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How to overcome
BODY DYSMORPHIA

A brief history of
GETTING DINOSAURS WRONG

GET MORE TIME

How to actually find more hours in your day and avoid burning out



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Health

How much booze is safe to drink?

Space

How humans are changing the Moon's surface

Medicine

Why hearing aids help you live longer

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What is the
reminiscence
bump? → p78



FROM THE EDITOR



What went wrong? Modern life, and the conveniences it offers, was supposed to give us all the free time in the world. Drivers deliver whatever we desire to our doors; ovens spit out ready-made meals in mere minutes; and robots dust, mop and vacuum our floors while we eat. And yet, collectively it seems we never have enough time these days. In fact, it's gotten so bad that scientists have even coined a term for it: time famine.

The phrase first emerged in scientific literature in the late 90s to describe the dissonance between the conveniences of modern life and the shared sense that our free time was under more pressure than at any other period in history. It's been worthy of study ever since and to find out what's actually going on, Dr Ruth Ogden has been running a pan-European study that explores the experience of time in the digital age. To see her take on the matter head to p56.

But if you want my view, which comes with no academic authority whatsoever, I blame the smartphone. Not only does it drown me in a torrent of communications that demand my urgent attention at all hours of the day, it also provides an unending stream of videos, photos and tweets that draw me in and soak up my free time like a sponge. Boredom is what I need. Want to feel like you've actually got too much time on your hands? Try being bored.

If that's too extreme, however, then maybe join me in my New Year's resolution instead: take a book with you wherever you go and next time you feel the urge to reach into your pocket and stare into the black mirror, pick up the book (or magazine) instead and read a few pages. At the very least, it'll be a better use of your time.

Daniel Bennett

Daniel Bennett, Editor

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ON THE BBC THIS MONTH...

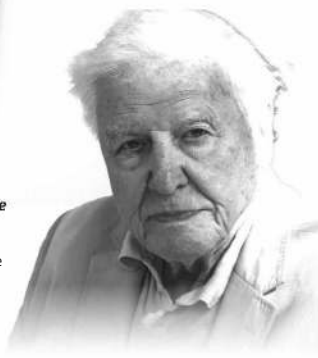
The Life Scientific Podcast

In the last episode of the year (and the 300th episode of the podcast), Prof Jim Al-Khalili was joined by computer scientist Prof Michael Wooldridge, who delivered this year's Christmas Lectures, to talk about how our worst fears regarding artificial intelligence are overblown. Available now on BBC Sounds



Just One Thing – Weight Loss Special

Dr Michael Mosley and regular BBC Science Focus columnist Prof Giles Yeo provide a brilliant dissection of why it's so hard to lose weight. They look at why it's become such a problem in modern life and what you can actually do to shed some pounds and keep them off. Available now on BBC Sounds



Attenborough and the Giant Sea Monster

In case you missed it, this one-off film sees Sir David join two fossil hunters as they delve into the discovery of a lifetime: a giant, intact skull of a pliosaur – the *T. rex* of the seas – that was found on the UK's Jurassic coast. Available now on BBC iPlayer

CONTRIBUTORS



DR STEVE BRUSATTE

Dinosaurs aren't what they used to be. Literally. Our vision of how they lived evolves every week. Steve, a palaeontologist, explores how that change takes place. → p48



DR RUTH OGDEN

Feel like you never have enough hours in the day? Professor of time psychology Ruth unpacks some simple strategies to help you take control your schedule. → p56



CARLO ROVELLI

Theoretical physicist and best-selling author, Carlo shares his exciting theory about what happens inside a black hole when it can collapse no further. → p64



DR TONI PIKOOS

Body dysmorphia is on the rise and with it, the numbers of cosmetic surgery procedures. Ruth looks at why we're so dissatisfied with the way we look. → p72

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WANT MORE?

Don't forget that *BBC Science Focus* is available on all major digital platforms. We have versions for Android, as well as an iOS app for the iPad and iPhone.



Can't wait until next month to get your fix of science and tech?

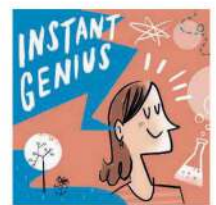
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EYE OPENER

We have ignition

HOKKAIDO, JAPAN

The rocket engine being test fired here has been built to be kinder to the environment. Unlike other engines, which commonly use some sort of rocket fuel (refined kerosene, for example), this one burns biomethane derived from cow manure.

The engine is called the Zero and is being developed by Interstellar Technologies, a Japanese rocket company, to launch small satellites without adding extra carbon dioxide (CO₂) to the atmosphere.

That's not to say biomethane is an emission-free fuel. CO₂ is still released when biomethane is ignited. But unlike fossil fuels, combustion of biomethane is CO₂ neutral (it doesn't add to the natural production of CO₂) and also means a reduction in the use of fossil fuels.

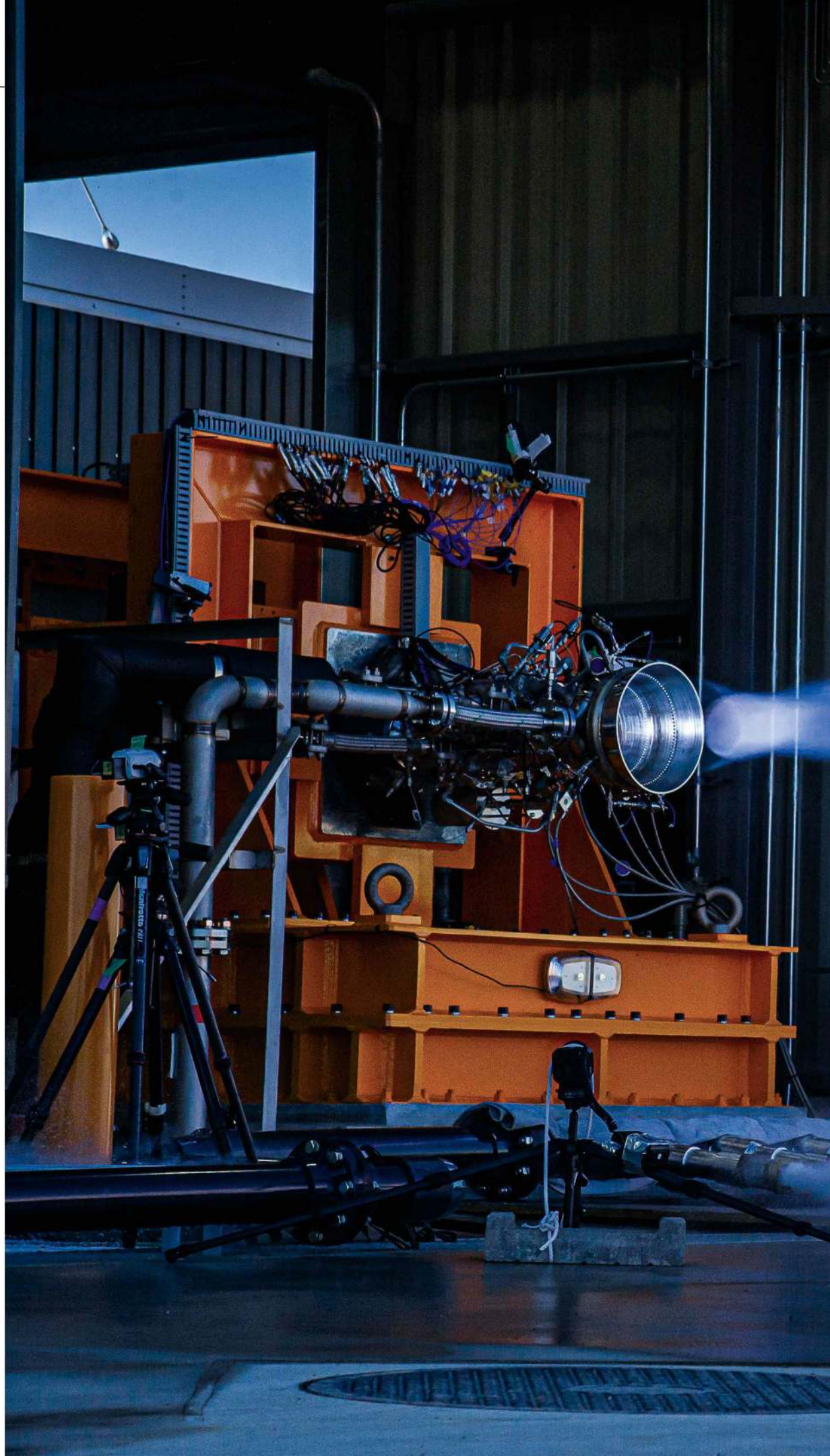
"As more and more rockets launch, it becomes more important that we minimise the impact that they have on the environment if we're to continue with space travel," says Dr Russell Hall, the lead for sustainable manufacturing at WMG, University of Warwick. "More sustainable space travel is possible, though it may take time and needs to be fully thought through."

INTERSTELLAR TECHNOLOGIES

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EYE OPENER

99 black balloons

BRITISH COLUMBIA,
CANADA

Nature photography requires patience to get that perfect shot. Patience paid off for Shane Gross, who captured this image of a family of tadpoles in a lake in British Columbia.

Tadpoles tend to hide in deeper water at night in order to avoid predators like water bugs and leeches. But during the warmer parts of the day they swim to the more oxygen-rich shallows to feed on plants and algae.

This process is repeated daily for six to eight weeks before they finally metamorphose into Western toads, a common species in Canada and the United States.

"It was a real spectacle to behold," says Gross. "But it was very challenging, photographically. I wanted to capture the whole scene, showing the tadpoles' habitat as they swam among lily pad stems. Luckily, the tadpoles weren't shy – in fact, when we floated still in the water, they would nibble on us and our cameras!"

SHANE GROSS/NATUREPL.COM

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EYE OPENER

Power tool

NAKA, JAPAN

This is the JT-60SA, the world's largest nuclear fusion reactor. After initial tests in October and November were successful, the device, built by a Japanese and European consortium, was declared operational at its inauguration on 1 December 2023.

Inside this 16m-high (52ft) structure is a doughnut-shaped chamber filled with hydrogen gas. Powerful magnets around the chamber accelerate the hydrogen to huge speeds and force the hydrogen atoms to coalesce into helium plasma, an ionised gas. This reaction releases huge amounts of energy and is exactly the same process that keeps the Sun burning.

"If such reactions are sufficiently controlled and can be maintained at a high rate, then high fusion power with low waste production can be obtained," says Dr Jerónimo García Olaya, the JT-60SA Experiment Leader for EUROfusion and the French Alternative Energies and Atomic Energy Commission (CEA). "Fusion power can represent a huge step forward towards green energy production."

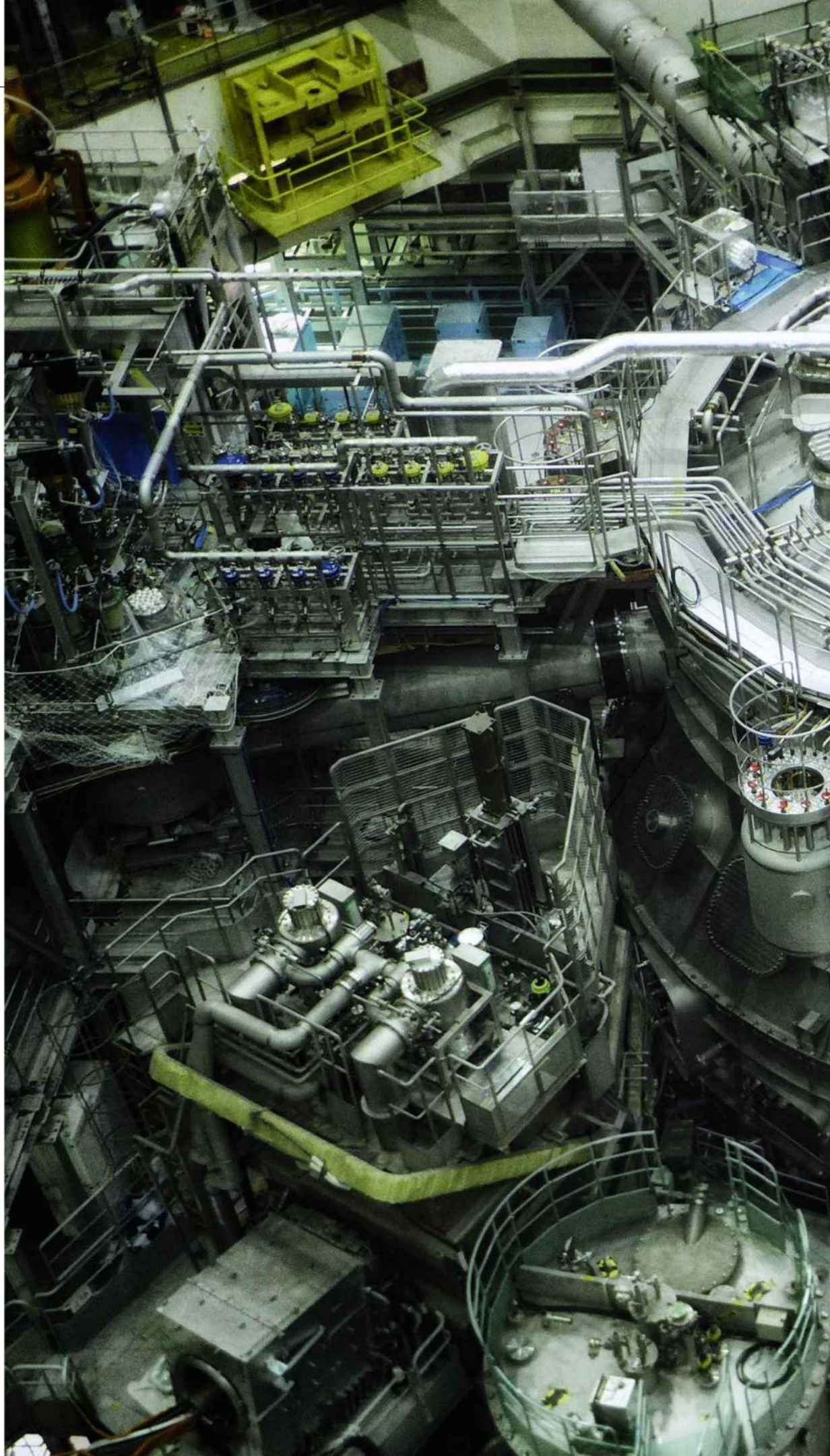
The JT-60SA will undergo a series of upgrades before testing begins again in 2025.

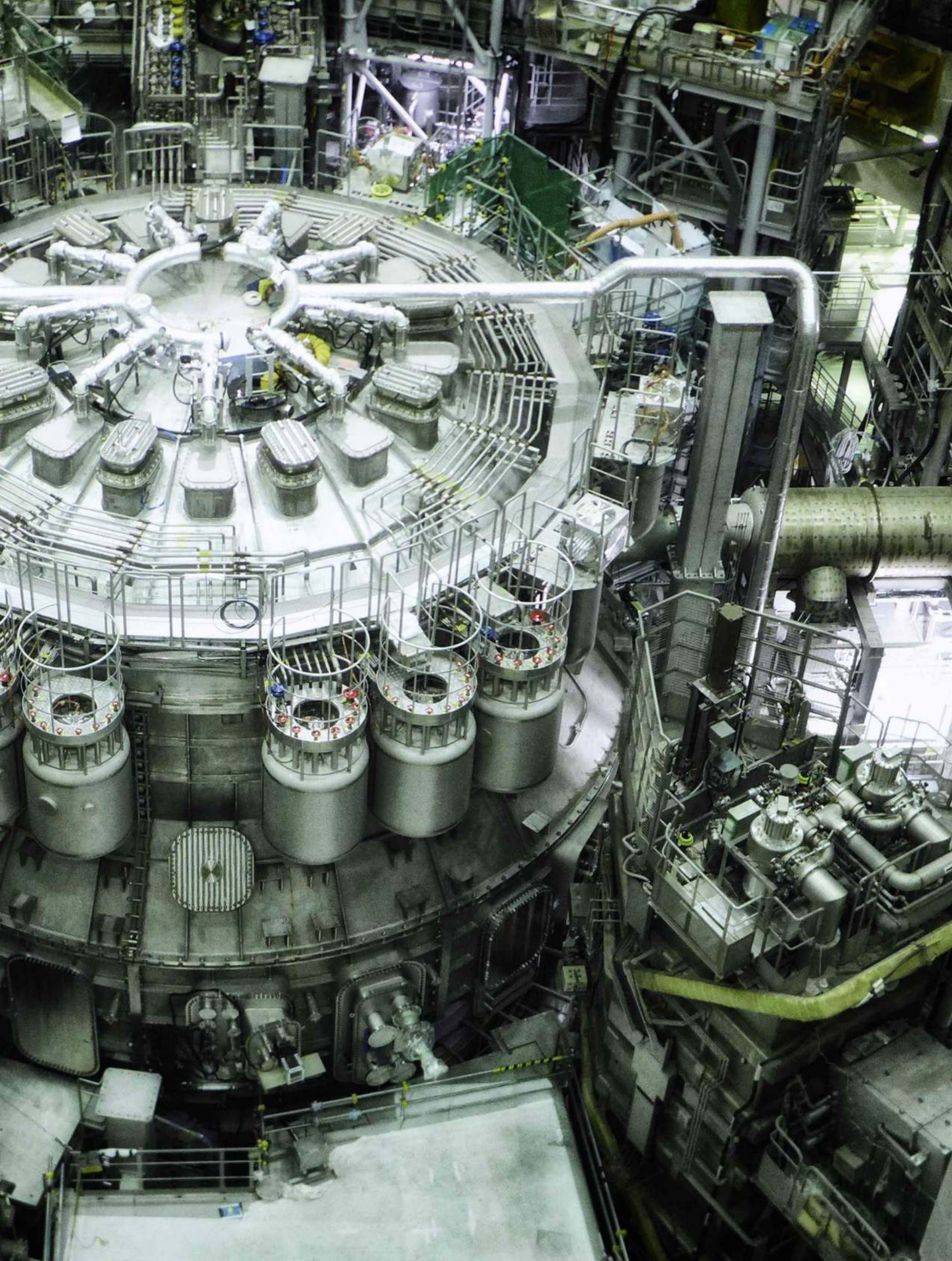
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YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND OUR MAGAZINE

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LETTER OF THE MONTH



Going to waste

Reading Gary Stubbs's letter of the month (December, p12) reminded me of a thought I had about generating power from pipes and sewers. Large quantities of clean water are pumped into our homes, and sewers must surely have a continuous flow of waste and rainwater flowing through them. Couldn't either or both of these be used to generate some power? On the off chance it is a viable option, I'm afraid I'll have to decline the invitation to maintain any turbines installed in the sewage pipes.

Thomas Jones, via email

WRITE IN AND WIN!

The writer of next issue's Letter of the Month wins a pair of popular science paperback books. Put pen to paper (or fingertips to keyboard) and you could get your hands on *Beasts Before Us* by Elsa Panciroli and *Our Dogs, Ourselves* by Alexandra Horowitz.



Dream worlds

If we accept such strange ideas as the many-worlds theory, quantum entanglement and Schrödinger's famous thought experiment (as many scientists do), then might it be possible that, when we're dreaming, our minds temporarily communicate with a version of ourselves in one of the many other worlds these ideas suggest exist?

If our minds are in some way linked like this, it might explain why I had trouble waking myself up from a recent lucid dream. It was only when I felt all alone, and unobserved, in the dream that I was able to exert control. Perhaps, prior to that sensation, I was connected to the mind of another me, in some sort of arrangement similar to an entanglement?

John Waterman, via email

Plant consciousness

I found the news story headlined 'Plants scream when we forget to water them' (May, p21) fascinating. I wonder if it's possible that plants might communicate in other ways too. For example, it's not just humans who make use of plants that have medicinal properties. Could such plants be advertising their properties in some way to animals in order to make other species aware of their potential benefits?

Oliver Parfitt via email



Could be plants be saying more than we realise?

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“YOUR ‘DESSERT STOMACH’ IS ACTUALLY AN EVOLUTIONARY HOLDOVER FROM YOUR ANCESTORS’ DAYS ON THE SERENGETI”

DR GILES YEO, p30

Happy birthday JWST

The James Webb Space Telescope turns two

On 25 December 2023, the James Webb Space Telescope (JWST) celebrated its second birthday. Since its launch on 25 December 2021, the JWST has been capturing images of the Universe around us in unprecedented and jaw-dropping detail. Here are just a couple of the images it caught during its second year of operation (more can be seen on the *BBC Science Focus* Instagram feed), along with a few of your reactions to them...



bb_johns

Very beautiful.

carolynlyman_

Happy birthday James Webb Telescope and thanks to all who put so much into this magnificent space telescope. Thanks to NASA for continuing to support! Love it!

gnkbuzz

Spending billions on this project just for the sake of capturing random images from space, so that we can use them as wallpaper for laptops and mobile phones. But one thing, these billions can only be justified if an alien world along with alien lifeforms are captured and those images are posted. Until then, this is just a billion-dollar toy peeping through the Universe.

gretchen_lhommedieu

JW Telescope is the most marvelous creation in hundreds of years. It's amazing to me, even if I don't understand all of it.

jasonjoneshome

I love it all so much ... [It's] incredible, but always scares me when I think about it all – that we are minuscule but, at the same time, big and complex and wonderful too. Then I feel sane and not overwhelmed by it all.

junecooper147

Just wonderful.



