomic clock into space to measure the rate at which time passes at an altitude of 10,000km (6,214 miles), compared to that on Earth’s surface. The measurement precisely matched that expected from Einstein’s theories. At sea level, time progresses by one-billionth of a second less per year than at the summit of Mount Everest. **AG**

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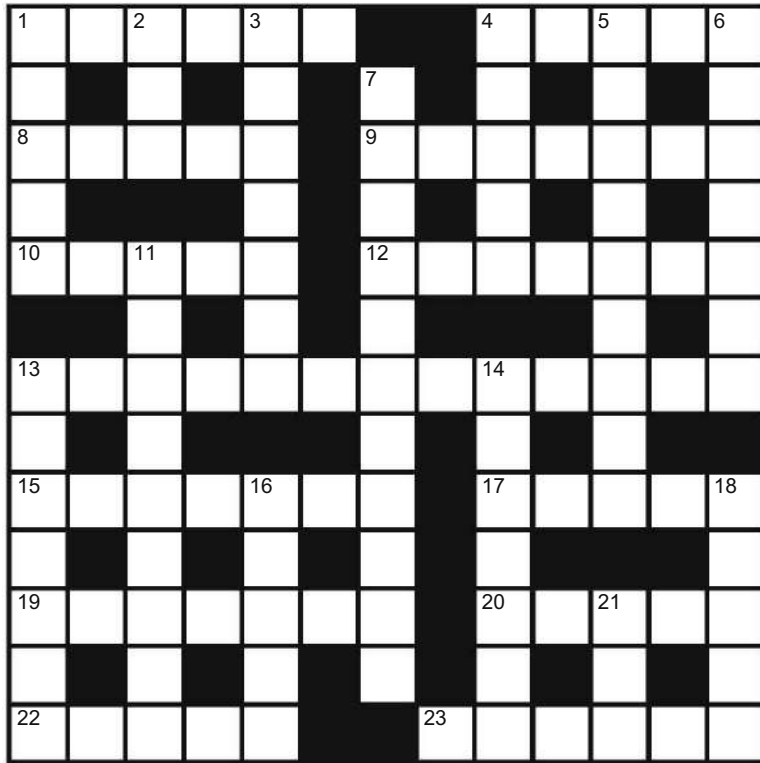
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CROSSWORD

PENCILS AT THE READY!



ACROSS

- 1 Location around a royal building (6)
- 4 Bully with hesitation, then cringe (5)
- 8 Risk not starting walk (5)
- 9 Unruly trio wandered round America (7)
- 10 Wonderful fireplace, by the sound of it (5)
- 12 Require small light when annoyed (7)
- 13 Understand how to succeed as a photographer (3,3,7)
- 15 Nobleman and former queen holding one in the past (7)
- 17 European nerd holds record, initially (5)
- 19 Reportedly notice team coast (7)
- 20 Turn pets out, distressed (5)
- 22 Party, and not for a contributor (5)
- 23 Lack of newly-woven thread (6)

DOWN

- 1 Called after parking accident (5)
- 2 Little room for experiment (3)
- 3 Feline treatment for the ache (7)
- 4 Hag gets right into shape (5)
- 5 Club to behold application for crustacean (9)
- 6 Rise awkwardly, owing what's left (7)
- 7 Doorman rants about starting truck (11)
- 11 Divert Internet, worried about answer (9)
- 13 Calculated visitor, by the sound of it (7)
- 14 Pen old university student put in jacket (7)
- 16 Colder and more risky, but not initially (5)
- 18 Drawing, removing first boat (5)
- 21 Teacher seen back in prison (3)

ANSWERS

For the answers, visit bit.ly/BBCFocusCW
Please be aware the website address is case-sensitive.

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WHEN'S THE BEST TIME FOR A CAFFEINE HIT?

Wakey-wakey! Find the sweet spot for a coffee shot and science says the benefits are grande



They don't call it go-juice for nothing. Caffeine is the world's favourite performance-enhancing drug. And it is a drug, not a nutrient – the most widely taken psychoactive stimulant known to humankind. In the UK, we knock back 98 million cups of coffee every day.

Besides getting us moving in the morning, it's known to improve athletic performance, from strength to endurance, as well as cognitive skills like alertness, reading speed and problem-solving.

"There's a massive list of supposed performance-enhancing substances," says James Betts, professor of metabolic physiology at the University of Bath. "You can count on one hand those that clearly work and I would have caffeine at the top of that list because the effects are so potent, so consistent, and because it's absorbed by just about every tissue in the body."

Those effects are driven by quite varied biology. Caffeine stimulates the nervous system and increases adrenalin to make us less tired. It promotes fat-burning for energy, allowing the body to save its glycogen stores, which is how caffeine improves endurance. It also jams receptors for a neurotransmitter called adenosine, which encourages us to sleep. That's

partly what causes us to feel alert and full of energy after a cup of Joe.

The flipside of caffeine's go-faster potency is that we can sometimes feel its effects when they're not useful to us. A coffee late in the day can make it harder to fall asleep. Or too much caffeine overall can make us feel jittery or anxious if we don't have an outlet for the power-up it gives us.

So when should you take your caffeine hit to optimise its effects? Science is beginning to understand the nuances. Betts's research looks at how the timing of nutrient or substance consumption affects human health. In 2020, he found that drinking a strong coffee straight after a poor night's sleep can impair your blood sugar control as the day continues.

"When people have a poor night's sleep and then have caffeine right before their breakfast, this results in significantly higher glucose and insulin response," Betts says. "So people lost metabolic control – they couldn't tolerate sugar. In other words, it impairs your body's ability to handle the breakfast."