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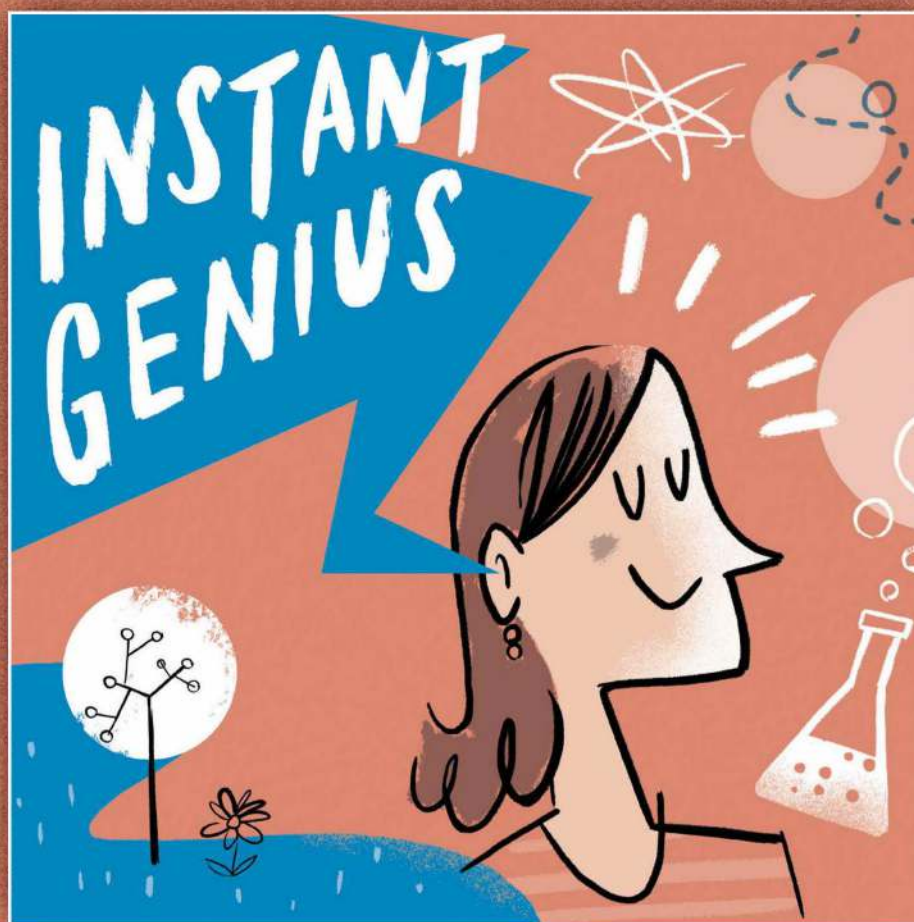
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with
Dr Zazie Todd



TESTOSTERONE MYTHS
with
Dr Channa Jayasena



ALIEN LIFE
with
Prof Avi Loeb



DEMENTIA
with
Prof Tara Spire-Jones

“We are on the cusp of drastically changing our relationship with the Moon”

Dr Justin Holcomb p24

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Your oldest organ is likely to fail first. And now science can tell you their ages p23

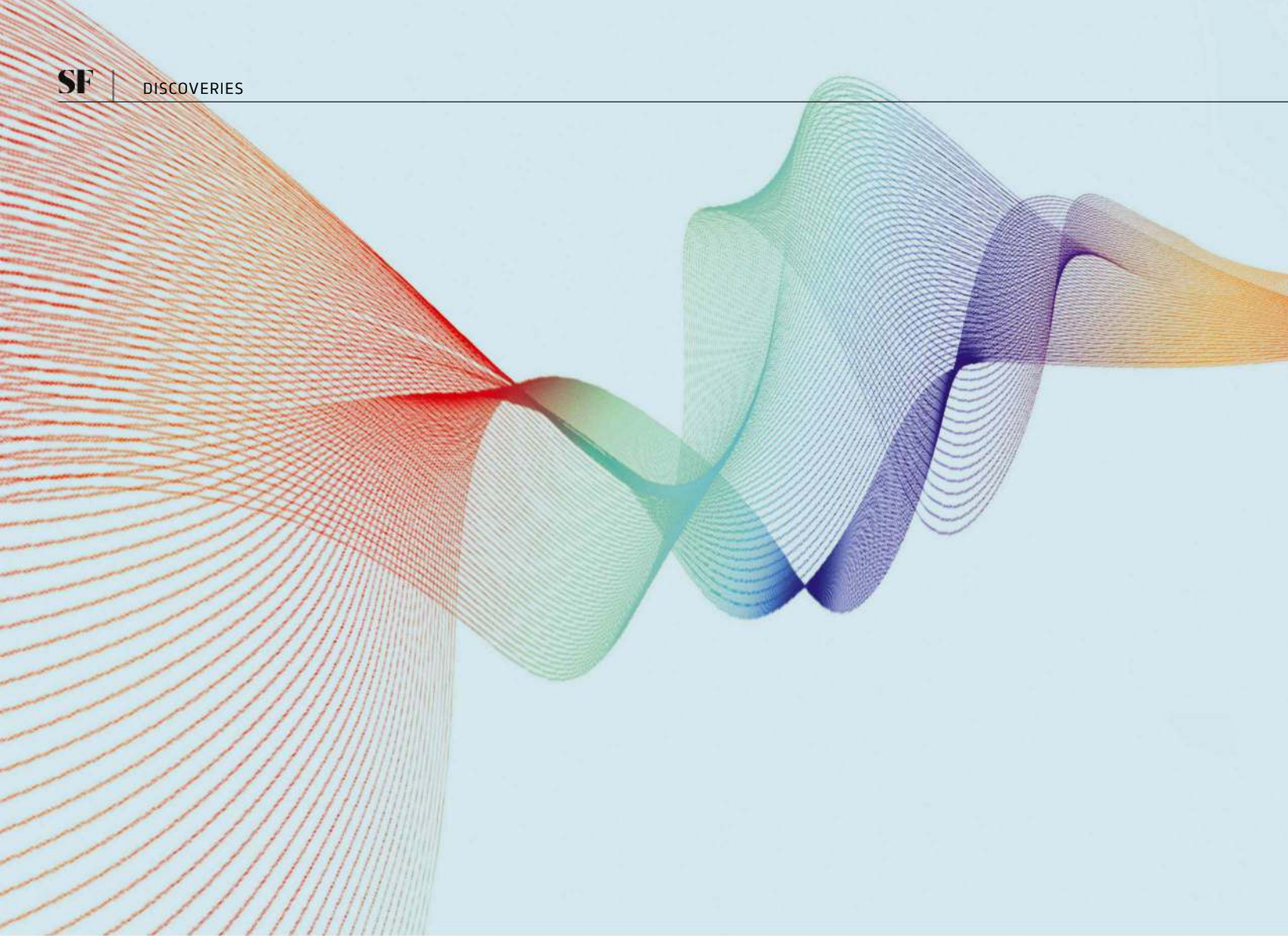
PRIMER

LUNAR EPOCHS

Human exploration of the Moon is pushing it into a new geological era p24

We've been leaving our marks on the Moon since the first probe reached it in 1959. Will the new space race lead to more dramatic and lasting changes to the lunar surface?





MEDICINE

HEARING AIDS REDUCE THE RISK OF DEATH BY ALMOST 25 PER CENT, STUDY FINDS

Turn up the volume: it's good news for hearing aid wearers

ABOVE Hearing loss has been consistently associated with cognitive decline, dementia and poor physical health

Not sure whether hearing aids are worth getting? Well, scientists at the University of Southern California (USC) investigated their benefits and the results are loud and clear: hearing aids can reduce your risk of death by almost 25 per cent.

Despite there being 40 million adults in the US who suffer from hearing loss, only one in ten people who need hearing aids actually uses them. In the UK, only three in ten people who need the devices use them, though 11 million are affected by hearing loss.

The USC scientists hope the findings of their study will encourage people to use hearing aids.

“Personally, as someone who uses a hearing aid, I find this result exciting,” Dr Janet Choi (opposite), lead researcher of the study and otolaryngologist with Keck Medicine of USC, told *BBC Science Focus*. “It suggests that there may be a potential protective role of hearing aid use against mortality among those who could benefit from hearing aids.”

The scientists believe that lower levels of depression and dementia are behind the longer lifespans. Improved hearing, according to Choi,



“Lower levels of depression and dementia are behind the longer lifespans”

goes hand in hand with improvements in mental health and cognition. These improvements promote overall health and therefore longevity.

Published in the journal *The Lancet Healthy Longevity*, the study is the largest to date to investigate the effect of hearing aids on mortality, examining 10,000 participants in total.

In the group of 10,000, the scientists identified 1,863 people as having hearing loss. Of these, only 237 people regularly wore hearing aids – meaning at least once a week for five hours. The majority, 1,483 people, were ‘never users’ of

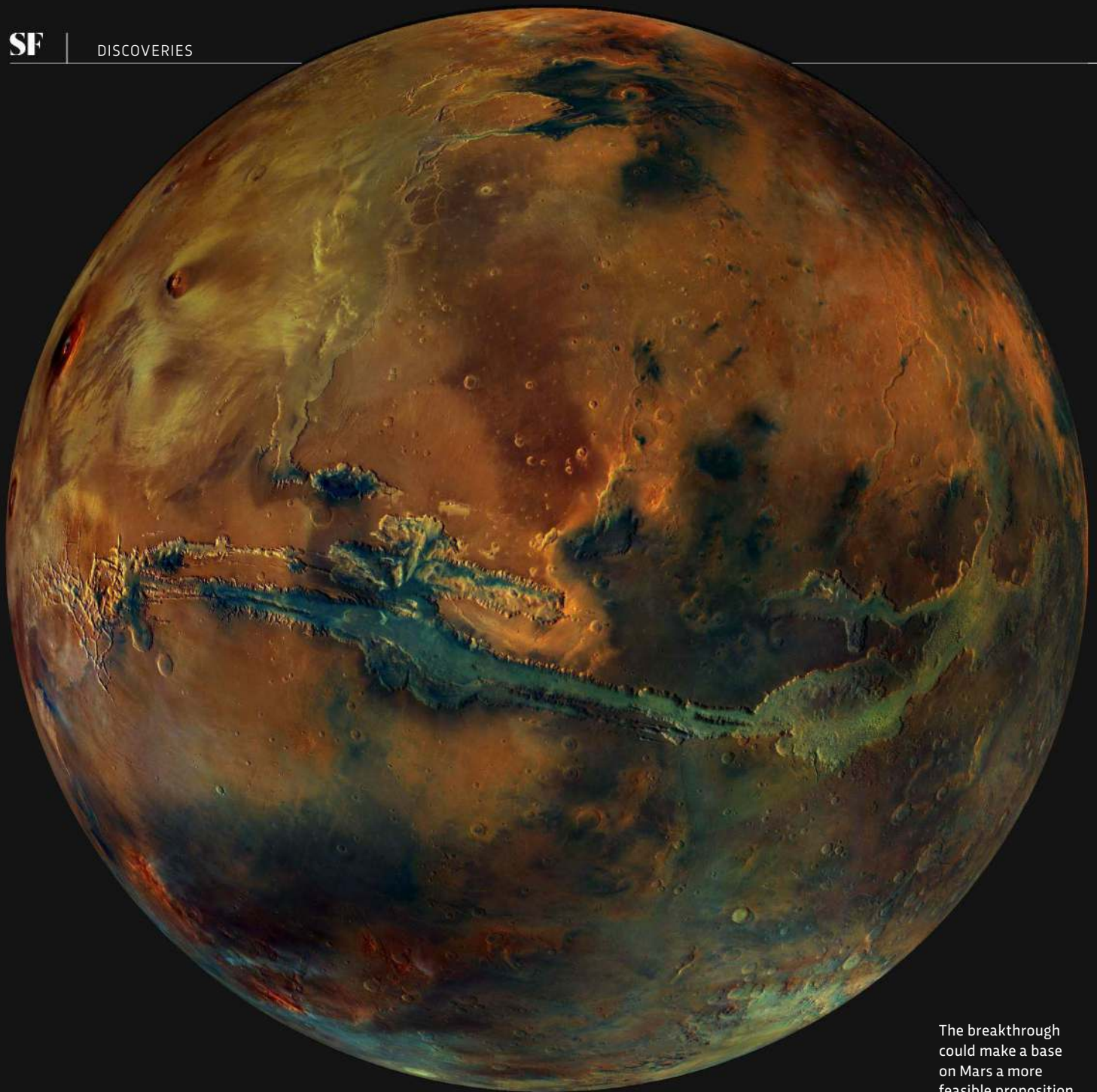
hearing aids. The researchers described the remaining group as ‘non-regular users’, meaning they wore the devices less than once a month.

The researchers found that the mortality risk was 25 per cent higher in never users compared to regular users. They also found that this was a steady rate: variables such as the degree of hearing loss, age, ethnicity, income and others didn’t change the benefits of hearing aids.

Interestingly, the study didn’t find a difference between non-regular users and never users. When it comes to hearing aids, this suggests you need to go all-in: occasional use of the devices likely doesn’t boost your lifespan.

“I encourage anyone experiencing hearing difficulties to get their hearing tested and determine the type and severity of their hearing loss,” Choi said. “You’ll likely be amazed by the sounds you’ve been missing, which you won’t realise until you have your hearing tested and, if suitable, try a hearing aid.”





The breakthrough could make a base on Mars a more feasible proposition

SPACE

PHOTOSYNTHESIS WITHOUT PLANTS COULD MAKE LIFE ON MARS POSSIBLE

Researchers have found a way to harness light to help us explore space and save Earth

Scientists have developed a process that mimics photosynthesis, but without plants – and it could help make it possible for us to live on Mars.

It involves harvesting solar energy and storing it in chemical bonds, which scientists can then convert into products such as fuel, fertilisers and breathable air. Essentially, the process captures light and transforms it into useful chemicals, much like a plant does.

Researchers at the University of Warwick are behind the development,

in partnership with the European Space Agency (ESA), the Georgia Institute of Technology, in the US, and the Centre of Applied Space Technology and Microgravity, in Germany.

Semiconductors, like those in solar cells, are used to absorb light in the same way that chlorophyll (the green pigment in plant leaves) can. Once stored, the solar energy can then be converted, with scientists using it to split compounds such as water into oxygen and hydrogen. In a space setting, the oxygen would be essential for breathing

HEALTH

DAYTIME FATIGUE SLEEP DISORDER COULD BE AFFECTING MILLIONS

If you find yourself feeling sleepy throughout the day, a not-so-rare sleep disorder could be to blame

while the hydrogen could be used to make fuel for spacecraft.

The process, according to the researchers, wouldn't need big industry infrastructure or even electricity to work because it generates electricity itself. What's more, it can produce other molecules depending on which semiconductor is used. For example, the scientists hope to use this method

“Semiconductors are used to absorb light in the same way chlorophyll can”

to convert carbon dioxide (CO₂) in Earth's atmosphere into 'solar fuels'. While there's only a comparatively small concentration of CO₂ in Earth's atmosphere, converting it into fuel could play a part in the fight against climate change. On Mars, however, the CO₂ concentration is incredibly high – around 96 per cent.

The energy conversion process will be tested in a rocket later this year or in 2025. During the mission, a rocket containing an experimental version of the process will fly to the edge of space and then return after spending five to six minutes in microgravity.

The researchers hope that, if it's successful, the process will have applications for life on Earth and Mars. This, according to Dr Katharina Brinkert, associate professor at the University of Warwick, will involve experts from a variety of fields in what she calls a “Manhattan Project for the energy challenge”.

“I think there's a lot to learn from each other because a lot of the problems we have for space [travel] are so pressing that we can't go unless we solve them,” Brinkert told *BBC Science Focus*. “But we're trying to solve the same problem on Earth, because we need more efficient, reliable, sustainable energy sources to tackle climate change.”

Despite a good night's sleep, many people still find themselves feeling drowsy and fatigued throughout the day. According to a study published in December, this could be explained by a sleep disorder that might be more common than previously thought.

Idiopathic hypersomnia is a neurological disorder that can cause people to feel very tired during the day, sleep for excessive periods of time, have difficulty waking up and even wake up disorientated.

While similar in nature, idiopathic hypersomnia is different to the more common narcolepsy. Narcolepsy can also cause people to feel tired throughout the day, but sufferers tend not to sleep excessively and can wake up feeling refreshed from naps.

“It has been difficult to determine the prevalence of idiopathic hypersomnia because expensive and time-consuming sleep testing is required to make a diagnosis,” said the study's author Dr David T Plante, from the University of Wisconsin-Madison in the US.

“We examined data from a large sleep study and found that this condition is much more common than previous estimates, and as prevalent as some other common neurologic and psychiatric conditions such as epilepsy, bipolar disorder and schizophrenia.”

The researchers behind the study analysed sleep data collected from 792 people with an average age of 59.

Every participant had to complete an overnight sleep study, as well as a daytime nap study, measuring how fast they fell asleep.

The participants were surveyed further on daytime sleepiness, fatigue, the amount of time spent napping and how many hours of sleep they get on a worknight and non-worknight.

In the surveys that measured sleepiness, a score range was set up between 0 and 24. Questions included how likely a person is to nod off while sitting, talking and while stopped in a car. On average, people with idiopathic hypersomnia had a score of 14, while those without averaged nine. Anything over 10 was deemed concerning.

With the results of the tests, the researchers were able to determine that 12 people had probable cases of idiopathic hypersomnia. This indicates a prevalence of 1.5 per cent in the wider population.

The study only assessed employed people, however. So the researchers note that the true prevalence of idiopathic hypersomnia could be even higher if the unemployed population were to be included.



NATURE

GENIUS DOGS KNOW TENS OF TOYS BY NAME... BUT TRULY GIFTED CANINES KNOW OVER 100

If your pooch can retrieve its toys by name rather than chewing them to pieces, you may have a genius on your hands



Scientists have pinned down the characteristics of a unique type of genius dog, and it all comes down to how well they know their toys. These dogs are known as Gifted Word Learners (GWLs), as they know the names of many of their toys and can retrieve them on command.

Published in *Nature Scientific Reports*, the study confirmed that these canine geniuses are incredibly rare. In fact, it's one of the first studies to investigate the

“By the time the study had finished, 50 per cent of the pups observed knew the names of over 100 toys”

characteristics of these dogs in depth, with a sample size of 41 rather than just one or two dogs.

The researchers found that, on average, the genius dogs knew 29 toy names. However, GWL dogs learn words so quickly that, by the time the study had finished, 50 per cent of the pups being observed knew the names of over 100 toys.

To establish whether the dogs were GWLs, the researchers asked the owners to first send in videos of their dogs retrieving their

TECHNOLOGY

DECLINING COOKIES COULD BE WORSE FOR YOUR PRIVACY THAN ACCEPTING THEM

Choosing whether to accept or reject cookies is a catch-22



Max, a five-year-old border collie from Hungary, knows the names of over 200 toys

toys by name. After this, the researchers met the owners in a ‘virtual lab’ to test this toy retrieval in more controlled conditions. The team then gave each of the owners a survey to complete, which asked questions about their dog’s life experience, the owners’ experience of training them and how the dogs learned the names of their toys.

The study, conducted by scientists from Eötvös Loránd University in Budapest, Hungary, reveals that owners of GWL dogs report that their gifted pups are able to learn the name of a new toy in under 30 minutes.

According to the study, certain breeds are more likely to be GWLs than others. While 56 per cent of the GWL dogs in the study were border collies, there were several non-worker breeds too (including a corgi and a Shih-Tzu).

The majority of owners surveyed didn’t have a professional background in dog training. In fact, most didn’t even intend to teach the dogs this trick; the dogs simply learnt the names of the toys by having their owners say things like ‘Do you want to play with your snail?’

“The relatively large sample of dogs documented in this study helps us to identify the common characteristics that are shared among these dogs and brings us one step closer to understanding their unique ability,” said Prof Ádám Miklósi, head of the Department of Ethology at Eötvös Loránd University and co-author of the paper.

If you click ‘reject all cookies’ whenever you visit a new website, you may be revealing more about yourself than you think, says new research.

Cookies are pieces of data stored on your devices for various purposes, such as remembering your login details. They can also track your online behaviour so that companies can tailor adverts to you. Many people don’t like this, whether because they want to keep their personal information private or because they don’t want companies using it to sell them things.

But new research, announced at NeurIPS 2023 (an AI conference that took place in December 2023), revealed there’s a particular demographic that rejects cookies more than other people – and the advertisers know this. So cookie-rejectors may not really be keeping their information private after all.

Cookie rejection tends to depend on your age and location. If you live in America and are over 34 years old, this is likely to be you. If you click ‘reject all’, the algorithm assumes you’re part of this demographic and applies ‘collaborative filtering’ to tailor content to you. It notes what other users in this group search for and offers you the same.

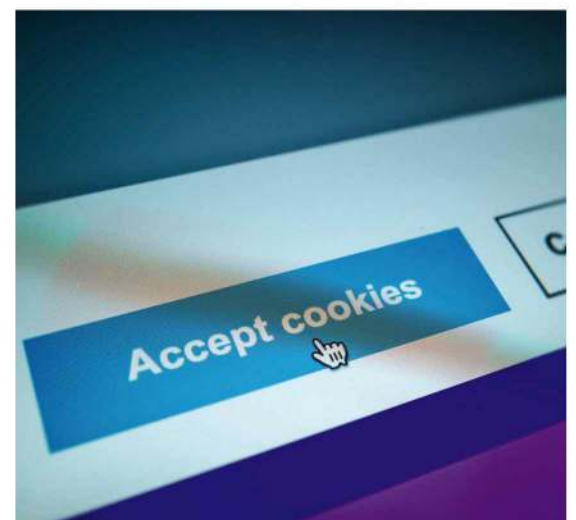
“The advertisers might have five pieces of information from one person who’s accepted the cookies and only two pieces of information

from the person who’s declined them (the website they’re currently on, and the fact that they’ve declined cookies). But there’s more information encoded in that decision,” one of the study’s authors, IBM research scientist Dr Elizabeth Daly, told *BBC Science Focus*.

The researchers believe this demographic is more likely to reject cookies because older people are less trusting of tech companies. In fact, only 28 per cent of older Americans say they accept cookies, compared to the 40 per cent of younger Americans (under 34 years old) who usually accept cookies.

Further, the US doesn’t have the same data protection laws as the EU, so American users may be aware that their information is less robustly protected. The highest rate of cookie acceptance in the world is in Poland, where 64 per cent of users usually click ‘accept all cookies’.

The authors hope that their research will inform policymakers when it comes to creating rules for regulating new technology like AI.



GASTRONOMY

SCIENTISTS DISCOVER A SIMPLE TRICK THAT CAN DRASTICALLY IMPROVE YOUR COFFEE

By grinding your coffee with a splash of water, espressos can be made more consistent and intense

There are countless methods and devices that claim to improve the taste of your coffee, but scientists have discovered a trick that involves a few drops of water.

The process of grinding coffee beans creates friction, which generates static electricity that can cause the particles of coffee to stick together. But scientists report that coffee beans holding a higher internal moisture level produce less static electricity. This, according to their findings published in the journal *Matter*, makes for a more reliable and intense espresso. All you need to do to raise the moisture content is simply add a splash of water to the beans before grinding them.

“The central material benefit of adding water during grinding is that you can pack [your coffee machine] more densely because there’s less clumping,” said the report’s senior author Dr Christopher Hendon, a computational materials chemist at the University of Oregon, USA. “Espresso is the worst offender, but you would also see the benefit in brew formats where you pour water over the coffee, like a stovetop. Where you’re not going to see a benefit is for methods like the French press, where you submerge the coffee in water.”

A volcanologist collaborated on the project, as the process of grinding coffee beans mimics a phenomenon that occurs during volcanic eruptions, in which magma breaks into small particles that rub against each other and produce lightning.



Grinding coffee beans with a splash of water can enhance the drink’s taste

BIOLOGY

RATES OF AGEING IN YOUR ORGANS REVEALS WHICH WILL FAIL FIRST

Scientists may now be able to predict both when and how your body might fail. But it’s not all doom and gloom...

We may not (yet) be able to see the future, but scientists can now predict which of your organs will fail first, according to a new study. But rather than a morbid window on your fate, the discovery could allow doctors to target these ageing organs early, before the symptoms of disease appear.

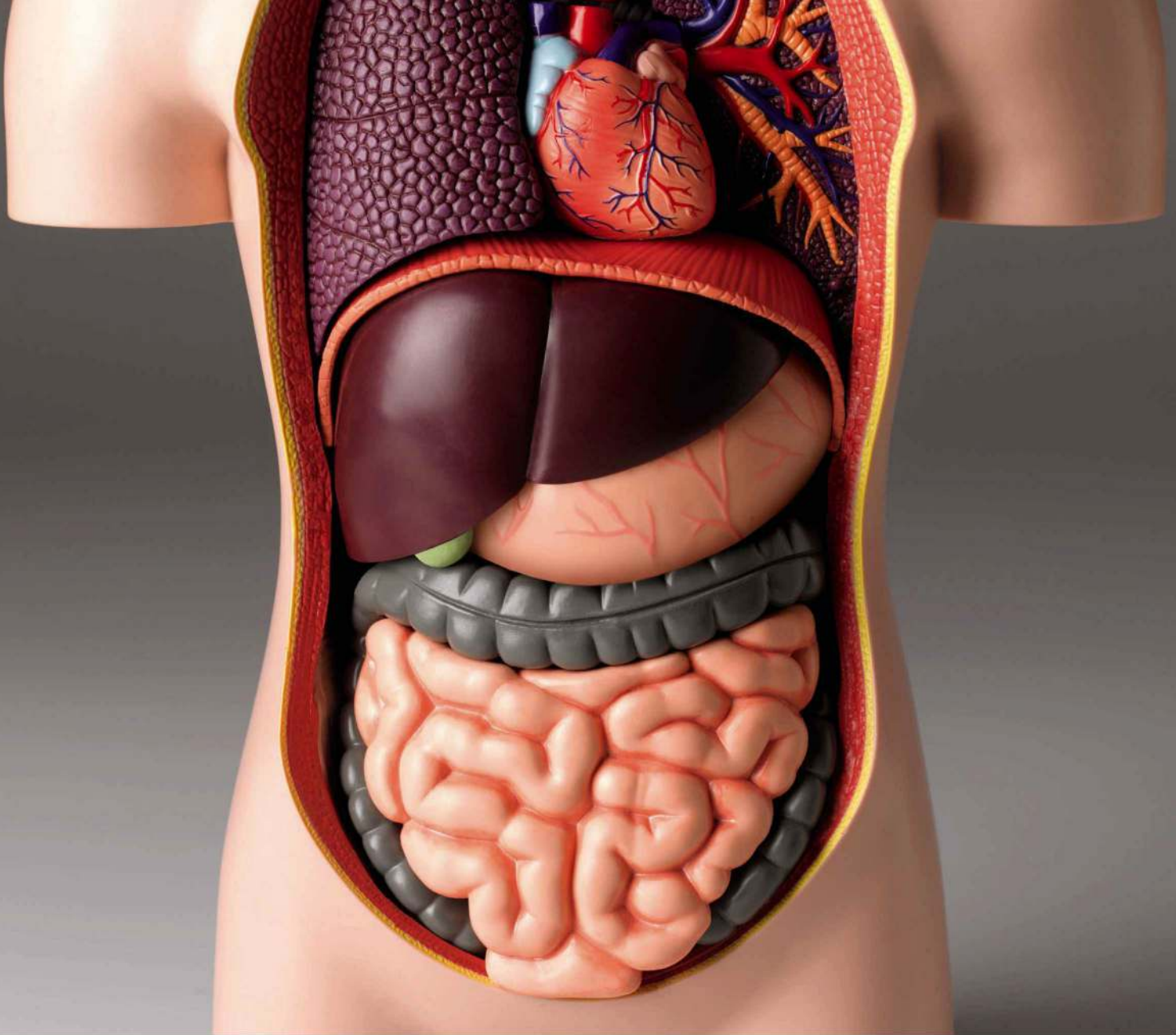
The study, published in *Nature*, reveals that one in five healthy adults aged over 50 has at least one organ that’s ageing too fast. This means they have a heightened risk of developing a disease in that organ over the next 15 years. But how can ageing happen at different rates within the same body?

Everyone has two ages. There’s your chronological age, the one you celebrate every year on your birthday that (unless you lie about it) increases by one each time. The other, your biological age, is more flexible and changes depending on how healthy you are. Scientists calculate your biological age by studying the complex combinations of biological signs in your body.

In a study involving over 5,000 people, researchers at Stanford Medicine at Stanford University, California worked out the biological ages not of the participants themselves, but of their organs. They did this by studying the proteins in their blood.

What this revealed was that when the age of someone’s organ is higher than that of the same organ in other people of the same age, that person has a higher risk of disease.

Rather than being on the same track towards death, every one of our organs is dying at a different rate. Certain proteins in our blood are linked to certain organs, and unusually high or low levels of these proteins often accompany accelerated ageing and vulnerability to disease.



The Stanford scientists began their investigation by analysing the blood of 1,400 healthy people aged 20 to 90. They then fed these peoples' protein combinations into a machine-learning algorithm, which they trained to predict age. The scientists tested the algorithm on 4,000 more people to verify its accuracy.

"If we can reproduce this finding in 50,000 or 100,000 people, it'll mean that by monitoring the health of individual organs in apparently healthy people, we might be able to find organs that are undergoing accelerated ageing," said Dr Tony Wyss-Coray, professor of neurology at Stanford and senior author of the study.

It may one day be possible that a simple blood test can tell which, if any, of a person's

"Rather than a morbid window on your fate, the discovery could allow doctors to target these ageing organs early – before the symptoms of disease appear"

organs are ageing rapidly and help predict whether that person is at risk of a particular disease. Accelerated ageing of a person's heart could indicate future heart issues, for example. "We might be able to treat people before they get sick," Wyss-Coray added.

PRIMER

LUNAR EPOCHS

Have humans pushed the Moon into a new geological age?

In our short history of space exploration, humans have already changed the Moon significantly. From the cultural heritage of our first footprints to the damage caused by the crash landings of our spacecraft, our presence is practically frozen in time in the Moon's dusty regolith.

The Moon has been in its current epoch, the Copernican, for the last 1.1 billion years. Now, researchers are arguing for the formalisation of a new epoch: the lunar Anthropocene. This epoch, the researchers argue, began in 1959 when Russia's Luna 2 spacecraft became the first craft from Earth to land on the Moon.

We spoke to one of those researchers, space archaeologist Dr Justin Holcomb at the University of Kansas in the US, to learn more.

WHAT MARKERS SUGGEST THAT A NEW EPOCH HAS STARTED ON THE MOON?

The Anthropocene on Earth is a complex issue because, if humans became the dominant force or agent of change, we need to have a record of that. But the geomorphological systems on Earth are constantly erasing that record. Everything is discarded and then cycled into the environment in various ways, like being buried into the ground and then getting size-sorted and moved around, or having plants growing through it.

The beauty of the Moon is that it has less active systems that are serving to erase the record of human

activity. The main agent of change on the Moon, historically, was just meteoroid bombardment, which is pretty slow. Except now, we have the human variable, which is quite significant. The Moon represents a good laboratory for the experiment of testing the lunar Anthropocene, because of its limited systems and its ability to record the entirety of human history.

WHAT ARE SOME OF THE BIGGEST IMPACTS WE'VE HAD UP THERE?

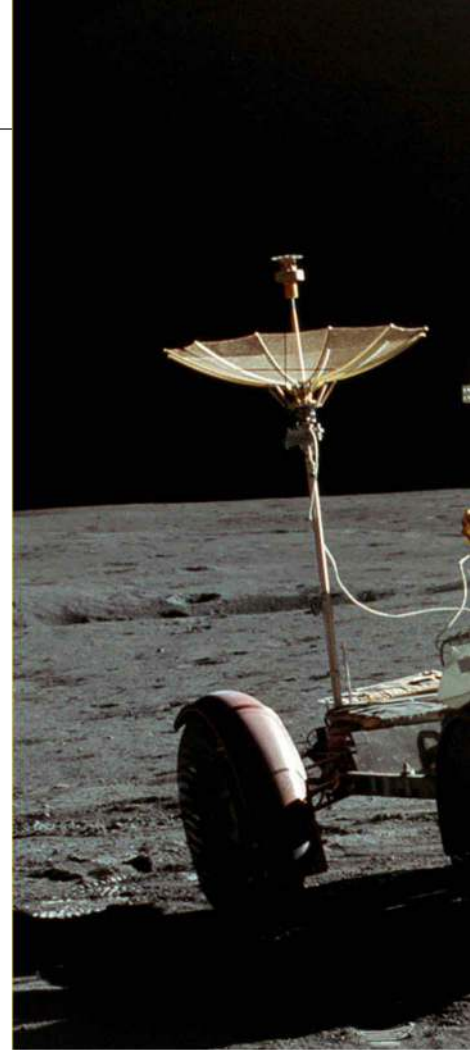
The most significant impact to the Moon is when we land. That's what makes humans different to a natural background of impact: we don't just make an impact – we then walk and drive around and sample things.

The more negative type of impact is accidental crashes – unplanned wrecking into the Moon – and that's a significant risk as we move forward in this era of the new space race.

Since 2019, there have been around six accidental crashes. These pose a real risk to the areas of more planned activity like Tranquility Base, where we have the first footprint. Unplanned crashes could hit those, and once those are gone, they're gone forever.

WHAT ARE SOME OF THE OTHER THINGS WE HAVE LEFT THERE?

There are all kinds of things! [The astronaut] Charles Duke left a photo of his family, which probably instantly turned brown. There are also golf balls, human faeces, urine bags and vomit

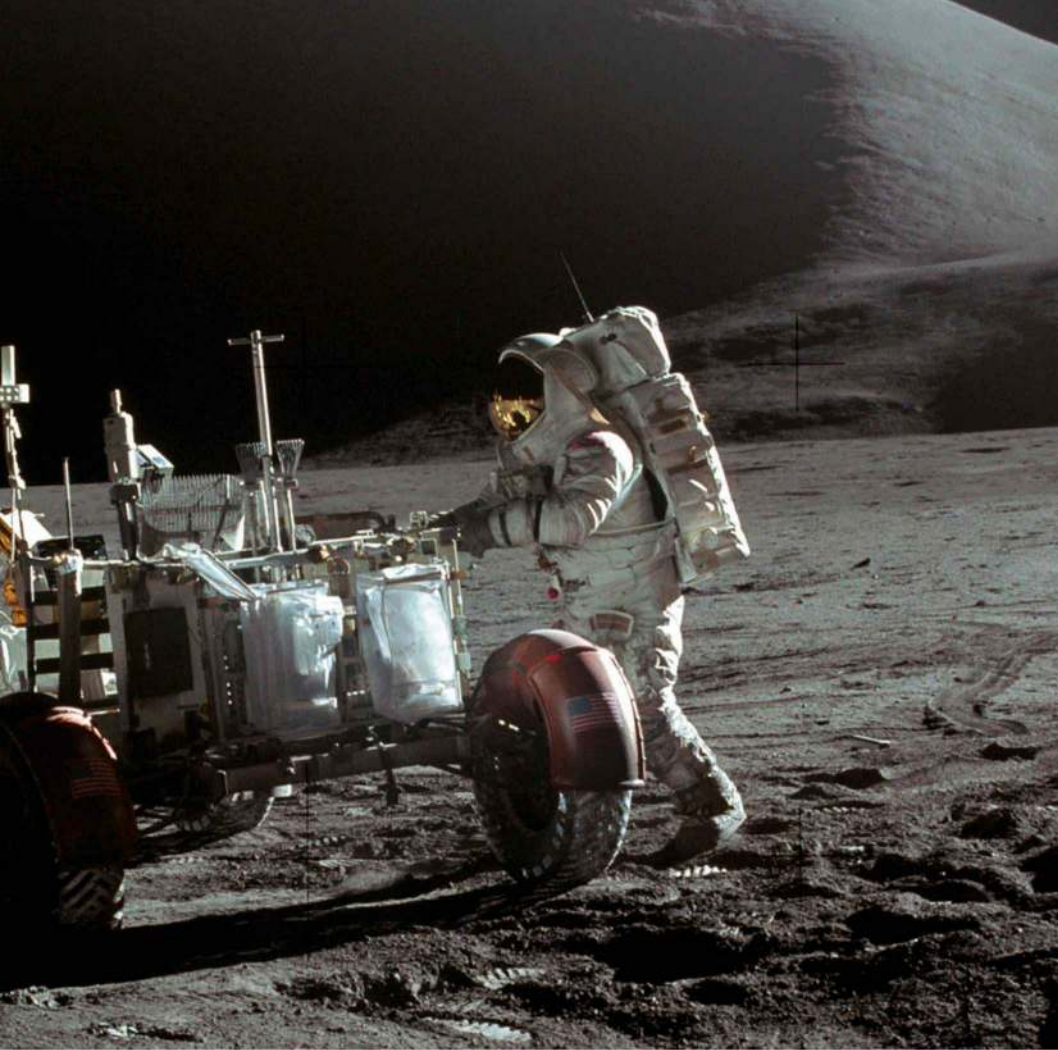


bags. One private company launched a mission that had tardigrades on it that crashed into the Moon. India's rover has its national emblem on its wheels so as it drives around, it leaves this imprint on the Moon.

One of the common narratives is that the Moon has a space trash problem. But it's not trash; it's heritage, and it records our history as a species. So we don't need to solve a space trash problem, we need to solve a space heritage problem – and that means we need completely different solutions that are geared towards protection as opposed to removal.

THE EARTH ANTHROPOCENE IS DEFINED BY HUMAN ACTIVITY CHANGING THE PLANET'S CLIMATE AND ECOSYSTEMS. SO HOW IS HUMAN ACTIVITY CHANGING GEOLOGICAL PROCESSES ON THE MOON? HOW FAR COULD HUMANS THROW THE MOON'S SYSTEMS OUT OF BALANCE?

It's not necessarily that the lunar Anthropocene is going to be defined as a climate change, because there's not a climate on the Moon. Instead, it's going to be defined in the rock record. The significance of humans causing



LEFT Apollo 15 astronaut James Irwin with the lunar rover on the Moon in 1971

BELOW The Duke family photograph laying on the surface of the Moon, left by Apollo 16 astronaut Charles Duke in 1972



“The beauty of the Moon is that it has less active systems serving to erase the record of human activity”

geomorphic change (the movement of lunar regolith around the surface) is threefold. Firstly, we know that rocket fuel can potentially contaminate ice, which tends to be found in the permanently shadowed areas on the Moon. One of the reasons we’re returning to the Moon is because of ice, as it contains hydrogen that can be turned into fuel.

Secondly, humans could have a potential impact on the Moon’s exosphere [its thin, tenuous atmosphere]. This is more speculative, but as we’re also going back to the Moon to mine, what about mining tailings and plumes? How are they going to influence the exosphere – will they produce a big cloud? Will they create a hazy environment on the lunar surface? That’s a problem.

Thirdly, we can’t always predict where our rockets are going to land. So there’s this corpus of important space heritage at risk of being destroyed.

HOW COULD FUTURE SPACE MISSIONS IN 2024 AND BEYOND CHANGE THE MOON EVEN FURTHER?

I think we’re in the middle of a transitional period when it comes to space exploration in our species’ history. Sputnik was the first time we successfully exited our atmosphere. That was in 1957 and now we’re on the cusp of drastically changing our relationship with the Moon.

If we take all the times we’ve impacted the Moon with either an accidental crash or purposeful impact or landing since 1959, it’s around one per year. But there are around

493 launches from Earth planned for this year and, of those, 17 are going to the Moon. That’s 17 times the rate of our historical impact. And this is just the beginning. It’s not the right decision to wait [to formalise the lunar Anthropocene] until that number is something like 100 or 200, which it will be very soon.

With the new focus on mining, there may be a lot of capital to be made on the Moon. The important thing here is that, in the new space race, as compared to the space race of the mid 20th century, private companies are involved. That’s changed the game. **SF**

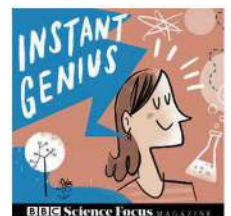
DR JUSTIN HOLCOMB

Justin is a postdoctoral researcher at the Kansas Geological Survey, University of Kansas.

DISCOVER MORE

LISTEN

For the full interview, listen on *Instant Genius*: [sciencefocus.com/instant-genius-podcast](https://www.sciencefocus.com/instant-genius-podcast)



COMMENT

PHYSICS, AI AND MUSIC SHARE A COMMON THREAD. YOU JUST HAVE TO KNOW WHERE TO LOOK

Studying science can lead you in many directions and open doors on to unexpected possibilities along the way

Occasionally in academia, you meet those rare, brilliant individuals who can seamlessly bridge several scientific disciplines. Prof Leon Cooper was one such person. Known for his New York accent, perfectly groomed hair and fine Italian suits, Cooper was a Nobel Laureate in physics and a maestro of interdisciplinary exploration.

I witnessed his brilliance while at graduate school in 1993. In the elevators of the physics department, he would pose the most probing questions to young researchers. “Do you really believe in what you’re working on?” he’d ask, steering conversations beyond the technical and into philosophical territory.

Bonding over our shared love for music, our encounters became a canvas for passionate discussions. It was during these discussions that I discovered Cooper’s profound contributions to an electrical phenomenon called superconductivity.

Essentially, at room temperatures, electric current encounters resistance. But near absolute zero (-273°C) current flows through superconductors with zero resistance. This superconductivity effect could play a pivotal role in the future of clean energy, as well as enable medical and technological innovations.

But what causes superconductivity? Cooper posed that a concept now called ‘Cooper Pairs’ was behind it. These are pairs of electrons that effectively bind together, changing their properties so they can traverse a wire unimpeded. This insight earned Cooper the 1972 Nobel Prize in Physics, along with John Bardeen and John Robert Schrieffer.

A year after receiving the Nobel Prize, he took the helm of the Institute of Brain and Neural Systems at Brown University, applying theoretical approaches from particle physics to the brain.



PROF STEPHON ALEXANDER

(@stephstem)
Stephon is a theoretical physicist based at Brown University, Rhode Island. He also explores the connections between music, physics, mathematics and technology.

Fast forward to the mid-90s and the landscape of machine learning was fast developing. Although computers of that era weren’t as powerful as today’s, the basic theory underpinning machine learning existed. And Cooper made significant contributions to the creation of neural networks – algorithms inspired by the structure and function of the human brain.

One of his tools for developing such networks was the Ising model, which emerged from the physics of atomic spins. To understand it, try imagining atoms in a grid on a slab of metal. Then envision the atoms as tiny magnets that are either pointed up (representing a positive ‘spin’) or down (a negative ‘spin’). It’s the way all these atomic magnets interact that determines whether the metal becomes a magnet or not.

A broad class of machine learning architectures draws parallels between the Ising model’s atoms and the neurons in the brain. In the Ising model, neighbouring atoms communicate with each other through the energy of their spins. This atomic energy is lowered if the neighbouring spins ‘agree’ with each other. It’s similar to how the brain works: neurons can send a signal to each other or not based on the signals of their neighbours.

Inspired by Cooper’s spirit of mixing disciplines, I began a new scientific endeavour with cosmologist Prof Robert Brandenberger. Since 1997, we’ve been trying to use neural networks (and thus the Ising model) to understand the structure of the Universe.

Cooper’s thinking could be used to overcome emerging challenges in music too. Specifically, composing music with machine learning. While artificial intelligence (AI) has excelled in dissecting recorded tracks into their key parts, creating original music has proven a formidable frontier.

Behind all music hides certain rules that govern how chord progressions are formed and, as of now, AI models struggle to grasp these rules. In partnership with Robert Rowe, a professor of music technology at NYU, we’ve set out to overcome this challenge. Our solution, the Pentahelix, is a model inspired by jazz improvisation and offers a ray of hope in addressing this issue.

Imagine the Pentahelix as a lattice, similar to the Ising model, but with a honeycomb-like structure. Instead of representing spins, the lattice points correspond to potential musical tones. Within this framework, numerous tones can encode musical chords and melodic patterns. Essentially, it provides a structured way to organise musical elements.

By using the Pentahelix, we can gain insights into the strategies and patterns jazz musicians employ in their creative process. This not only enhances our understanding of musical improvisation, but also opens up new possibilities for music composition and performance.

As we await the outcome, there’s a profound sense that Cooper would take pride in the continued pursuit of transformative ideas and perspectives. This journey from superconductivity to jazz improvisation exemplifies the enduring power of interdisciplinary exploration. It shows what’s conceivable in the realms of science and technology, and where the next boundaries could be broken.

“Cooper made significant contributions to the creation of neural networks”





COMMENT

DON'T LET BAD NEWS BRING YOU DOWN. THERE ARE REASONS FOR HOPE

Changes happen every day, and with science's help, many of them have the potential to improve the world

Over the last few years, the flow of bad news has felt relentless. And towards the end of 2023, we were reminded by events at the latest UN climate conference in Dubai that global efforts to overcome the worst effects of climate change are progressing much slower than the pace of global warming.

But that's no reason to sigh and abandon all hope just yet. Because there was a genuine breakthrough at that COP28 meeting. For the first time, countries agreed to "transition away from fossil fuels in energy systems". Whatever you think of these COP meetings – and they're far from perfect – for once, the world came together and said: "We want to stop burning oil, gas and coal."

However small a victory finally acknowledging the key cause of climate change might be after almost 30 years, it's a win nonetheless. And it's just one of several significant leaps forward happening around the world today.

You may not have heard of it, but there's a technological transformation taking place in the UK – one that's gradually weaning us off fossil fuels.

For instance, every single month of 2023 saw an estimated 17,000 households add solar panels to their properties – not bad considering solar energy is now the cheapest source of electricity in history, according to the International Energy Agency. And to store all that cheap electricity, battery plants are popping up all over the country at an astonishing rate.

Sure, this change is happening later, and more slowly, than most climate scientists would have hoped. But it is happening.

Amid all of today's eco-anxiety, I've found it helpful, even therapeutic, to remind myself that inspiring scientific discoveries are continuously being made. And although not all of them will help us get out of this human-made mess, they're almost always fascinating.

One example is a particularly clever fuel source created by researchers at the University of Cambridge. The team has managed to produce 'floating fuel factories' based on artificial leaves. It's early days for this technology, but the eventual aim is to create carpets of leaves that would use sunlight to convert water and carbon dioxide into fuel.

Rather than burning fossilised sources of carbon, projects like this would create new fuel that actually uses atmospheric carbon dioxide as an ingredient.

Even artificial intelligence – probably the most maligned, feared and revered tech topic of our times



“Other species that were thought to be lost forever have also made a comeback”

– will play its part. In November 2023, a team of researchers developed an AI that could soon predict the ingredients and properties of 2.2 million materials unknown to science (our current recipe book of matter contains around 20,000 inorganic materials). It’s hoped at least some of them could be used to create more efficient and safer batteries.

But it’s not all about humans. In 2024, we must make progress in bettering the world for the other species we share this fragile planet with.

The truth, when it comes to biodiversity, is that we’re not doing well. The natural world is continuing to degrade and decline, with one in six species in the UK now under threat. Humanity is still waging a suicidal war on nature, to borrow a term from UN Secretary-General António Guterres.

But recent months have seen some encouraging signs of how dramatically nature can recover if we give it a chance – and some space.

Consider the blue whales in the Seychelles region of the Indian Ocean. Although it was thought these gigantic mammals (the largest ever to have lived on Earth) were wiped out in that area by Soviet whalers during the 1960s, they have returned. After studying underwater sound recordings, scientists revealed that blue whales were singing their deep, pulsing song in the Indian Ocean for several months of 2023.

Other species that were thought to be lost forever have also made a comeback. These include the blind De Winton’s golden mole that ‘swims’ through sand – an animal presumed extinct since the 1930s. The creature was rediscovered by conservationists and geneticists using environmental DNA (genetic fingerprints left behind by the animal in the sand).

This mole, which is only found in South Africa, is actually the twelfth species to be rediscovered by the Search for Lost Species project, which was launched just six years ago. Others include a giant bee, a climbing salamander and the gloriously named Attenborough’s long-beaked echidna.

Much closer to home, a furry icon of the British countryside was reintroduced to one of the most beautiful places in England. Last August, hundreds of captive-bred water voles were released in a boggy, restored valley habitat in the Lake District.

Certainly, all these breakthroughs and glimpses of success shouldn’t make us complacent. But they should give us hope. And we need that as we take on the challenges of 2024.



VICTORIA GILL

Victoria is BBC News's award-winning science correspondent. Her reporting can be found on television, radio and online.



COMMENT

FULL TO BURSTING, BUT STILL CAN'T TURN DOWN DESSERT? BLAME EVOLUTION

Don't be surprised that you have a 'dessert stomach'. They existed long before we even dreamt of sticky toffee pudding

Picture the scene: I'm sitting in quite a swish pub in a small village outside Cambridge. It's a Thursday evening in early December, so it's dark and cold outside. Here inside the pub, however, there's a warm cozy fire, and the whole place is decked out in festive decorations. Michael Bublé is crooning Christmas songs on the radio and I have a large glass of Malbec in my hand.

Right now, at this moment, life is good.

It's been a long day (a long week, actually), so this is definitely the place to be. It's one of those 'gastropub' establishments that serves lovely food and I've just enjoyed a weekday date night with my wife Jane.

For dinner, we both had the cured trout to start, then for our main courses, Jane chose the hake and I opted for a burger and chips. The portion sizes were healthy and both of us were pretty full by the time we had finished.

When they get back to the village, they would clearly have to consume at least 2,000 calories to recoup their expenditure, otherwise their lives would be unsustainable in the long term. Since there's no guarantee that they'll catch an antelope the next time they go hunting, if they only ate to their metabolic need, they wouldn't survive very long.

Hence the hedonic part of the brain kicks in. This governs the feeling of reward we get from eating, driving us to chow down more than we actually need. But how do we get past the mechanical difficulty of a stomach packed full of 2,000 calories of food?

Well, our brains become pickier. They begin to crave foods that are more calorically dense – foods that for every given gram contain more calories. This allows us to fill in all the nooks and crannies in our stomachs. So what foods are the most calorically dense? Those that are high in sugar and fat. And what foods are high in sugar and fat? Desserts.

In other words, your 'dessert stomach' is actually an evolutionary holdover from your ancestors' days on the Serengeti. It's there to make sure that even when you're full, you still crave the right types of foods to ensure you're able to maximise your caloric intake at every meal. After all, there was never a guarantee of when the next meal would arrive.

You've probably spotted the obvious issue here: while this drive kept us alive in regular cycles of feast and famine, many people today live in a cycle of feast and, well, more feast. I most certainly didn't need that sticky toffee pudding (although I did really enjoy it and didn't regret it for one minute).

Incidentally, the 'dessert stomach' isn't just some weird human phenomenon. Obviously a lion isn't going to be topping off its freshly killed antelope luncheon with a crème brûlée and a glass of chilled Muscat. But let's just consider the grizzly bear during the salmon runs in the Pacific Northwest of America as an example.

Grizzlies arrive at the swimming buffet of the salmon runs, which take place in the autumn, with the intention of storing as much fat as possible for the coming winter hibernation.

When they start feeding, the bears eat pretty much the whole fish, down to the bone. But as they get more and more full, and store more and more fat, they switch to just eating the skin of the salmon and the thin layer of fat that lies underneath. Why? Because this is the most calorically dense part of the fish. The bears begin to change what they're eating to maximise their energy storage.