As well as bungy-jumping energy levels, poor blood sugar control may increase your risk of conditions such as type 2 diabetes and heart disease.

"Waiting until the hour after breakfast probably means that you've completed your digestion and absorption of the nutrients, and then it's safer to have your coffee," Betts says.

It's also a good idea to time your caffeine intake around tasks or

exercise. If you want to get more from a workout or run a faster 5K, Betts recommends a coffee 45–60 minutes before you start.

"It can take that long to peak in the system and in its effects," he says. "We know that even in people who have a lot of caffeine, the effects last for an hour or two. In people who don't drink so much caffeine, the effects last for four to six hours, so they can have the coffee way before."

For cognitive tasks, the research is mixed. Everyone knows a well-timed coffee can boost a person's concentration for an exam or presentation. A paper from Johns Hopkins University in Baltimore, in the US, also found that caffeine immediately after study can improve memory consolidation.

However, research has shown that too much caffeine can lead to poor academic performance if students use it so much that it affects their sleep quality, sleep duration or their daytime sleepiness.

Ultimately, Betts believes caffeine is a good thing, especially when you have it in the morning. And there's a convincing pile of evidence to suggest it can protect against mass killers like heart disease and dementia, as well as other diseases.

"I think one of the biggest benefits of caffeine is the fact that it helps you get up and go in the morning. And living an active, busy lifestyle is one of the healthiest things someone can do," Betts says.

Double espresso to go? **SF**

by **IAN TAYLOR**
Ian is a freelance science writer and the former deputy editor of BBC Science Focus.

"EVERYONE KNOWS A WELL-TIMED COFFEE CAN BOOST A PERSON'S CONCENTRATION FOR AN EXAM OR PRESENTATION"

'Brightling'



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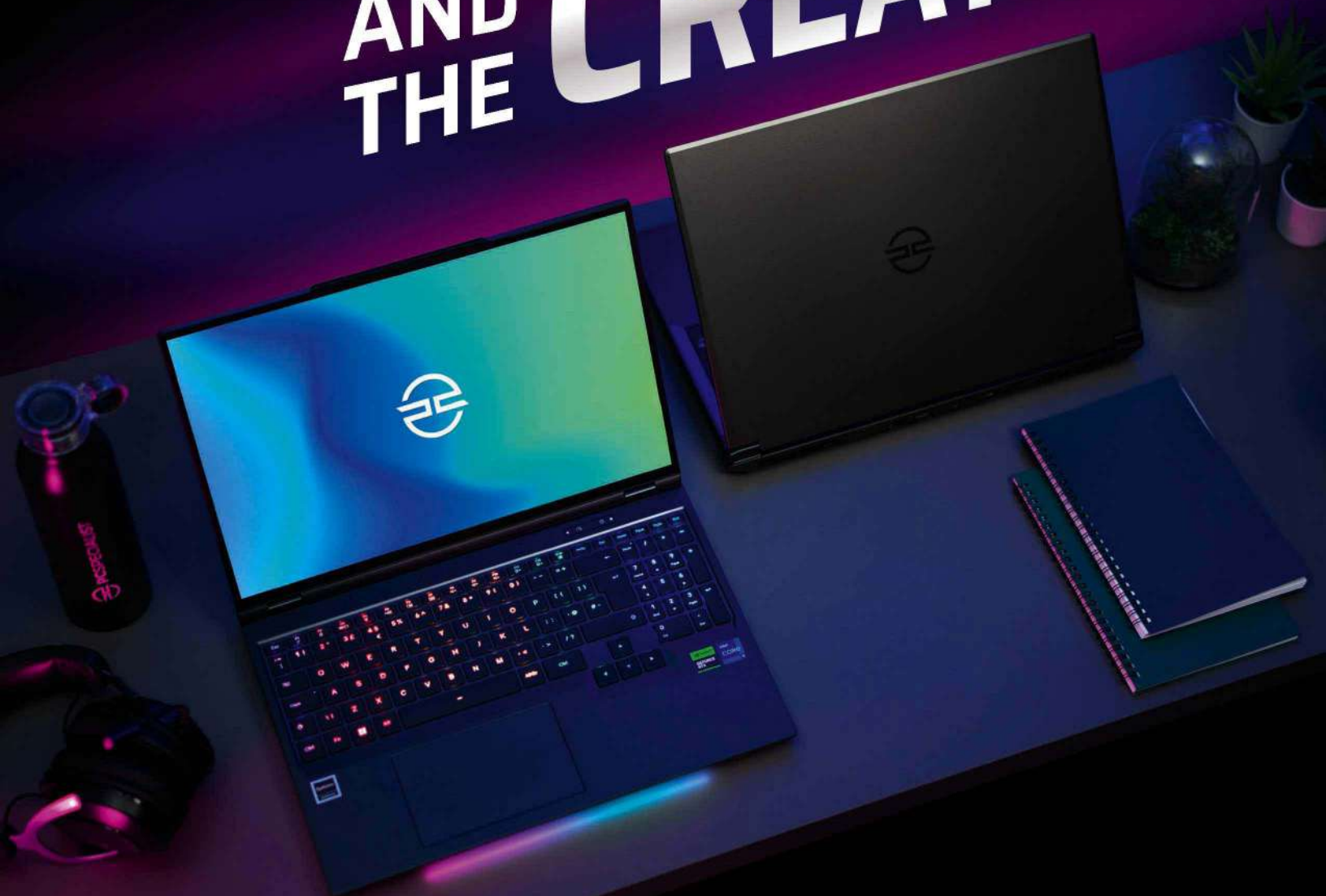
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