Desserts are clearly a human cultural construct, but the phenomenon of maximising the calorie density of food that is craved as you, I or an animal gets full, is conserved through evolution. So, yes, it's not your fault that you can find room for dessert, even after a satisfying meal.

"I most certainly didn't need that sticky toffee pudding (although I did really enjoy it)"



DR GILES YEO

Giles is Yeo a geneticist at the University of Cambridge, whose work focuses on food intake, genetics and obesity. He is also a presenter on the BBC show Trust Me, I'm A Doctor.

You know what happened next, though. The waiter came around with the dessert menu and asked if either of us could be tempted. Full though we were, yes, we most certainly could. Both of us ordered dessert (on a weeknight, as well). I had a sticky toffee pudding with ice cream and my wife went for a slice of tarte au citron with crème fraîche. The 'dessert stomach' strikes once again.

Here's the question though, why is it specific to desserts? Would I have had another burger? Would Jane have had more hake? Absolutely not. So, what's special about desserts that we can 'find' room for them?

To answer this question, we have to look to evolution. Flashback to 50,000 years ago on the Serengeti and your ancestors are dragging an antelope back to the village. Metabolically speaking, it has cost them 2,000 calories to stalk, chase and bring down the animal.

REALITY CHECK

THE SCIENCE BEHIND THE HEADLINES

COVID inquiry | Dengue fever | Dream tech



REVIEW

COVID INQUIRY: WHAT DID WE LEARN AND WHAT CAN WE DO BETTER IN FUTURE PANDEMICS?

Masks, social distancing, lockdowns... how effective was the UK's response to the COVID-19 pandemic?



“That the UK didn’t maintain its stocks of PPE was one of the main drivers of the high mortality rates in health and social care workers”

BBC

For more fact-checking news, visit the BBC’s Verify website at bit.ly/BBCVerify

One of the hard lessons we learnt over the past four years is that public health relies on us balancing the benefits and harms of any action we might take to reduce the impact of disease. The recent COVID inquiry reminded us of that. But balancing those benefits and harms is difficult when you’re not sure what they may be. Getting a clearer understanding of what works and what doesn’t was one of the aims of the inquiry. So what did we find out?

WHAT HAPPENED AT THE START OF THE PANDEMIC?

In the early weeks of the pandemic, being a resident or member of staff in a care home carried some of the highest risks of death from COVID. The virus spread into care homes as elderly patients were discharged from hospitals to free up beds for COVID admissions. Even before the pandemic, we knew that it was almost impossible to stop the spread of infections like norovirus and influenza once they were introduced into care homes.

Even if we had been able to test all patients before transfer, we wouldn’t have prevented the care home epidemic. Tests done while someone is incubating COVID are often negative until they become infectious.

DID PERSONAL PROTECTIVE EQUIPMENT WORK?

The importance of personal protective equipment (PPE) in reducing infection risk in hospitals and care homes was well accepted before COVID. That the UK didn’t maintain its stocks of PPE was one of the main drivers of the high mortality rates of health and social care workers. One study showed that availability of PPE was one of the main factors affecting transmission of COVID in care homes.

More uncertain at the start of the pandemic were the benefits and risks of community non-pharmaceutical interventions (NPIs). NPIs refers to those control measures that don’t include vaccines or drugs, such as closing schools, banning meetings and wearing face coverings.

At the start of the pandemic, we knew that NPIs would be effective at reducing the spread of the virus,

though we didn’t know by how much. Several groups showed, early on, that different NPIs had differing impacts on the spread of infection.

Banning indoor gatherings and closing non-essential businesses, such as pubs and restaurants, were most effective, but stopping people meeting up outdoors, not so much.

DID WEARING MASKS HELP DEFEND AGAINST COVID?

The value of masks was a hotly debated issue. Early in the pandemic, many experts doubted their value outside of hospitals. But the evidence shows that wearing masks did reduce transmission of COVID in the community, at least until the emergence of the Omicron variant.

There have been conflicting studies on the value of masks in school, however. Using US data, one study showed that mask mandates in schools reduced infections, at least in the first couple of weeks. But over a full term there was no difference in infection rates between schools where masks were required and schools where they were not.

DID ISOLATING HELP?

The value of self-isolation is another area where the overall effect is unclear. In theory, testing and self-isolation should have reduced the transmission of COVID. But studies found that a substantial →

BELOW There is evidence to show that enforced mask-wearing did reduce COVID transmission in the early stages of the pandemic





RESEARCH CHECK

ABOVE According to a study in the US, it's not clear how effective a measure mask-wearing was at school

→ proportion of infectious people would need to self-isolate and we never identified more than about a half of all infections, so it's doubtful that self-isolation rates would have made much difference. By January 2022, staff having to self-isolate put more stress on the NHS than treating the increased wave of COVID admissions.

HOW EFFECTIVE WERE LOCKDOWNS?

Initially we didn't know what impact lockdowns could cause to people's health. Since then, we know that lockdowns were associated with mental and musculoskeletal health problems, and developmental problems in children.

Whether the benefits of NPIs outweighed their harms is not just a scientific issue but a wider debate across society as a whole. My view is that those early controls were more beneficial until most people had received two doses of vaccine. Then the harm probably outweighed the benefits.

HOW EFFECTIVE WAS THE VACCINE ROLLOUT?

The real success during the pandemic was the fast development of effective vaccines, without which we would have seen many more deaths. But, as my group's work showed in January 2021, these vaccines were never going to generate herd immunity and eradicate the virus. Vaccines do prevent infections, but only for a few months.

Adverse effects were seen with vaccines, of most concern were cerebral thrombosis and myocarditis. But these outcomes were even more common in people who had a COVID infection. Claims that COVID vaccines have contributed to the excess mortality we're still seeing are not supported by the evidence, as people who have been vaccinated are not more likely to die than the unvaccinated, after adjusting for age. Also, the advancements in vaccine science during the pandemic are likely to have benefits for other infectious diseases for decades to come.

by **PROF PAUL HUNTER**

Paul is a professor in medicine at the University of East Anglia's Norwich Medical School. His research covers the epidemiology of emerging infectious diseases.

ANALYSIS

DENGUE FEVER: HOPE FOR AN END TO A DEADLY DISEASE

The dengue virus is spreading. A plan to release billions of bacteria-infected mosquitoes could beat it

Half of the global population is at risk of dengue, which is currently endemic in 100 countries. Between 2000 and 2019 there has been a 10-fold increase in dengue cases and 2023 saw the highest number of cases on record. The past year saw record-breaking outbreaks in Bangladesh, Peru and Burkina Faso.

Climate change is fuelling the increase in this mosquito-borne viral disease, leading to larger outbreaks, quicker time between outbreaks and longer transmission seasons. Climate modelling studies forecast dengue spreading to more temperate parts of the world and putting even more people at risk. Now, the people behind a project named The World Mosquito Program are trying to solve the problem using a bacteria.

You may think of dengue as a 'tropical disease', but ominously there are now reported cases of mosquito-transmitted dengue in France, Italy and Spain.

Dengue is a self-limiting viral disease caused by four serotypes; DENV-1, -2, -3 and -4. While infection with one serotype affords immunity against a future infection of the same type, the danger comes when a person is subsequently infected by a different serotype. This can lead to dengue hemorrhagic fever (DHF), which can be fatal.

Dengue has earned the label 'breakbone fever' for good reason. While 80 per cent of cases are asymptomatic, when symptoms occur, they include high fever, muscle and joint pains, severe headache, pain behind the eyes, nausea and vomiting.

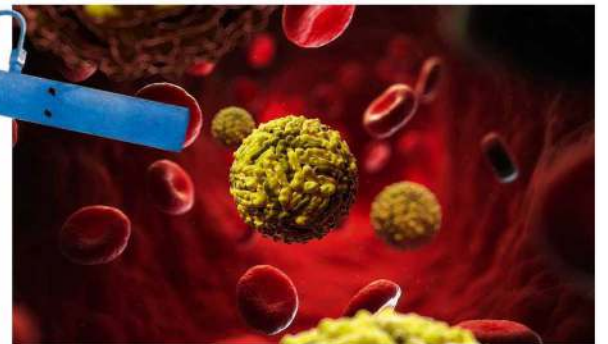
Symptoms start 4–10 days after infection and can last from two days up to a week. DHF, or severe dengue, presents with severe abdominal pain, persistent vomiting, bleeding gums or nose, blood in stools or vomit, pale and cold skin, and exhaustion. With no antivirals available, treatment centres can only work on alleviating the symptoms.

Dengue is spread via the bite of an infected female mosquito species, *Aedes aegypti*, typically found in tropical and subtropical regions. Originating in the forests of West Africa, *Aedes aegypti* spread across the globe during the African slave trade and has continued to hitchhike with human and goods transportation ever since.

Other *Aedes* species can also transmit dengue to a lesser extent. The highly invasive Asian tiger

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“Ominously there are reported cases of mosquito-transmitted dengue in France, Italy and Spain”



mosquito, *Aedes albopictus*, a secondary vector, is the likely culprit for dengue transmission in Europe. Unlike malaria mosquitoes, which typically bite at night and can be kept away with insecticide-treated bed nets, dengue mosquitoes are day biters, making them extremely difficult to control.

Aedes aegypti has adapted superbly to living with humans, their preferred blood source, becoming a highly urbanised mosquito. Stagnant water is key to the mosquito life cycle as it provides an oviposition (egg-laying) site and a habitat for the developing aquatic larvae and pupae.

Aedes aegypti exploits small pools of water that accumulate in human-made containers, such as

CLOCKWISE FROM ABOVE LEFT A worker sprays mosquito repellent on the streets of Indonesia; activists in India protest against the increasing numbers of dengue cases; an artist's impression of dengue virus in the bloodstream

rubbish, used tyres, flowerpots and so on, to breed. Humans have been the major driving force for the success of dengue mosquitoes.

Dengue prevention centres on targeting the mosquito. Integrated vector control management is a multi-pronged attack on *Aedes aegypti*, with insecticide spraying at its core. Worryingly, insecticide resistance has developed in mosquito populations globally, threatening the effectiveness of insecticide-based tools.

Control strategies also include eliminating or adapting breeding sites to stop *Aedes aegypti* from laying eggs in stagnant water (removing rubbish that can accumulate water and placing covers on →



ABOVE Dengue is spread through the bites of infected female *Aedes aegypti* mosquitoes

→ water storage containers). Bacteria toxins are also applied to water bodies to kill mosquito larvae. These strategies are labour intensive, as identifying, treating and eliminating all breeding sites is challenging. As such, there's a desperate need for new mosquito control methods.

Cue the World Mosquito Program (WMP), which has come up with a non-chemical and non-genetic modification-based approach for dengue control. A bacteria called *Wolbachia*, which occurs naturally in many insect species, but not *Aedes aegypti*.

The WMP found that 'infecting' *Aedes aegypti* with *Wolbachia* prevented the dengue virus from developing in adult females. From a logistic perspective, the method is self-sustaining as *Wolbachia* is passed on to the eggs via mating and can therefore spread through wild populations.

The WMP has reported significant reductions in dengue cases where *Aedes aegypti* carrying *Wolbachia* have been released. Given that *Aedes aegypti* also transmits the Zika and chikungunya viruses, the WMP has developed a potential 'three-for-the-price-of-one' method for arboviral disease control.

It's safe to say mosquitoes are the most hated insects, but, despite their notorious reputation, of the 3,500 mosquito species, only a handful transmit disease. They're also important to the ecosystem.

Mosquitoes are a food source for fish, frogs, reptiles, bats and birds, and as the male insects feed on nectar (only the females drink blood), they're also pollinators. The WMP approach is species specific, targeting only *Aedes aegypti*, which contrasts with the 'blunt tool' approach of insecticides, which can affect non-target insects.

The current climate change trajectory we're on is bringing increasing temperatures and changes in rainfall patterns, which will benefit this formidable tiny insect and her virus cargo. As such, we need as many weapons in our armoury as possible to combat the increasing global threat of dengue.

by **DR CLARE STRODE**

Clare is a reader in vector biology at Edge Hill University, in Lancashire.

COMMENT

DREAM TECH: NEW 'HALO' PROMISES INCEPTION-STYLE DREAM CONTROL

A US start-up is working on a headband designed to induce lucid dreams. But can it work and is it safe?

Imagine getting ready for bed, brushing your teeth, setting your alarm and then putting a device on your head that will enable you to control your dreams. It might sound like something out of a Christopher Nolan movie, but it's also the real-life promise of a new headband called Halo that's being developed by Prophetic, an American tech company.

Halo is slated for release in 2025. The idea behind it is that the headband will allow you to have more lucid dreams and enjoy greater control over their content in ways that will benefit your waking life, from solving problems to practising guitar.

The defining feature of a lucid dream is your awareness of being in a dream. In some cases, you might also be able to exert a degree of control over what happens in that dream.

These kinds of dreams can occur spontaneously during rapid eye movement (REM) sleep without the help of technology. Some individuals are more predisposed to having them than others, but around half of us can expect to have a spontaneous lucid dream at least once in our lives. But is there a way we can take advantage of this strange phenomenon?

Earlier research has already provided a tantalising glimpse of how lucid dreams could be used for real-life benefit. For instance, one study carried out by neuroscientists at the University of Bern, Switzerland, showed that participants who practised flipping coins into a cup in their lucid dreams showed superior performance the next day compared with control participants.

The approach taken by the team behind the Halo device is two-pronged. First, they're using EEG (electroencephalography) and fMRI (functional magnetic resonance imaging) to collect vast amounts of brain data from volunteers experiencing lucid dreams.

The idea is to build a detailed map of what's happening in the brain during different types of lucid dreams. This information will be key for the second area of investigation, which involves using transcranial focused ultrasound or tFUS (delivered via the headband) to manipulate brain activity in a way that will induce, sustain and influence lucid dreams.

Like other so-called non-invasive brain stimulation techniques, such as transcranial magnetic stimulation or transcranial direct current stimulation, tFUS can alter

×

“Earlier research has already provided a tantalising glimpse of how lucid dreams could be used for real-life benefit”



a relatively new approach to brain stimulation and it's not entirely clear what the long-term consequences of zapping your brain with high-frequency sounds might be.

Although it's non-invasive in the sense of not involving any kind of surgery, the technique does affect your neurons by interfering with the passage of ions across their membranes, which is probably something to consider carefully.

A second issue to consider is that some sleep scientists believe dreams have basic functions, including consolidating memories from the day or processing emotional experiences.

One potential concern is that by using a device to alter the nature of your dreams, you risk interfering with the usual function of dreaming.

If dreaming has a function, then your becoming lucid in a dream and altering its plot or contents might affect that function.

“We're very rarely lucid in our dreams,” says Blagrove. “And not being lucid may be part, or all, of what's required for any effective function of dreams.”

A final consideration is that if you want to have more lucid dreams, but you're not sure about wearing a brain-zapping device to bed, there are other options. There are already a number of established techniques for inducing lucid dreams that don't involve cutting-edge technology.

One of these techniques involves training yourself, during the day, to pair a sound with thoughts of self-awareness. Then you set a timer to play that same sound during the night when you're likely to be in an REM phase of sleep (during the early hours) so the sound will cue you to become self-aware while dreaming. This approach is cheaper than the Halo, which is expected to cost up to \$2,000 (approx £1,500) and, without a metal

contraption on your head, you'll probably be able to sleep more comfortably. **SF**

—
by **DR CHRISTIAN JARRETT**
Christian is a cognitive neuroscientist and science writer. His books include Be Who You Want: Unlocking the Science of Personality Change.

brain function, except rather than using magnetic fields or electrical currents, it involves using high-frequency sound.

The advantages of tFUS, according to its advocates, include an ability to reach deeper areas of the brain (including those involved in sleep function) and improved anatomical accuracy.

The basic rationale behind the Halo isn't all that far-fetched. In previous research, scientists have already established that lucid dreaming tends to be associated with frontal brain activity in the gamma frequency (the firing frequency of groups of neurons, as recorded by EEG).

Also, electrical brain stimulation can be used to increase sleepers' brain activity in the gamma frequency, thereby increasing their chance of experiencing dreaming lucidity. “It's plausible that the sound stimulation could induce the high-frequency brain activity that's associated with lucidity,” says Prof Mark Blagrove, a sleep scientist at Swansea University and the co-author of the book *The Science of Art and Dreaming*.

“Sound stimulation has been used to induce low-frequency slow waves in slow-wave sleep, so the method proposed is credible.”

So, is there any reason not to be excited about the Halo headset? One issue to bear in mind is that tFUS is

'A gem of a book.'
Alice Roberts

'Captivating, clever and charming.'
Rebecca Wragg Sykes

'Intriguing'
Nature

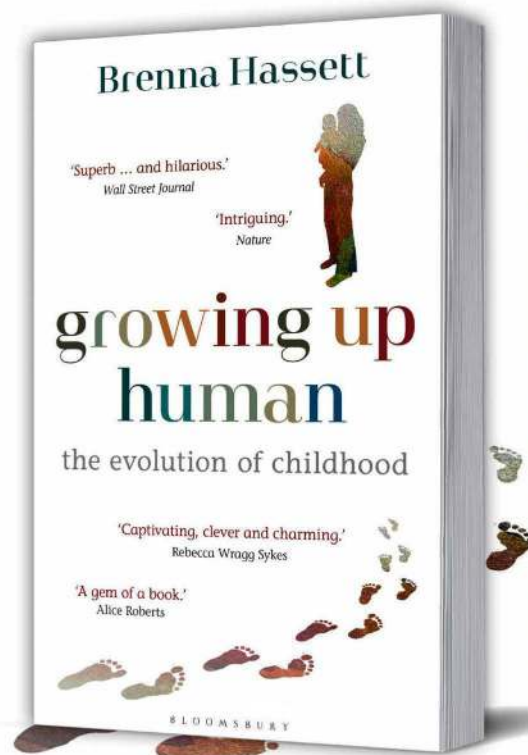
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INNOVATIONS

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ANALYSIS

IMMUNE SYSTEM MAPPING

The Human Immunome Project could help us get ahead of pandemics **p42**

NEW TECH

IDEAS WE LIKE

Our pick of this month's greatest new gadgets **p44**



The Meta Quest 3 brings us both full immersion and mixed reality **p40**



REVIEW

META QUEST 3

Will Meta's third-generation VR headset change our view of the metaverse? **p40**



65 MILLION
The number of active VR users in the US as of 2023
(Credit: Zippia)

23 million

The number of jobs that are expected to involve VR by 2030 (Credit: Oberlo)



The amount by which sales of VR headsets are growing annually
(Credit: IDC)

REVIEW

Meta Quest 3: Could this finally make virtual reality good?

Alex Hughes straps on the Meta Quest 3 to see if it truly is the future of virtual reality

The giants of the tech world seem dead set on making virtual reality (VR) a daily part of our lives. No matter how many times it fails, they just keep coming back to insist the next headset, the next upgrade or the next iteration of it will be the key to a whole new experience.

I've become pretty sceptical about these claims. Having yet to encounter a truly viable at-home VR experience, Mark Zuckerberg's regular claims that he hasn't wasted billions on his huge Meta project are falling on deaf ears here. But with the Meta Quest 3, he might finally be on to something.

It launched in the UK in October and, dare I say it, might represent enough of an improvement to actually make me like virtual reality. It could even make this whole simulated experience business seem like a viable venture, after all. So I spent some time with the Meta Quest 3 to find out if it really does live up to the hype.

VIRTUAL REALITY KEPT COMPACT

The Meta Quest 3 is simple in design. It comes with a headset, two controllers (with batteries) and a charger. The headset has two straps, one that goes over your head and one that goes around the back of it. These can both be adjusted for a comfortable fit.

While there's clearly some weight to the device (the headset is 515g/1.1lbs), it isn't enough to ruin the experience. I was able to wear the headset for several hours at a time without too much inconvenience. It is, however, very front-heavy, with all of the weight sitting before your eyes.

The two controllers are small, but easy to use and all of the buttons are simple to find, even with the headset on. While the headset is rechargeable, the two controllers require batteries, but they do last for quite a while.



The headset and controllers of the Meta Quest 3 are simpler than its predecessors

"I TRIED TO SPEND SOME TIME WORKING IN THE METAVERSE, WRITING THIS REVIEW, IN FACT"

BLENDING WORLDS

Not just a virtual reality headset, the Meta Quest 3 delves deep into the idea of mixed reality. As the name suggests, it blends the virtual with the real, overlaying visuals with a video feed of the world around you.

This can be used to create truly unique experiences, like interacting with floating maps on your living room table, or learning how to fix a bike without completely ruining a real one.

Equally, Meta now allows you to switch out the two controllers for your hands in most experiences. The headset's cameras detect where your hands are, allowing



The Meta Quest 3 dives deep into the idea of blending the virtual and real worlds

you to type on floating keyboards and grab floating objects.

While you can choose to use the headset to learn new skills or experience gaming in a completely new way, this mixed reality can equally be a tool for more trivial ventures. You could load up a floating Netflix display while washing the dishes, check your emails while brushing your teeth, or, if social anxiety is something you've never experienced in your life, wear it to a party and interact with friends while simultaneously scrolling through a VR version of Twitter (sorry, I mean X).

While the quality of the mixed reality footage has been massively improved, it's still grainy. This is especially difficult if, like me, the room you've set up for virtual reality isn't exactly the brightest.

Meta loves the idea that this mixed reality experience is how we're going to be doing more things like gaming, working and socialising. But while it is vastly improved, it's by no means perfect.

I tried to spend some time working in the metaverse – writing parts of this review, in fact. Sitting down at the desk and drawing out an outline, I could continue to type using the hand recognition features with an array of floating displays. This is great for a quick Google, or typing a reply to someone, but becomes a nightmare for

longer pieces of text. Alternatively, you can connect your computer, using your keyboard and mouse in real time while viewing a host of displays through the headset. This works fine for a short period of time, but the weight of the headset and dimmed lights through the camera quickly become annoying.

THE VR EXPERIENCE

While improvements to camera quality and processing power have been made, the virtual reality aspects of this headset are more or less the same as what has come before.

I spent time playing games like *Pistol Whip* and *Broken Edge*, and testing out the virtual experiences of playing piano, painting, and even doing a quick workout class and meditation.

Having a go at these reminded me how fun virtual reality can be, especially when it comes to things like gaming. In the early days of VR, game libraries were pretty limited, but that's not the case anymore.

Scrolling through the market store reveals mixed reality and virtual reality games that will mess with your senses, induce an adrenaline rush or completely chill you out.

Of course, like any console, there is an equally large mess of absolutely terrible gaming experiences, piling together weird graphics and motion sickness for an unbearable cocktail.

VERDICT

Is the Meta Quest 3 the perfect virtual reality experience? No. It still feels like part of the build-up towards a model that can truly capture virtual and mixed realities in all their glory.

However, the Meta Quest 3 feels miles ahead of anything else that has come before it. The headset is small and portable, yet comfortable and packs plenty of power. At £479.99, it's relatively affordable, yet makes use of a market-leading camera and virtual reality technology.

In essence, the Meta Quest 3 is the best virtual reality on offer right now. Anyone looking to dip their toes into VR should start here. Year after year, the technology is improving drastically and Meta is leading that charge.

RATING

★★★★★

PROS

- Lightweight and highly portable
- Powerful processor
- Major graphical improvement
- Fantastic mixed reality

CONS

- Still expensive
- No eye-tracking
- Short battery life

Inside the bold mission to map every immune system in the world

The Human Immunome Project has a bold task over the next 10 years, but could help to prevent future pandemics and aid vaccine research

When we finally understand it, your immune system will provide a lot of answers. From what's actually causing any stomach aches to which vaccines will protect you from the next pandemic, there's a lot it can tell us.

But there's a problem. Scientists don't really understand your immune system or how it differs from others. Age, gender, race and even socioeconomic background can all impact your immune system, from changing your susceptibility to certain illnesses and diseases to altering your immunity to drugs.

But what if scientists had a map of every human immune system on the planet? Like a digital double to see exactly how each person's immune system ticks, and essentially know your immune system without ever running a test on you.

This is the lofty goal that the Human Immunome Project (HIP) is working towards.

The Human Genome Project was a 13-year-long project that sequenced all of the genes in the human genome. Following in its footsteps, the HIP could, if successful, help us get ahead of pandemics, develop better medicines, speed up drug development and even treat serious illnesses such as cancer or Alzheimer's.

WHAT IS THE HUMAN IMMUNOME PROJECT?

Through in-depth studies of the immune system and advanced artificial intelligence (AI) programs, the HIP team aims to achieve a lofty task: create a giant library of everything we know about the immune system.

"The immune system is generally made up of the genome, epigenome, transcriptome, proteome and microbiome. Across these, there are about 30,000 data points," says Dr Hans Keirstead, a leading stem cell expert and CEO of the HIP.

But to complicate things further the HIP is processing data from many different types of people. "If you sample

these data points from two organs, in seven different ethnicities, two biological sexes, six different age groups, five socioeconomic classes and five categories of immune health status, while also examining the immune system's reaction to different drugs and vaccines, you're well into the trillions of data points."

Making sense of this data will require AI but getting it means a lot of sampling. Test sites will be set up around the world, taking blood and tissue samples from participants. Over time, the number of people sampled will drastically increase at both testing sites and via at-home test kits.

BREAKING DOWN BARRIERS IN MEDICINE

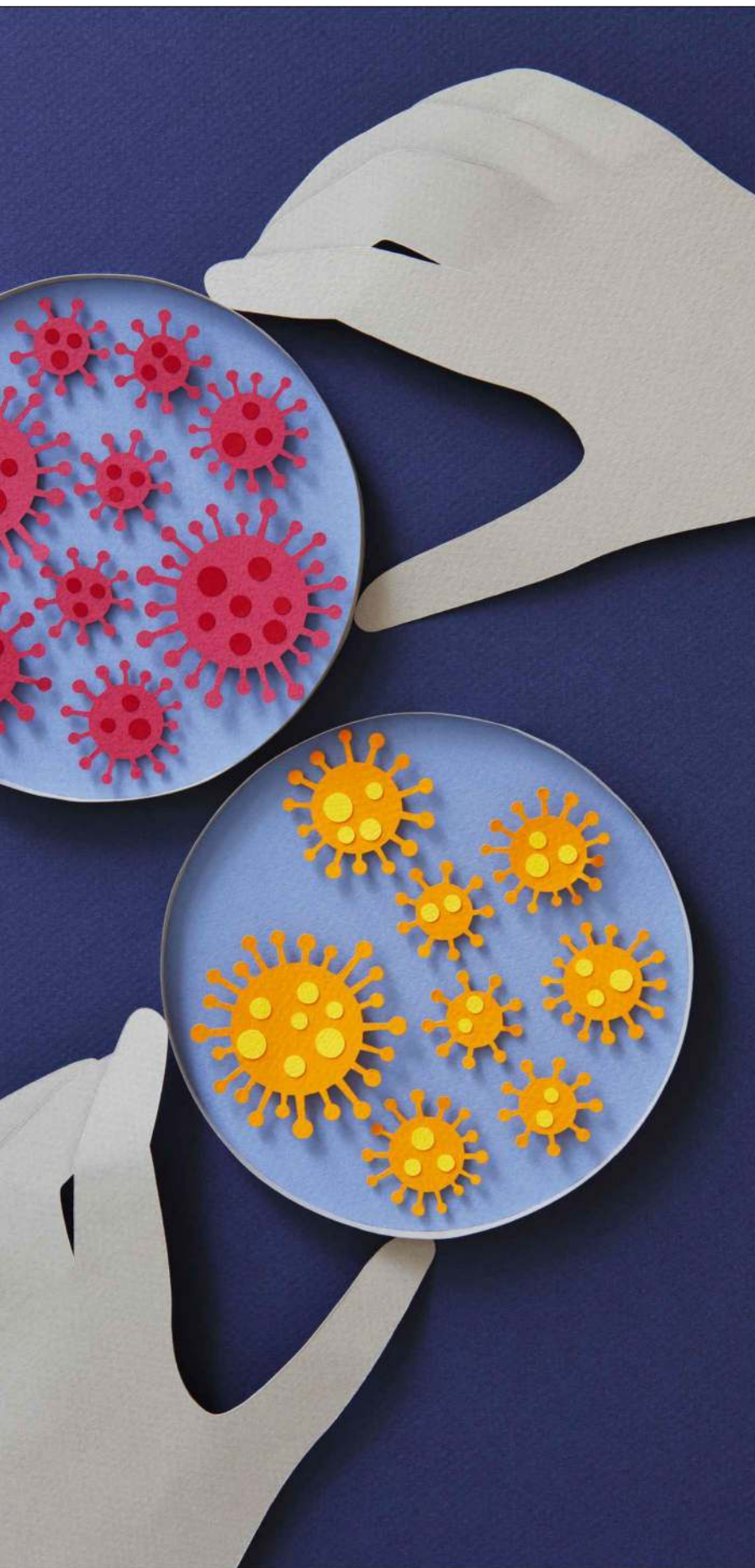
What's the point in spending all this time and money trying to better understand our immune responses?

"The health of humans is directly related to their immune systems. Everything to do with ageing, disease – it's all immunological," says Keirstead. "The project is formed around the singular mission to generate datasets covering all races, ages, genders and classes."

With this information, it can be quickly seen how, for example, a 55-year-old Caucasian man with a history of heart disease is going to respond to a particular drug. Highly technical, yes, but it's hard not to imagine a

"IF WE HAD THE DATA BEFORE THE COVID-19 PANDEMIC, THE NUMBER OF DEATHS WOULD HAVE PLUMMETED"

GETTY IMAGES



computer loading up some kind of immune system sandbox, making a character and finding out their immune system stats – a bit like *The Sims* video game, just with years of complicated immunology research and less of the made-up language.

Equally, it reduces the steps needed for notoriously long drug development. By identifying trends in the population, it's easier to see which drugs are most crucial and where they are needed. This could also make the healthcare system as a whole more affordable.

"We won't just be studying the white and wealthy, but all socioeconomic classes and ethnicities. We'll cover all of these categories in contrast to all of the key health conditions, a long but important task going right to the most granular level," says Keirstead.

"Once defined within the algorithm, a minority group can become a commercially viable group for drug development. We can use our research to show that there are this many people who could benefit from this drug or treatment, even if they're scattered around the world."

STOPPING THE NEXT PANDEMIC

Day-to-day drug development and a better understanding of the immune system across people throughout the world is a crucial part of the project. But another focus is to halt future pandemics. "If we had the data from the Human Immunome Project before the COVID-19 pandemic, the number of deaths and hospitalisations would have plummeted and the targeted drug development skyrocketed," says Keirstead.

"The HIP will provide a level of pathogen readiness because we'll understand how the immune system reacts to different pathogens. We just don't have that centralised kind of information today."

It's a big claim. But does it stand up? *BBC Science Focus* reached out to several experts who agreed that understanding this data was indeed important, whether to aid in pandemic prevention or vaccine development. Yet, some expectations might have to be tempered.

"Molecular immunology has come magnificently of age in recent years, revolutionising many aspects of medicine," said Danny Altmann, a professor in the department of Immunology at Imperial College London.

"These technologies produce big data, requiring AI to process it for maximal gain. These approaches sped up various aspects of our response to the pandemic – the Human Immunome Project is one of these initiatives that in the future may help to contribute further."

Interestingly, it's not just viral pandemics that the HIP is hoping to prevent in years to come. "If you ask me or any biologist how we could be wiped out, the answer is irrefutably bacterial or viral infections. That's one of the reasons for the project, to protect ourselves against anything and everything," says Keirstead.

If this all sounds amazing, it's because it is. It needs to map trillions of data points, perform countless global studies, load them into one of the most powerful AI systems ever made and tag all of the data with rigorous scientific methodology... it's a truly ambitious project.

Ideas we like...

Our pick of the month's
smartest tech

↓...A powerful webcam
in the palm of your hand

Webcams are boring, we all know that. But the start-up Opal is trying its absolute best to change this. The company, started by ex-Uber, Beats and Apple employees, went viral with its first webcam and now it's back with the Tadpole. Marketed as the world's first portable webcam, the Opal Tadpole is tiny and surprisingly affordable. Despite its small size, the camera features a directional mic that blocks surrounding noise, and offers an unexpectedly high-quality 4K camera. It can be clipped on top of any laptop and taken anywhere.

Opal Tadpole webcam
\$175 (approx £135), opalcamera.com



↓...A bold approach from Leica

Leica is known for a few things – great cameras, smart designs and prices that will leave you looking for a new hobby. However, taking a departure from the high-end, the company’s new project, known simply as the SOFORT 2, takes things back to basics. The digital camera doubles up as an instant camera, printing images from the back. It can be used to print photos taken by the camera, or for images directly from your smartphone. While not the first camera of this design, Leica has brought its camera expertise to offer a serious increase in camera quality and features.

Leica SOFORT 2
£350, leica-camera.com



↓...A smartphone that looks different

This device will seem familiar to any keen-eyed readers. Just a few months ago, it made its way into these very pages, but now things have moved on. No longer just a vague concept, the Humane AI Pin is a fully fledged product that you can buy. Currently, it’s hard to tell if this is revolutionary or just a fad that won’t last the year. Essentially, it’s a device to replace your smartphone, offering an AI assistant, camera and a display that lights up on your hand. The aim is to reduce reliance on a smartphone, so you can make calls, text, check maps and do all your phone tasks in an easier way.

Humane AI Pin
From \$699 (approx £550), hu.ma.ne



↓...A way to see what’s being said

Smart glasses are nothing new. We’ve seen countless near-identical pairs over the years, all offering a slight variation on the trend, but TranscribeGlass gives us something different. A smart pair of glasses with one single purpose: to transcribe. Designed for deaf people or those who are hard of hearing, they use a small microphone to pick up voices. Whether it’s from a conversation, a video or a museum tour, the glasses will automatically transcribe voices and display subtitles in front of your eyes. It all happens in real time and, according to the company, is highly accurate.

TranscribeGlass
£TBC, transcribeglass.com



↓...A smartwatch on a budget

While tech companies fight to make the best smartwatch, tracking every breath, heartbeat and feeling you might have, CMF is taking a different route. From the affordable sub-brand of tech start-up Nothing, CMF is all about making popular tech more affordable. The Watch Pro costs an impressively low £69. Most competitors at that price are somewhat limited, but CMF has managed to create something that looks (suspiciously) like the Apple Watch, while offering a lot of the same features. Sure, it isn’t quite as powerful, or feature-packed, but for this price it’s impressive what they’ve managed to cram into it.

CMF by Nothing Watch Pro
£69, intl.cmf.tech



IDEAS WE DON'T LIKE...

...AN OVERPRICED WELLNESS EXPERIENCE

Driven by the anti-ageing tech bros aiming to look 17 again, wellness technology is really taking off this year, with all sorts of reputedly therapeutic items that cost fortunes. The Tersa Sava is the perfect example of this, charging \$10,000 (about £7,850) for a glorified bathtub. Using sound technology and a sea of buzzwords, the Sava claims to take you to a higher state of consciousness. What does that mean? Essentially, it’s a giant pod that mixes vibrations and music to make you feel relaxed. Described as “womb-like and welcoming” by the company, the Sava seems more scary than relaxing to us.

Tersa Sava
\$10,000, tersa.co

...AN UNNECESSARY PHONE INVENTION

When it comes to a gimmick, there’s a razor-thin line between fun and flawed, and sadly Motorola stood on that line, slipped and fell down on the wrong side. Its new smartphone concept is a simple idea that follows the folding smartphone trend and, in theory, is clever. The device folds around your wrist, acting as a smartwatch, as well as a smartphone when unfolded. However, not only does it look clumsy on the wrist, replicating the slap bands of yesteryear, it also strikes us as impractical. Motorola flexible phone concept

£TBC, motorola.com



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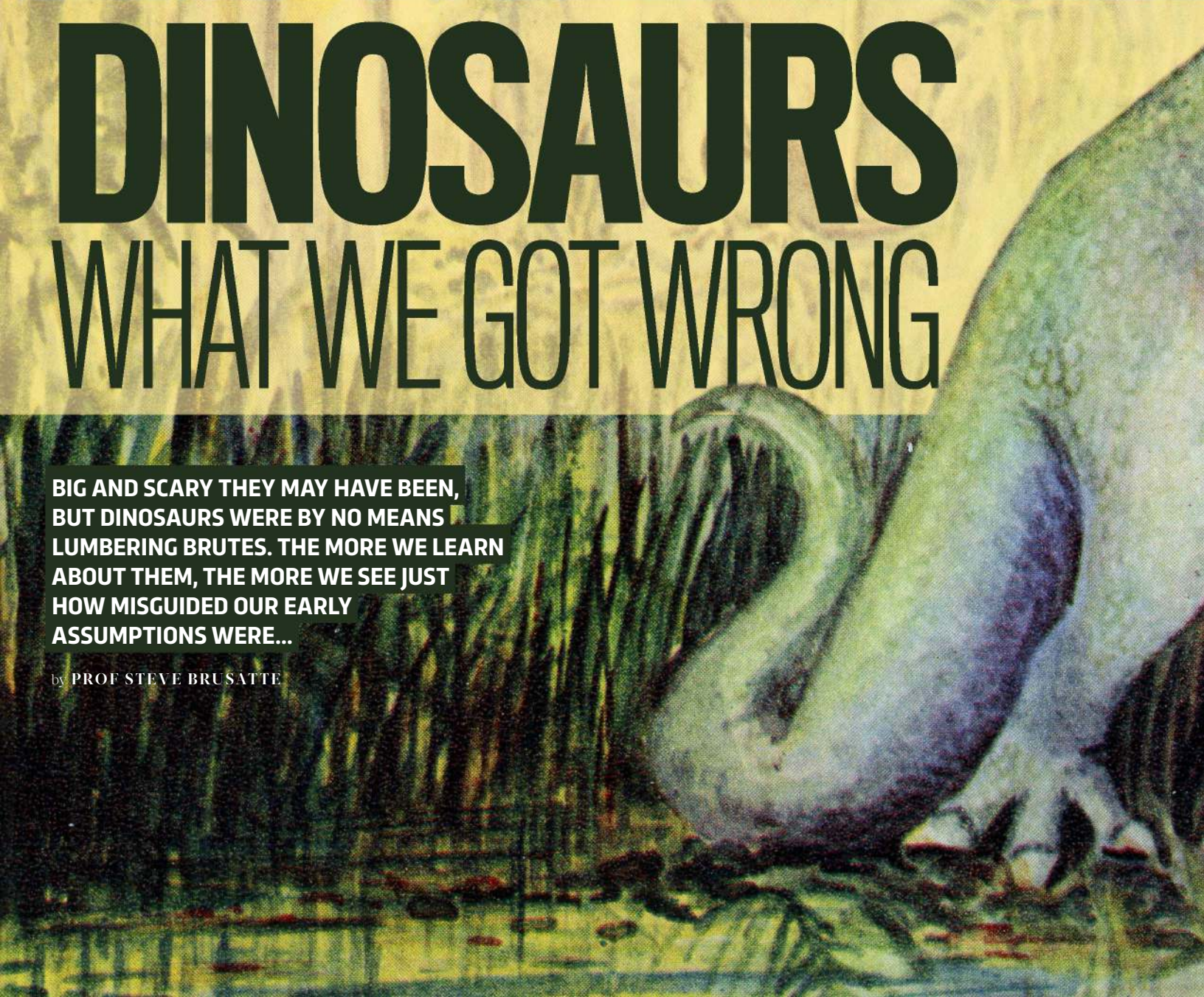


DINOSAURS

WHAT WE GOT WRONG

BIG AND SCARY THEY MAY HAVE BEEN, BUT DINOSAURS WERE BY NO MEANS LUMBERING BRUTES. THE MORE WE LEARN ABOUT THEM, THE MORE WE SEE JUST HOW MISGUIDED OUR EARLY ASSUMPTIONS WERE...

by PROF STEVE BRUSATTE





LEFT *T. rex* had a brain to match its mouth

MAIN An early, more upright and slender depiction of *T. rex*

BOTTOM *T. rex* as imagined with today's ideas of the dinosaur

TYRANNOSAURUS REX

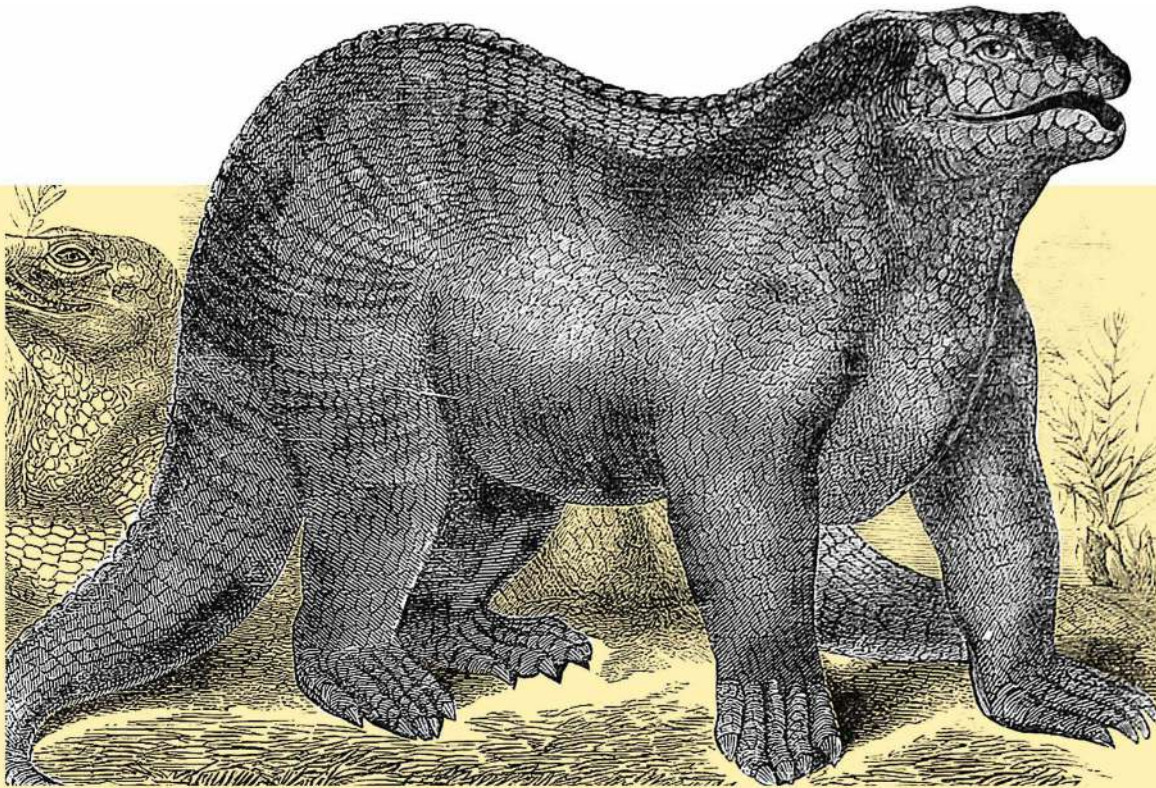
In 1902, in the desolate badlands of Hell Creek, Montana, the palaeontologist Barnum Brown spotted a jumble of enormous bones. They were from a muscular animal that stood several meters tall and walked on its hindlegs. The skull and jaws had the snarly grin of a fierce predator.

Brown shipped the bones back to New York, where they were displayed at the American Museum of Natural History in 1905. Crowds were aghast. The monster – a dinosaur christened *Tyrannosaurus rex* – was described by the *New York Times* as “the most formidable fighting animal of which there is any record whatever.”

In the 120 years since Brown's discovery, dozens of *T. rex* skeletons have been found in the 66-million-year-old Cretaceous rocks of North America. Scientists still regard *T. rex* as one of the largest and strongest carnivores in Earth history. But the ‘Tyrant Lizard King’ was no mere brute. It had a large brain and keen senses of smell and hearing, as revealed by CAT scans of fossil skulls. What made *T. rex* so special was that it had brawn and brains... and its body probably sported at least some wispy feathers.

GETTY IMAGES, ALAMY, GABRIEL LUCIETO





LEFT *Iguanodon* was initially envisioned as a hefty, rhino-style quadruped

BELOW LEFT Two pieces of *Iguanodon* bones from Gideon Mantell's collection

BELOW A more up-to-date visualisation of *Iguanodon*

IGUANODON

Some say Mary Ann Mantell discovered the first evidence of *Iguanodon* (some giant petrified teeth). Others believe it was her doctor husband, Gideon. Regardless, when Gideon presented the fossils, found in Sussex, to the Royal Society of London in 1822, the crowd was dumbfounded, and assumed the teeth must belong to some as yet undiscovered huge fish, or possibly a rhinoceros.

What they didn't, couldn't, know is that the teeth came from a dinosaur – because the term 'dinosaur' wasn't coined until 1842. Soon, however, it became

clear the teeth were reptilian and resembled scaled-up versions of iguana teeth. Hence, Mantell named the animal they belonged to *Iguanodon*.

The first artistic renderings of *Iguanodon* showed it in a lizard-like pose, grasping a branch between its hands and feet, and with a big horn on its nose. Later discoveries of complete skeletons revealed that *Iguanodon* was a ground-living giant that walked confidently on its hind limbs and sometimes on its forelimbs, and had spikes on its hands, which it probably used for self-defence.



ALAMY X2, GABRIEL UGUETO X2, SKYE MCDAVID/WIKIPEDIA, HANNAH CORNISH/THE GRANT MUSEUM OF ZOOLOGY UCL

DRYPTOSAURUS

Of the more than 2,000 known species of dinosaurs today, *Dryptosaurus* is an obscure one; not a household name like *Tyrannosaurus*, *Brontosaurus* or *Triceratops*. But it wasn't always so.

In the late 1800s, *Dryptosaurus* was one of the most famous extinct species of all. When its bones were discovered in a New Jersey marl pit (where a type of clay rich in carbonate was mined) in 1866, they were the first well-preserved carnivorous dinosaur skeleton known from North America.

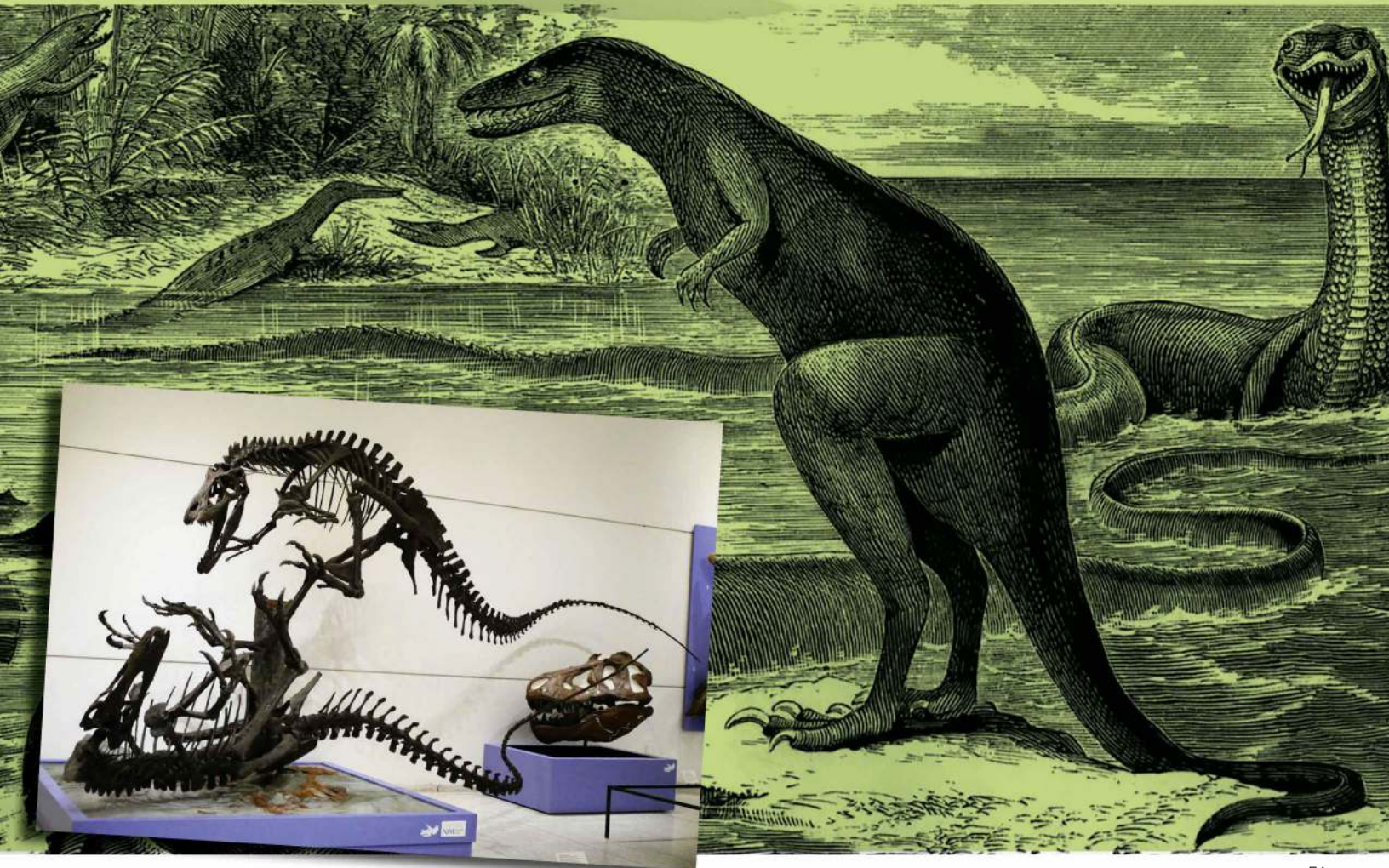
Initially christened *Laelaps* – or 'Hurricane', after the inescapable hunting dog of Greek mythology – the predator's name was later changed to *Dryptosaurus* ('tearing lizard') due to a taxonomic bookkeeping error. A shame, as '*Laelaps*' encapsulates the speed, ferocity and tenacity of this 67-million-year-old *T. rex* cousin.

When the great palaeoartist Charles Knight painted *Dryptosaurus* in watercolour for the American Museum of Natural History in 1897, his evocative scene of two playful, 'leaping *Laelaps*' was the first widely produced piece of art showing dinosaurs as active, dynamic animals. Old views were changing, however, and over the next century, dinosaurs would be reimagined as lively, vibrant, energetic bird-like animals, not the plodding overgrown lizards envisioned by Gideon Mantell and the first generation of dinosaur hunters.

LEFT *Dryptosaurus*, as we know it today

BELOW MAIN *Dryptosaurus* as imagined in 1869

INSET *Dryptosaurus* skeletons in the New Jersey State Museum



RIGHT Initial study of *Elasmosaurus* fossils led some to imagine a giant sea serpent crossed with a turtle

TOP RIGHT Most of *Elasmosaurus*'s 10.3m (34ft) length was due to its neck

BELOW RIGHT An *Elasmosaurus* skeleton displayed at the Rocky Mountain Dinosaur Resource Center in Colorado, USA

ALAMY X2, MCDINOSAURHUNTER/WIKIPEDIA, GETTY IMAGES, GABRIEL UCUETOX2



BELOW *Stegosaurus* as currently imagined

RIGHT Earlier depictions were unclear on its plates

FAR RIGHT Besides its plates, *Stegosaurus* is known for the spikes on the end of its tail



STEGOSAURUS

Everyone knows the *Stegosaurus* profile today: long body, low shoulders and a row of big vertical plates on its back – each big enough to dwarf a coffee table.

But when *Stegosaurus* bones were first found in the Jurassic-aged rocks (circa 150-million-years-old) of North America in the 1870s, palaeontologists had never seen anything like them. The prickly Yale professor, Othniel Charles Marsh thought they were from some strange, new aquatic species, a turtle, perhaps, with the plates lying flat on its back as a protective carapace. This inspired the name: *Stegosaurus*, the ‘roofed lizard.’

Later, after more complete skeletons were discovered, Marsh realised that the plates stood erect, but it still wasn't enough to explain their purpose. Scientists continue to debate this today. It's likely that they were display structures to attract mates and intimidate rivals, but they may also have been for thermoregulation.

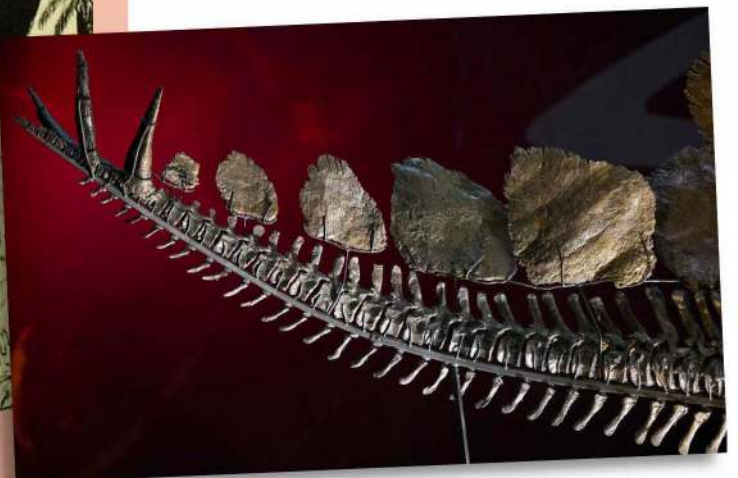
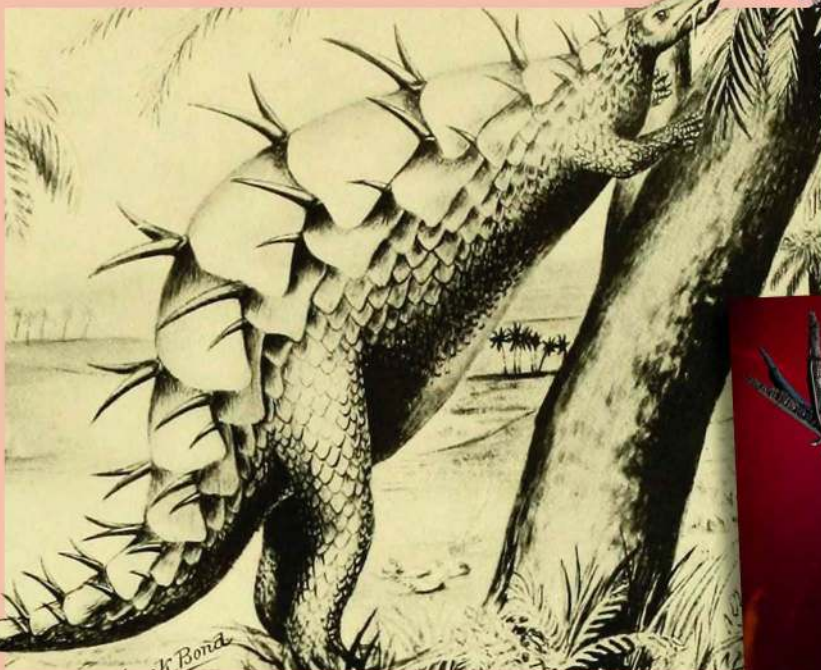
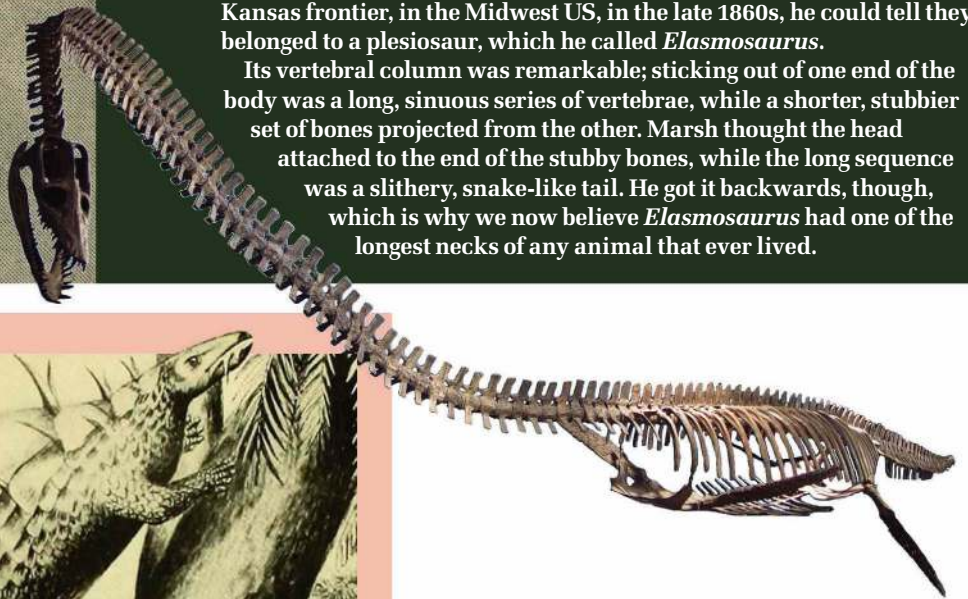


ELASMOSAURUS

At the same 1824 meeting where the first scientific name for a dinosaur was bestowed on *Megalosaurus*, naturalists also described the skeleton of another type of distantly related extinct reptile: a plesiosaur. It had a very unusual body: small head, long neck, squat belly, and all four hands and feet modified into paddle-shaped flippers. One scientist quipped that it resembled “a sea serpent run through a turtle.”

Plesiosaurs were so wacky that they continued to confound palaeontologists for decades. When the Philadelphia scientist Edward Drinker Cope was sent several crates of bones discovered on the Kansas frontier, in the Midwest US, in the late 1860s, he could tell they belonged to a plesiosaur, which he called *Elasmosaurus*.

Its vertebral column was remarkable; sticking out of one end of the body was a long, sinuous series of vertebrae, while a shorter, stubbier set of bones projected from the other. Marsh thought the head attached to the end of the stubby bones, while the long sequence was a slithery, snake-like tail. He got it backwards, though, which is why we now believe *Elasmosaurus* had one of the longest necks of any animal that ever lived.



ICHTHYOSAURS

Mary Anning was one of the greatest fossil hunters of all time. The daughter of a cabinetmaker in the seaside town of Lyme Regis, on England's southwest coast, young Mary collected fossils in the Jurassic-aged rocks near her home, which she sold to support the family's meagre income. In 1811, her brother Joseph found a skull with a big eye socket and long, pointed jaws studded with many tiny, sharp teeth. The next year, 12-year-old Mary found part of the skeleton of the same animal. More fossils soon followed, and they were odd: the hands and feet were flippers, the body was streamlined, and the tail was fluked.

What was it? A fish? A crocodile? Something else? The palaeontologists Henry De la Beche and William Conybeare argued that it was a new type of extinct water-living reptile, which they called an ichthyosaur ('fish lizard').

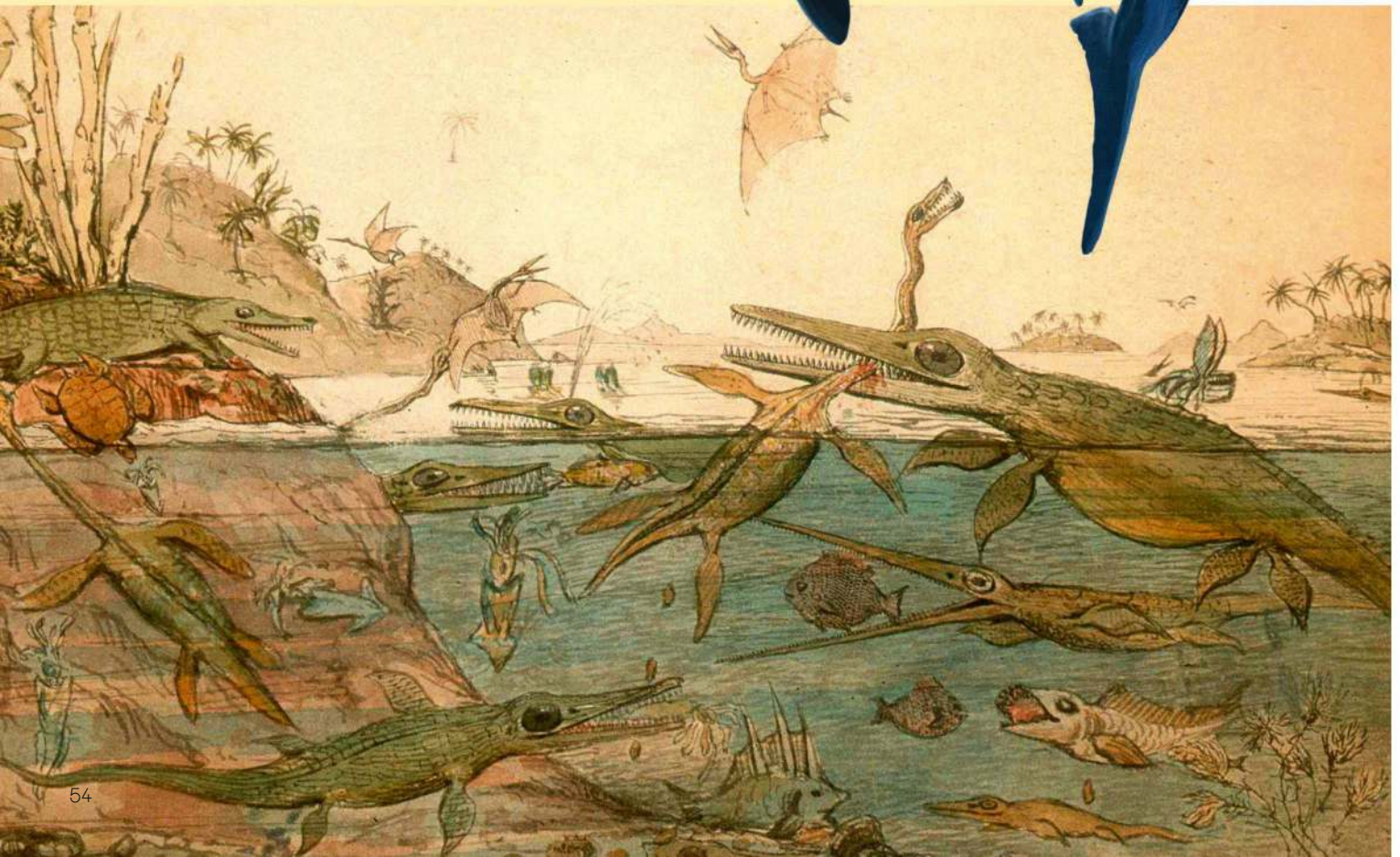
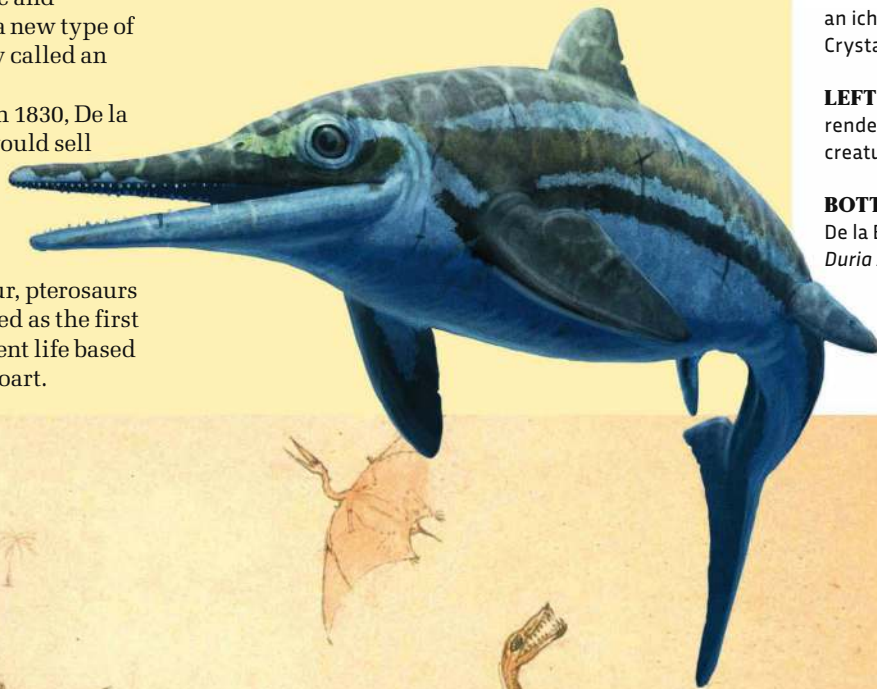
When Mary found herself destitute in 1830, De la Beche developed a generous plan: he would sell prints of a painting to his friends and give Mary the proceeds. He titled the painting *Duria Antiquior*. It showed a grinning ichthyosaur with its jaws clamped around the neck of a plesiosaur, pterosaurs flying overhead. Today this is recognised as the first visual representation of a scene of ancient life based on fossils. It was the first piece of palaeoart.



ABOVE A carving of an ichthyosaur at Crystal Palace

LEFT A more recent rendering of the creature

BOTTOM Henry De la Beche's painting *Duria Antiquior*





TOP LEFT Early visualisations of pterosaurs made them appear almost rodent-like

BELOW Up-to-date depictions of pterosaurs are more bird-like

BOTTOM A fossilised short-tailed pterosaur



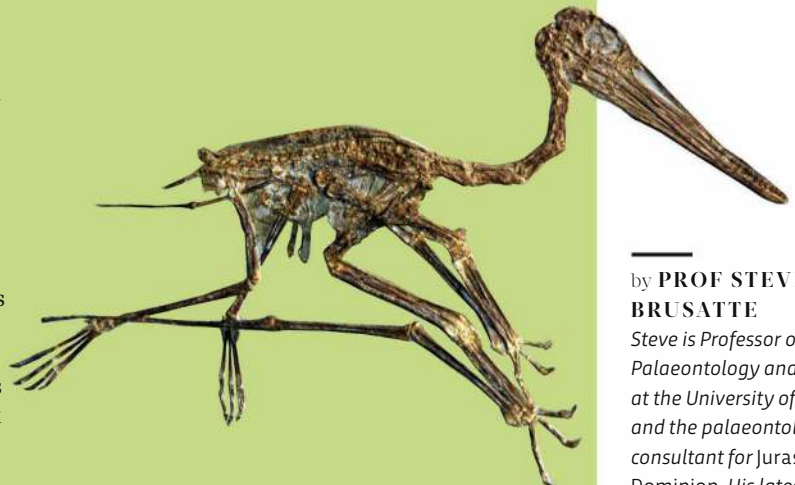
PTEROSAURS

In 1784, the Italian naturalist Cosimo Collini – once Voltaire’s secretary – held in his hands a most unusual object. It was a petrified skeleton of delicate bones in a block of limestone, with toothy jaws agape, a little body and, most peculiar of all, a stretched finger on each hand.

At the time, Biblical views of Earth history still reigned supreme. The concepts of evolution and extinction were not yet widely accepted. But this creature was so drastically different from anything currently alive. Some naturalists at the time argued that it still lived somewhere, maybe in the open ocean, where it used its long finger as a paddle. The eminent French anatomist George Cuvier knew otherwise, though.

Cuvier, one of the first people to articulate the idea of extinction to the public, recognised the long finger as the supporting architecture of a wing. This was a flying animal, which he called a ‘ptero-dactyle’, meaning ‘wing finger’.

Today we recognise pterodactyls, or pterosaurs as they’re formally known, as lightweight reptiles that glided and flew on wings made of skin anchored to the stretched finger. They weren’t dinosaurs, but close cousins. And they were the first animals with bones to ever evolve powered flight.



by **PROF STEVE BRUSATTE**

Steve is Professor of Palaeontology and Evolution at the University of Edinburgh and the palaeontological consultant for Jurassic World: Dominion. His latest book is The Rise and Reign of the Mammals (Picador, £16.99).

TIME TO CHANGE

Feeling time poor isn't an inescapable part of today's world. With a few science-backed strategies, it's possible to reclaim lost hours and finally feel in control of your day

by PROF RUTH OGDEN

Ever get that feeling there aren't enough hours in a day? That no matter what you do, and how hard you work, it's impossible to fit everything in? You may well be suffering from time poverty.

And you certainly won't be alone. Time poverty – defined by psychologists as a chronic feeling that you don't have enough time for the things that you need to do – is worryingly common. Research shows that the majority of us are battling with it, with one US study suggesting 80 per cent of people feel they don't have enough time in their day. That's a jump of 10 per cent from a decade ago.

Could these rates grow further? Considering how bad time poverty is for a person's health and happiness, it's a worrying thought. Studies show that time poverty is associated with increases in levels of the stress hormone cortisol, which can lead to increased blood pressure and risk of cardiac disease. In fact, the World Health Organization estimates that three-quarters of a million people die each

year from heart disease and strokes due to overworking.

B IS FOR BURNOUT

Time poverty can also change our eating habits, increasing cravings for sweet, high-fat food, which result in an increased likelihood of weight gain and obesity. Worse still, if any major health issues do arise, somebody experiencing time poverty is much less likely to seek help from a doctor. This means serious conditions can go undetected in those with the least time, resulting in poorer health outcomes in the long run.

Time poverty can also spill into our relationships. Rates of divorce, depression and anxiety are all greater in people who experience a chronic lack of time than those who don't.

And then there's the big B: burnout. Time poverty is its number one cause, creating

frazzled, unproductive and unhappy workers. Research shows that feeling like you don't have enough time can cloud your thinking, impair your memory function and focus, and leave you prone to making riskier decisions that can backfire. One analysis of 2.5 million Americans even found feelings of time poverty had a stronger effect on mental wellbeing than being unemployed.

This is all fairly alarming. Yet feeling time poor isn't inevitable in our modern world. There are people out there who feel they have enough time and – here's the kicker – they don't necessarily work less. In fact, one survey found that, on average, people who felt they weren't time-starved worked similar levels to those who did.

So what gives? Is it actually possible to carve out more hours in your day? Are there simple ways to feel more in control of your schedule? Absolutely.

First, we just have to find out the root causes of your time poverty – and then form a plan of attack with a few choice research-backed strategies. →



ILLUSTRATION: DANIEL CRESPO

TIME POVERTY: THE CAUSES

It's no surprise that the rise of time poverty is largely down to changes in our work lives. But not in the rise of work hours: there's some evidence that hours per week have actually dramatically and nearly consistently *fallen* over the past 100 years. According to one study, the average employee in the UK works 514 *fewer* hours per year – the equivalent of 64 working days – than 70 years ago.

However, while our work hours have fallen, the intensity and speed of that work has rocketed. After all, in the

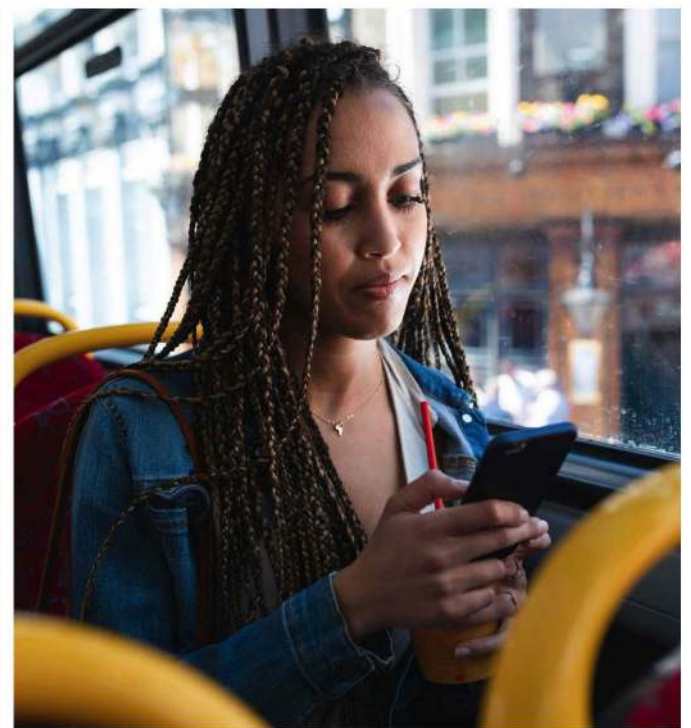


“BACK-TO-BACK ONLINE MEETINGS
AND THE PINGING OF MESSAGES
MEAN WE RARELY HAVE BREAKS”

pre-digital era, the absence of email, video calls and instant messages created a naturally slower work environment. Just imagine it: how many letters would you send each day if they had to be handwritten and posted? How many people would you meet with if you had to physically travel to see each one in person?

The immediacy created by modern technology has created a pressure-cooker working environment, dense with tasks. Back-to-back online meetings and the constant pinging of messages mean that we rarely have breaks in our day. And, unlike much of the past, our working hours have blurred with our leisure. In a world of permanent connectivity, many people feel pressure to always be available to ‘jump on a call’ after dinner, and to read and respond to emails on a Sunday. When the office is in the spare bedroom, it is all too easy to let work spill over into





family time, reducing the time we have for the things we love.

It also can't be ignored that the creeping of work into home life is particularly problematic for women. They're more likely to feel more time pressure as they still shoulder the biggest burden of household tasks – in developed countries, women spend on average twice as many hours on unpaid domestic tasks than men.

BUSINESS AND PLEASURE

It's a hard truth, but our jobs aren't the only cause of time famine. There's been a big shift in our personal lives and the very concept of 'free time'.

Recently, TIMED, a time perception research group that I lead, conducted in-depth interviews with 300 people from across Europe about how they use technology in their day-to-day lives. The research highlighted that there were scarily few moments in the day – from first thing in the morning to last thing at night – when people weren't using tech, particularly their phones. Now, we all secretly know our

ABOVE Constant notifications make it harder to relax and socialise

ABOVE RIGHT Many of us pick up our phones instead of enjoying the chance for a quiet moment

LEFT Modern technology has revolutionised the way many of us work, but can leave some feeling unable to 'switch off'

screen time is too high. You've probably spotted swarms of worrying headlines about it while looking at a screen. But the reason behind this staggering tech use is often missed. As the TIMED research showed, time spent on screens was motivated by people's desire to avoid having *any* periods of 'empty' time in their lives.

In a culture in which productivity is *the* measure of success, 'empty' time is now perceived to be wasted time. This means we're driven to fill all our non-work hours with digital activities that ensure no time is 'lost' – that every moment holds some form of productivity, authenticity and intellectual depth. From watching recipes, to brain-training and, well, reading articles about how to reframe your time, the march of self-improvement is endless. It all leaves us trying to shift that immovable feeling that our lives, at this time, aren't enough.

However, the research showed that periods online are prone to distraction, and that you can easily lose track of time on your phone. We've all been there: one minute we are logging on to Instagram for a quick look around, and the next thing we know, an hour has passed.

The result? Our online activities not only eat into our precious time, but they also foster feelings of guilt about how we've 'wasted' our time so far. As a result, we feel under even greater pressure to use what remaining time we have 'well'. Ironically, in an attempt to avoid wasting time, we often lose more than we gain. →

FIVE WAYS TO TAKE CONTROL OF YOUR TIME

Try the following to see if you can improve the way you manage your time... whether to free up an hour here or there, overhaul your life or appreciate how you spend your days



JUST SAY NO

Modern society tells us that saying yes to everything is at the heart of being a good friend, parent or employee. Whether it's taking on more at work or organising another hobby for your child, it can soon eat into your time.

Saying no can be daunting. You may worry people will think you're impolite or inconsiderate. So it may require some practice. What's the best way to say no calmly and assertively? Research suggests you won't look particularly likeable if you cite a lack of time (the thinking is everyone is in control of their own time and you're choosing not to use yours). Instead, consider a) asking for more time, b) being clear you're saying no due to circumstances out of your control, or c) not giving an excuse at all.

DO A TIME AUDIT

Mapping out how you use your time is a great way to see where you might be able to find some more. Start by doing a 'time audit': log all your activities over a period of time, a week, for example. Note: record *all* your activities – the meetings, doomscrolling, cooking, even sorting socks.

Don't worry, you don't need to track your time to the millisecond. Breaking down your day into 30-minute windows will keep things manageable. And it needn't be every day – just pick one weekday and one weekend day (avoid Mondays and Fridays as these tend to be atypical days). Once you have your time audit, you can start to take control. For some, time auditing can reveal small changes in routines that can free up extra time. For instance, something simple like batch cooking could help you claw back the 30 minutes per evening you usually spend preparing dinner. For others, however, a wholesale reappraisal of life beckons.

OUTSOURCE YOUR CHORES

One proven way to gain time is to buy it. You really can outsource those tasks you find particularly unrewarding and repurpose that time for leisure. Hiring a cleaner (even occasionally), purchasing a

robotic vacuum cleaner or paying for a food delivery are all examples of ways that you can purchase time to reduce time famine.

But won't this cost you more financially? Yes. But it's worth thinking about the reason behind your spending – research shows that investing your money in time, rather than things, is much better for your wellbeing. One study

suggested that spending £32 (\$40) a week on outsourcing tasks can bring you more happiness than if you spend the same amount of money on material goods.

Of course, this won't be possible for everyone. But you can also outsource without spending money. Redistributing tasks among household members, or trading your least favourite domestic chores with one another,

can help you to free up time without spending a penny.

Just remember: outsourcing will only make you feel less time impoverished if you use your newfound time wisely. Fill it with more work and you'll end up with less time and money than you started with. So if you do decide to outsource, make sure you have a clear goal for the time that you'll save, and stick to it.

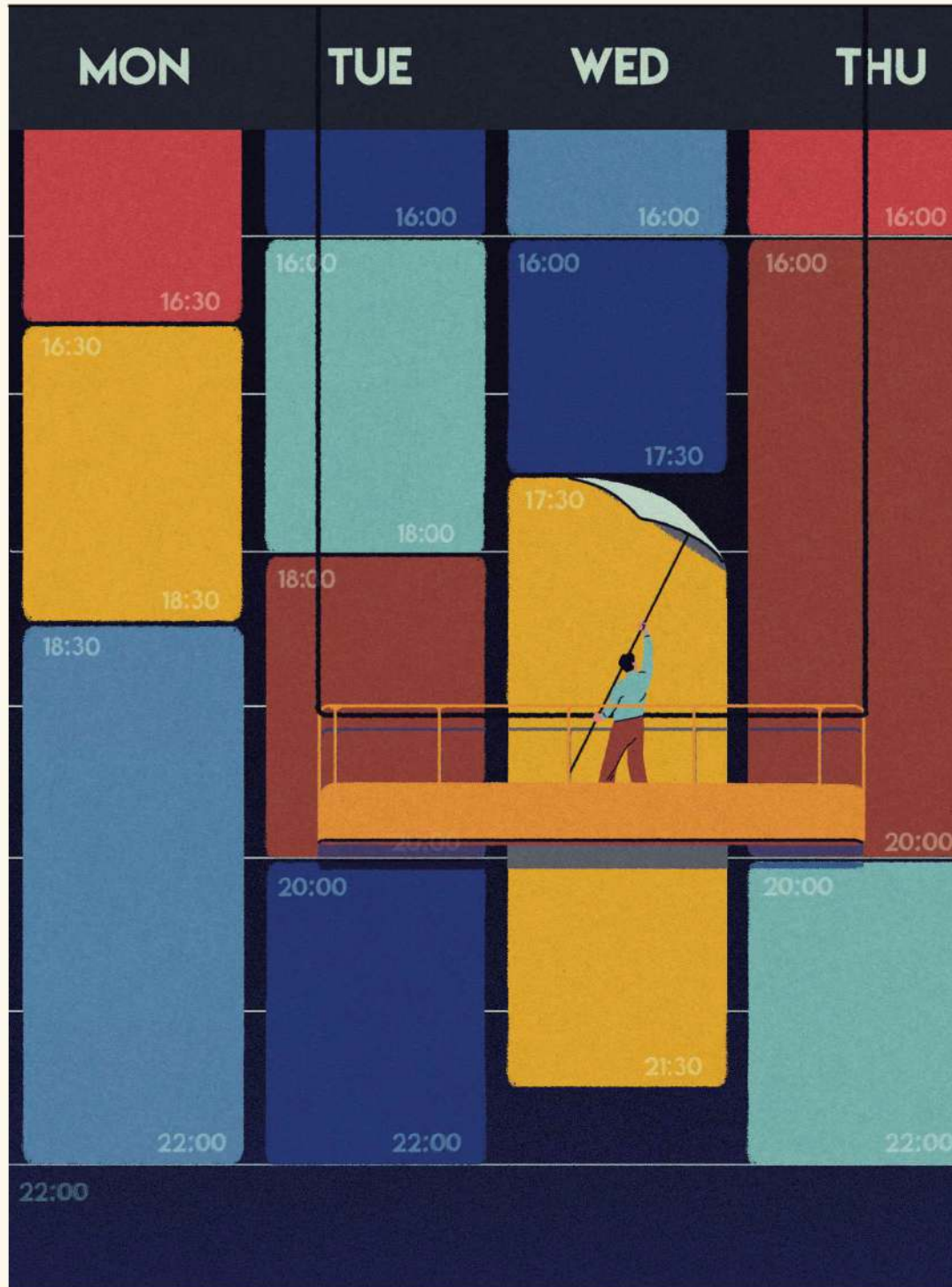
WRITE AN 'I DID' LIST

We all want to look back on our days and feel like we accomplished a lot. However, life is so hectic, and we're so busy adding things to our to-do lists, that we rarely take stock of just how much we have achieved. This can leave us with a constant sense of 'needing to do more'.

Keeping a diary of your daily achievements is one way to help you develop that much-needed sense of triumph. Try setting aside five minutes every few days to acknowledge just how much you have done.

Seeing this all down on paper also gives you the confidence to say no to new requests, helping you to free up future time.

Your 'I did' list could also make it feel like you've fitted more into your days. It's all down to how we perceive time: in general, periods that contain many memories are remembered as much fuller than those with few memories. Keeping a diary of your activities may therefore help you to remember the days, weeks and years as longer – there's some evidence that marking our time like this even combats the feeling that time passes more quickly as we age. Ultimately, though, it's a strategy best used to help confirm that you *are* doing enough – that your time, no matter how much you have, is being well spent.



BLOCK YOUR TIME

In essence, time blocking involves setting boundaries with yourself about your time use. This is done by allocating specific tasks to specific time-limited periods of the day. For example, you can allocate yourself just 30 minutes of social media use per day, which can only occur when you are commuting.

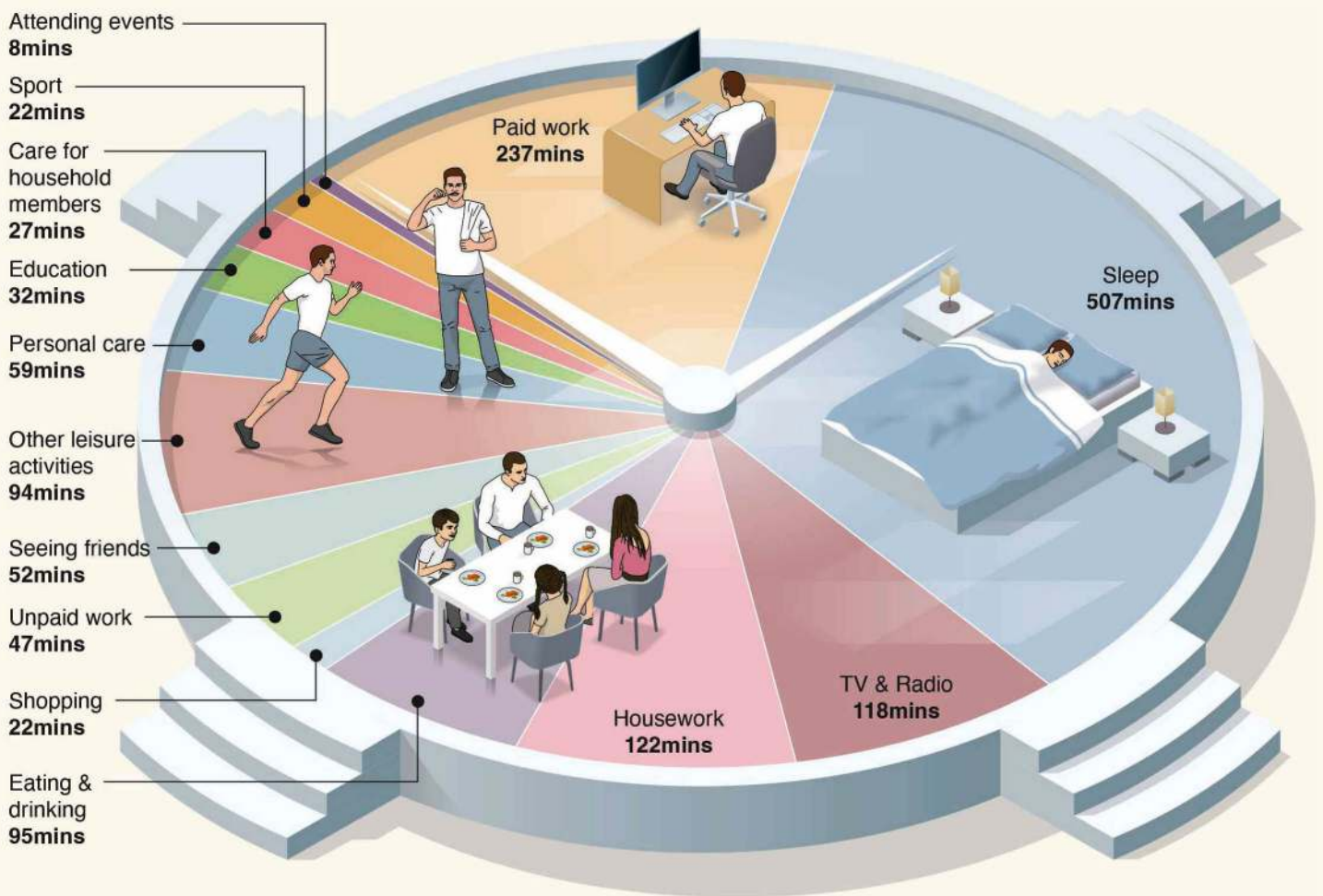
Time blocking helps us to compartmentalise activities. By stopping tasks from overlapping, or interrupting one another, we gain a sense of control over our time. One time block, one task. And with less need to do everything at once, your day won't be shredded into unproductive multitasking.

To succeed at time blocking, you need to know where you're wasting time and why – time auditing will help. For example, if you can't relax after work without clearing your emails, and as a result constantly check and respond to incoming messages, block off 15 minutes in the evening to do only email. After that, turn off email alerts or use downtime functions on your phone so you can't access them.

Alternatively, block time for relaxation. Even 15 minutes a day where you consciously decide to be uninterrupted and focused on a single leisure activity will help you to feel like you have a greater abundance of time. →

MINUTE-BY-MINUTE

Everyone in the world has 24 hours each day, but how does the typical person spend them? According to hundreds of time surveys from 38 OECD (Organization for Economic Co-operation and Development) member countries – including the UK, US, Japan and Canada – here’s how our days break down...



THE AVERAGE HUMAN DAY

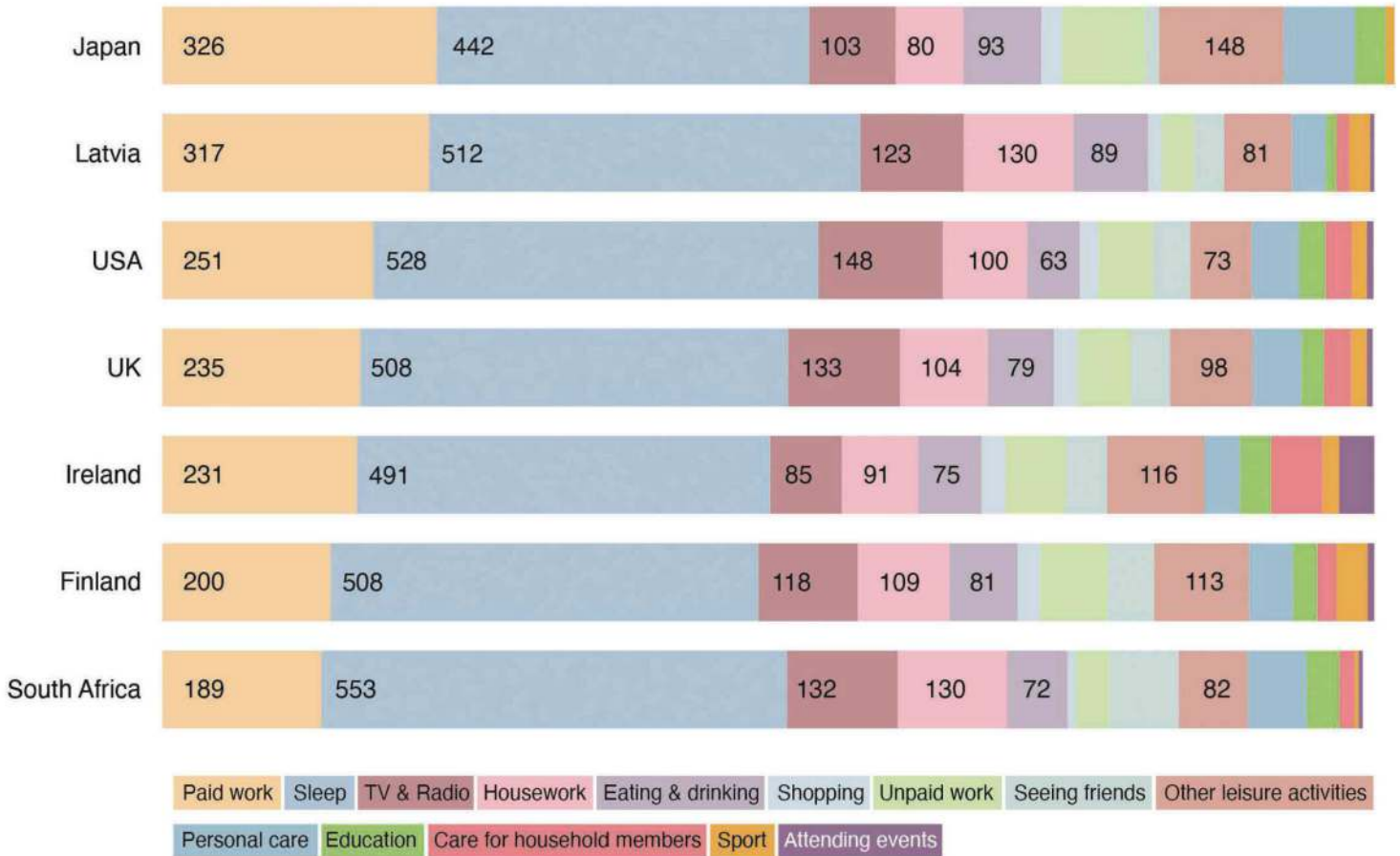
How the average person aged 16-64 in OECD countries spends their time on various activities

SOURCE: OECD

by **PROF RUTH OGDEN**
Ruth is professor of the psychology of time, and a lecturer at Liverpool John Moores University.

HOW DOES EACH COUNTRY SPEND ITS TIME?

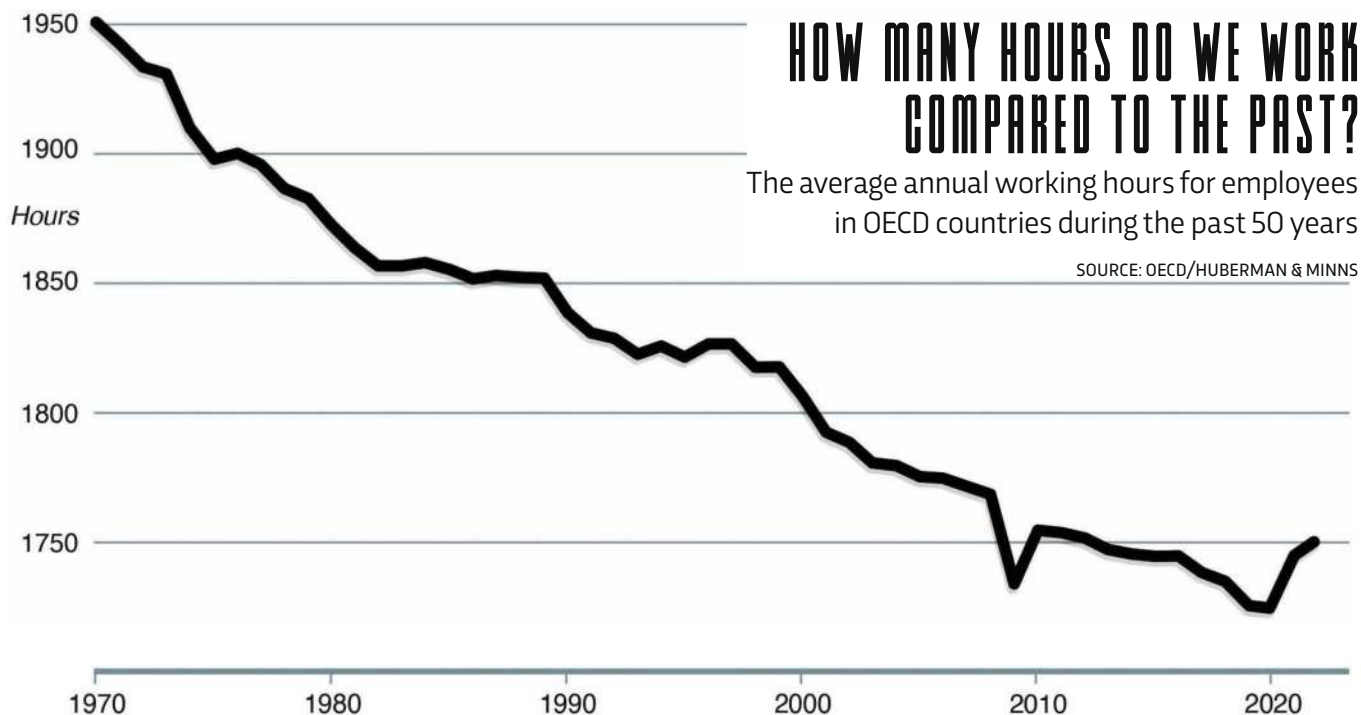
The average time (in minutes) people aged 16-64 spend on various activities SOURCE: OECD



HOW MANY HOURS DO WE WORK COMPARED TO THE PAST?

The average annual working hours for employees in OECD countries during the past 50 years

SOURCE: OECD/HUBERMAN & MINNS



ILLUSTRATIONS: DANIEL CRESPO, ACUTE GRAPHICS

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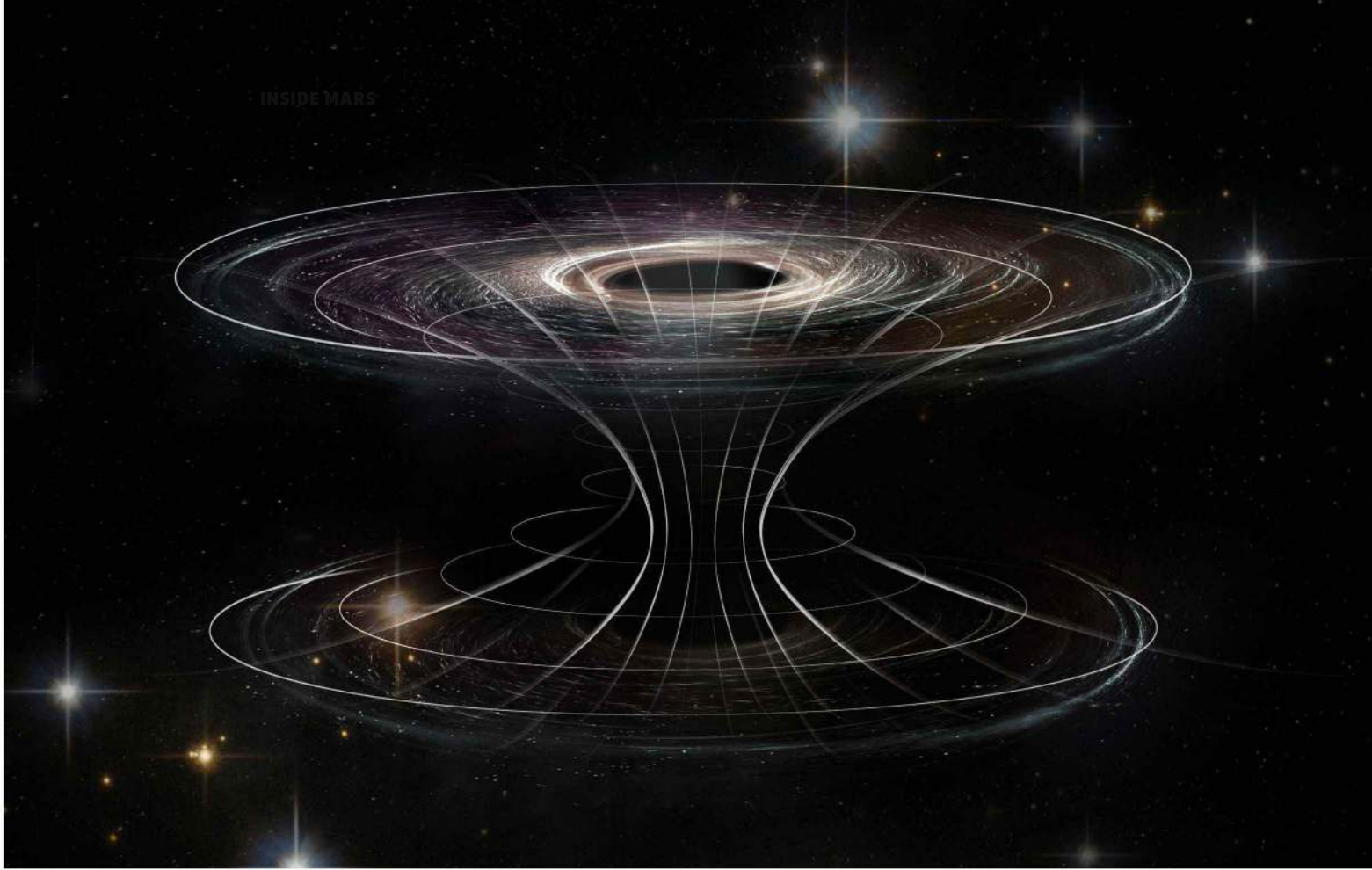




WHITE HOLES

by CARLO ROVELLI

**A NEW THEORY ABOUT
WHAT HAPPENS
WHEN BLACK HOLES
DIE COULD SOLVE
ONE OF THE BIGGEST
MYSTERIES IN PHYSICS**



Perhaps the most surprising scientific discovery of the last decade is that the Universe is teeming with black holes.

They've been detected in a surprising variety of sizes: some with masses only a bit larger than the Sun, others that are billions of times larger. And they've been detected in a variety of different ways: by radio emissions from the matter falling towards the hole; by their effect on the stars orbiting them; by the gravitational waves emitted as they merge; and by the extremely peculiar distortion of light they cause (think back to the 'Einstein ring', seen in the photos of Sagittarius A*, the supermassive black hole at the centre of the Milky Way, that graced the front pages of the world's newspapers not so long ago).

The space we inhabit is not smooth – it's pitted, like a colander, by these holes in the sky.

The physical features of all black holes were predicted by Einstein's theory of General Relativity and are

“THE SPACE WE INHABIT IS NOT SMOOTH – IT’S PITTED, LIKE A COLANDER, BY THESE BLACK HOLES IN THE SKY”

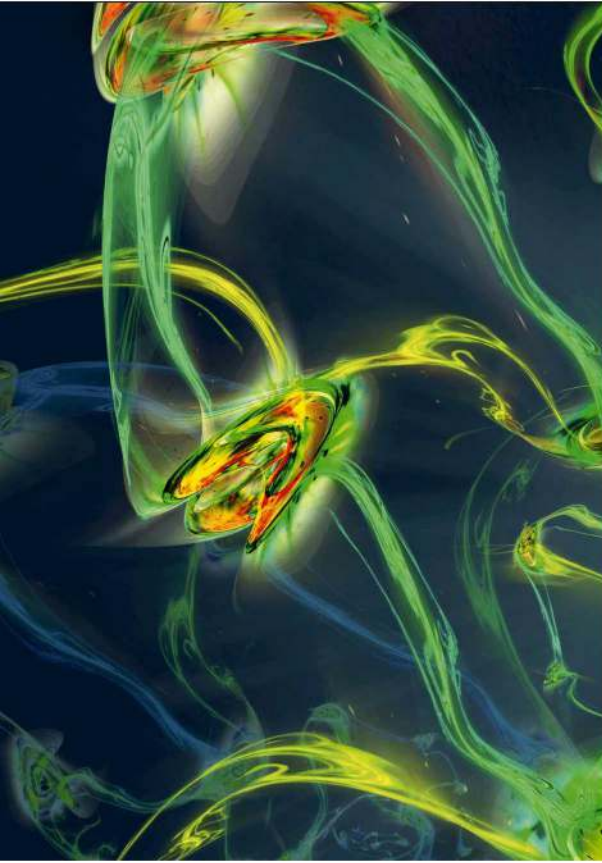
well described by the theory. Everything we know about these strange objects fits with Einstein's theory rather perfectly, so far.

But there are two key questions that Einstein's theory doesn't answer. The first: when matter enters the hole where does it go next?

The second: how do black holes end? Convincing theoretical arguments, first understood by Stephen Hawking several decades ago, indicate that in the distant future, after a life that depends on its size, a black hole shrinks (or as physicists say, 'evaporates'), by emitting hot radiation now known as

ABOVE Loop quantum gravity theory allows for black holes to rebound as white holes

ABOVE RIGHT Loop quantum gravity seeks to combine quantum physics and the force of gravity as per Einstein's theory of General Relativity



JARGON BUSTER

BLACK HOLE

A black hole is an area of spacetime where the gravity is so great that nothing, not even light, can escape. Most are formed from the remnants of large stars that die in supernova explosions. These occur when a star has burned all its fuel and collapses in on itself, leaving behind a very compact, dense object.

SUPERMASSIVE BLACK HOLE

A black hole that's more than 100,000 times the mass of the Sun is said to be supermassive. It's thought these cosmic giants lie at the centre of virtually all large galaxies.

SPACETIME

In classical Newtonian physics, space and time are thought of as separate entities. According to Einstein's theory of General Relativity, however, the fabric of the Universe can be modelled by combining the three dimensions of space with the one dimension of time, creating a four-dimensional entity known as spacetime. In his theory, Einstein proposes that gravity, rather than being thought of as a force in the traditional sense, produces a warping effect, resulting in what physicists refer to as 'curved spacetime'.

EINSTEIN RING

These rings of light are formed when light from distant objects passes by something extremely massive, such as a galaxy or supermassive black hole. The immense gravitational pull of such objects causes the

spacetime around them to warp. This results in the light passing through it being redirected in a way similar to light passing through a glass lens. This phenomenon is known as 'gravitational lensing'.

EVENT HORIZON

A black hole is defined by its 'event horizon', the imaginary membrane that marks the point of no return for in-falling matter and light. It defines the boundary where the velocity needed to escape exceeds the speed of light – the speed limit of the cosmos. This means that matter and radiation can fall into a black hole, but they can't get out.

HAWKING RADIATION

Although space may appear to be empty, this isn't the case. Even though empty space contains no mass, particles or quanta of energy, the quantum fields that define them still exist. Because they aren't required to have zero energy, these fields can create pairs of 'virtual particles.' These are typically particle-antiparticle pairs that form spontaneously, then quickly recombine and annihilate. Near a black hole, however, it's possible for one of those particles to cross the event horizon and be lost forever, while the other escapes into space as Hawking radiation.

DARK MATTER

Dark matter is an invisible type of matter that has mass, but can't be seen and doesn't interact with ordinary matter. According

to current estimates, it makes up 85 per cent of all the matter in the Universe, and 27 per cent of the total mass-energy. So far, many candidates have been proposed as a possible explanation for dark matter, such as weakly interacting massive particles ('WIMPs'), neutrinos or exotic supersymmetric particles, but its true identity remains a mystery.

LOOP QUANTUM GRAVITY

One of the biggest challenges facing physicists is the fact that the two most successful theories, quantum mechanics and relativity, can't be combined. One possible solution being explored is loop quantum gravity or (LQG). The theory states that, rather than being continuous as relativity suggests, spacetime is instead made up of a network of small discrete packets, such as those described by quantum mechanics.

STRING THEORY

Another attempt to unify quantum mechanics and gravity is string theory. The basic idea is that fundamental particles such as quarks and electrons, are actually a single point in one-dimensional strings, vibrating at different frequencies. In order for the mathematics underlying it to work, extra dimensions, a total of 10 or 11, would need to exist. It also offers up the possibility of the existence of concepts loved by science fiction writers, such as the multiverse.

Hawking radiation. This results in the hole becoming smaller and smaller, until it's tiny. But, what happens next?

The reason these two questions are yet to be answered, and that Einstein's theory doesn't provide an answer, is that they both involve quantum aspects of spacetime. That is, they both involve quantum gravity. And we don't have an established theory of quantum gravity yet.

AN ATTEMPT AT AN ANSWER

There is hope, however, because we do have tentative theories. These theories aren't established yet because, to date, they haven't been supported by experiments or observations. But they are developed enough to give us tentative answers to these two important questions. And so we can use these theories to make an educated guess about what is occurring.

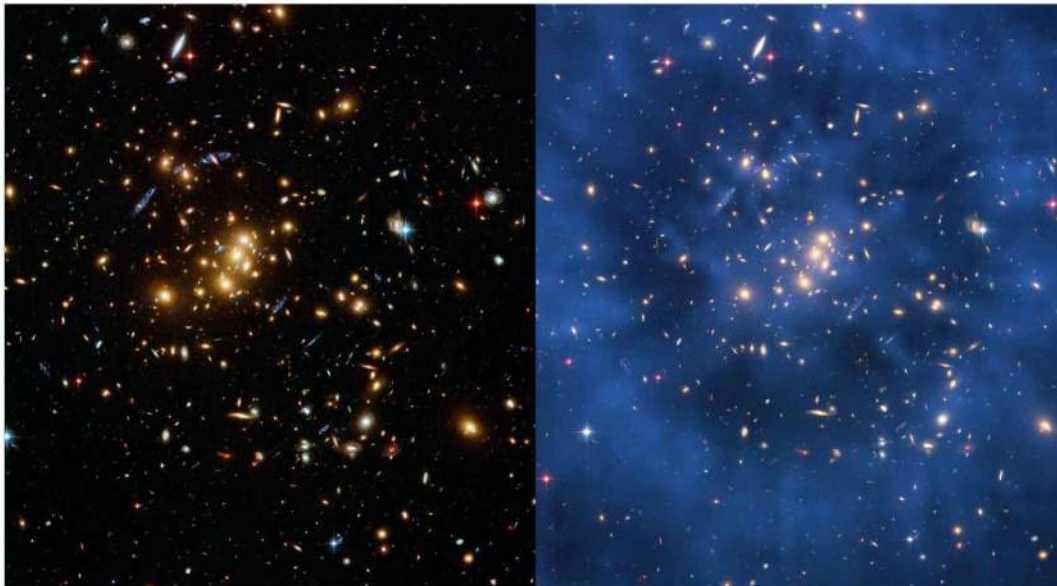
Arguably the most detailed and developed theory of quantum spacetime is loop quantum gravity, or LQG – a tentative quantum gravity theory that has been steadily developing since the late 1980s. Thanks to this theory, an →

“THE INTERIOR OF A BLACK HOLE EVOLVES UNTIL IT REACHES A PHASE WHERE QUANTUM EFFECTS BEGIN TO DOMINATE”

→ interesting answer to these questions has emerged. That answer is given by the following scenario.

The interior of a black hole evolves until it reaches a phase where quantum effects begin to dominate. This creates a powerful repulsive force that reverses the dynamics of the interior of the collapsing black hole, making it ‘bounce back’. After this quantum phase, described by LQG, the spacetime inside the hole is once again governed by Einstein’s theory, except that now the black hole is expanding rather than contracting (see ‘Collapse and rebound’, p71).

The possibility of an expanding hole is indeed predicted by Einstein’s theory, in the same manner in which black holes were predicted. It’s a possibility that has been known



about for decades; so long, in fact, that this corresponding spacetime region even has a name: it’s called a ‘white hole’.

THE SAME IDEA, BUT IN REVERSE

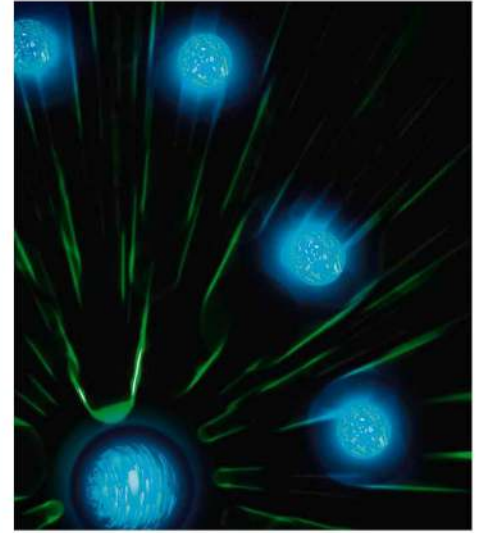
The name reflects the idea that a white hole is, in a sense, the reverse of a black hole. It can be thought of in the same way that a ball bouncing upwards follows an upward trajectory that’s the reverse of the downward trajectory taken when that ball fell.

A white hole is a spacetime structure that’s similar to a black hole, but with time reversed. Inside a black hole, things fall in; inside a white hole, however, things move out. Nothing can exit a black hole; likewise, nothing can enter a white hole.

Seen from the outside, what happens is that, at the end of its evaporation, a black hole, which is now tiny because it

ABOVE The galaxies visible on the left are being magnified and distorted by the gravitational lensing caused by dark matter (denoted by the blue shading in the image on the right)

RIGHT Hawking radiation is the theoretical radiation emitted by virtual twin particles being separated by the gravity at a black hole’s event horizon



ABOVE It's thought Hawking radiation is what gradually causes black holes to evaporate

has evaporated away most of its mass, mutates into a tiny white hole.

LQG indicates that such structures are rendered quasi-stable by quantum effects, so they can live for a long time. White holes are sometimes called 'remnants' because they're what remains after the evaporation of a black hole. The transition from black to white hole can be thought of as a 'quantum leap'

This is akin to the Danish physicist Niels Bohr's concept of quantum leaps, in which electrons jump from one atomic orbit to another when they change energy. Quantum leaps cause atoms to emit photons and are what causes the emission of light that allows us to see objects.

But LQG predicts the size of these tiny remnants. From this follows a characteristic physical consequence: the quantisation of geometry. In particular, LQG predicts that the area of any surface can only have certain discrete values.

The area of the horizon of the white hole remnant must be given by the smallest non-vanishing value. This corresponds to a white hole with the mass of a fraction of a microgram: roughly the weight of a human hair.

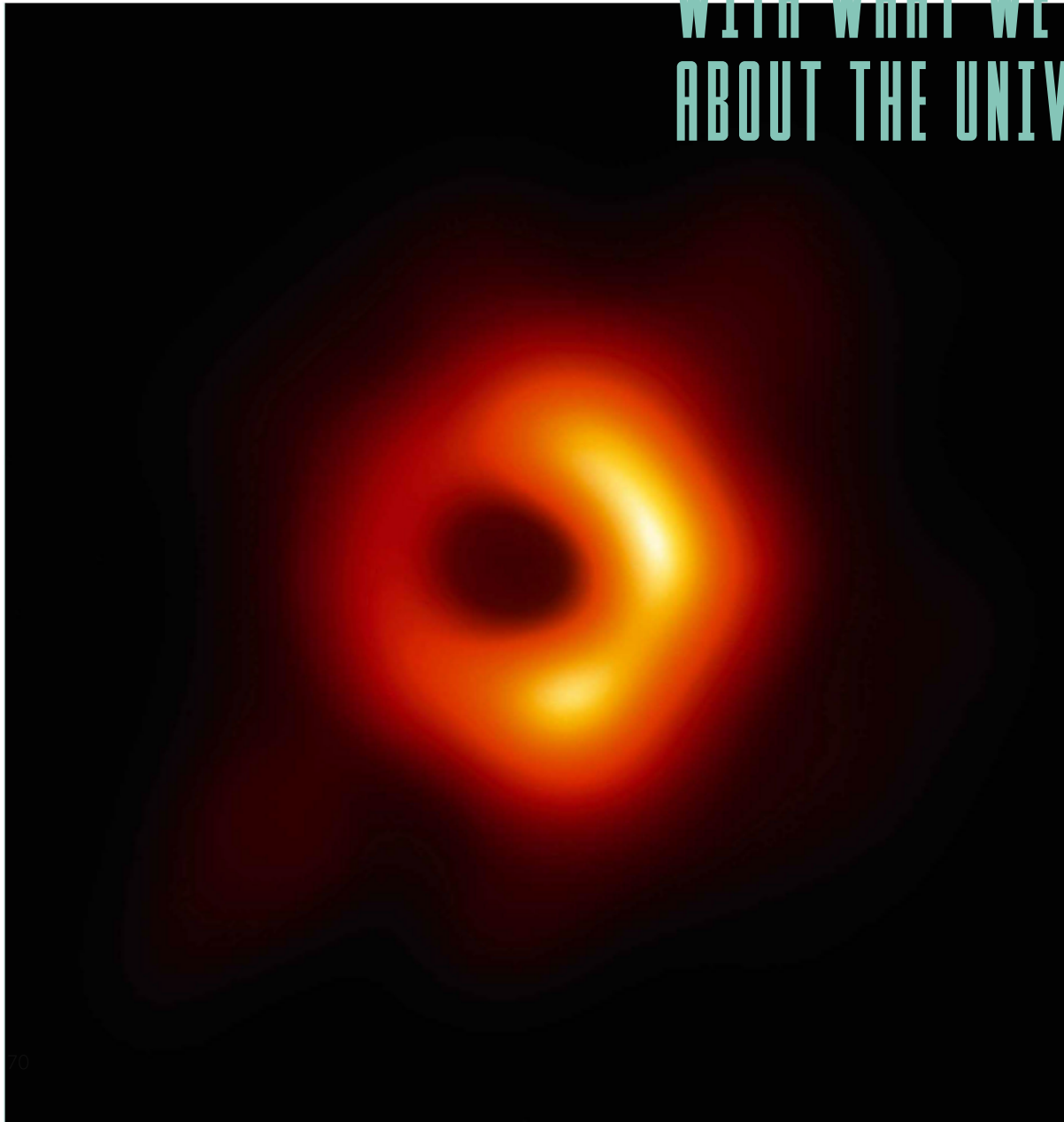
This scenario answers both questions posed earlier. What happens at the end of the evaporation is that a black hole quantum leaps into a long-living tiny white hole. And the matter that falls in a black hole can later exit from this white hole. →

→ Most of the energy of the matter will have already been radiated away by Hawking radiation – low-energy radiation emitted by the black hole due to quantum effects that cause it to evaporate. What exits the white hole isn't the energy of the matter that fell in it, but a residual low-energy radiation, which nevertheless carries all the residual information about the matter that fell in.

An intriguing possibility opened by this scenario is that the mysterious dark matter that astronomers see the effects of in the sky could actually be formed, entirely or in part, by tiny white holes generated by ancient evaporated black holes. These could have been produced in early phases of the Universe, possibly in the pre-Big Bang phase that appears to be also predicted by LQG.

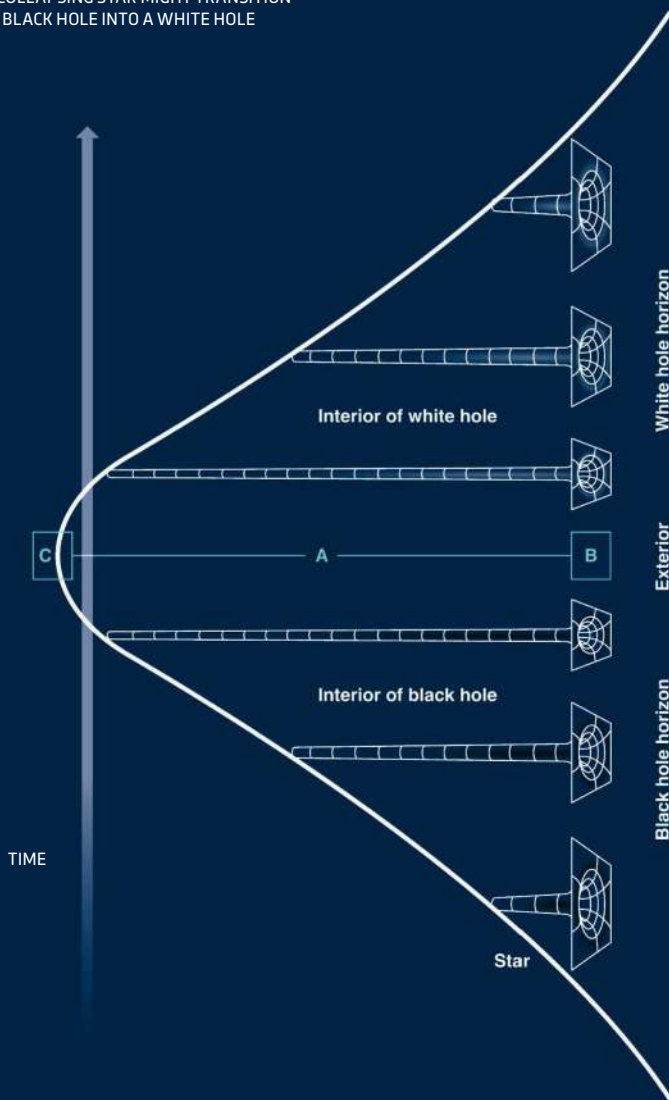
This is an attractive possible solution to the mystery of the nature of dark matter, because it provides an understanding of dark matter that relies solely on General Relativity and

“FOR NOW WE MUST
STUDY THIS SCENARIO
AND ITS COMPATIBILITY
WITH WHAT WE KNOW
ABOUT THE UNIVERSE”



COLLAPSE AND REBOUND

HOW A COLLAPSING STAR MIGHT TRANSITION FROM A BLACK HOLE INTO A WHITE HOLE



KEY

ZONE A: THE TRANSITION OF INTERNAL GEOMETRY AS A BLACK HOLE BECOMES A WHITE HOLE

ZONE B: THE REGION IN WHICH THE HORIZON SWITCHES FROM THAT OF A BLACK HOLE TO THAT OF A WHITE HOLE

ZONE C: THE REBOUND OF THE COLLAPSED STAR THAT FORMED THE BLACK HOLE

SOURCE: *WHITE HOLES – INSIDE THE HORIZON*, CARLO ROVELLI

Ideas on how to do so using detectors based on a quantum technology have already been proposed. If dark matter is composed by white hole remnants, a simple estimate shows that a few of these objects might fly through a space the size of a large room every day.

For now, we must study this scenario and its compatibility with what we know about the Universe, waiting for technology to help us detect these objects directly.

It's surprising that this scenario wasn't considered previously, though. A reason can be traced to a hypothesis adopted by many theoreticians with a background in string theory: a strong version of the so-called 'holographic' hypothesis. According to this hypothesis, the information inside a small black hole is necessarily small, contradicting the above idea. The hypothesis is grounded on the idea of eternal black holes: in technical terms, the idea that the horizon of a black hole is necessarily an 'event' horizon (an 'event' horizon is by definition an eternal horizon). If the horizon is eternal, what happens inside is effectively lost forever, and a black hole is uniquely characterised by what can be seen from the outside.

But quantum gravitational phenomena disrupt the horizon when it has become small, preventing it from being eternal. So the horizon of a black hole fails to be an 'event' horizon. The information it contains can be large, even when the horizon is small, and can be recovered after the black hole phase, during the white hole phase.

Curiously, when black holes were studied theoretically and their quantum properties disregarded, the eternal horizon was considered their defining property. Now that we understand black holes as real objects in the sky, and investigate their quantum properties, we realise that the idea that their horizon must be eternal was just an idealisation. Reality is subtler. Perhaps nothing is eternal, not even the horizon of a black hole. **SF**

by **CARLO ROVELLI** (@carlorovelli)

Carlo is a theoretical physicist and writer based at Centre de Physique Theorique de Luminy in Marseille, France.

LEFT The first direct visual evidence of a black hole (the one at the centre of the elliptical galaxy Messier 87 in the Virgo constellation) was captured by the Event Horizon Telescope in April 2017

quantum mechanics, both well established aspects of nature. It also doesn't add ad hoc particles of fields, or new dynamical equations, as most of the alternative tentative hypotheses about dark matter do.

NEXT STEPS

So, can we detect white holes? Direct detection of a white hole would be difficult, because these tiny objects interact with the space and matter around them almost uniquely through gravity, which is very weak. It's not easy to detect a hair using only its gravitational attraction. But perhaps it won't remain impossible as technology advances.

The background features a vibrant, abstract design with wavy, organic shapes in shades of blue, green, and red. The blue shapes are at the top, green in the middle, and red at the bottom. The overall effect is dynamic and layered.

THE BROKEN MIRROR

Body dysmorphia – the all-consuming obsession with perceived flaws in our looks – is sweeping the globe. One in five young people is thought to be affected. What can be done and how is tech changing the way we see ourselves?

by **DR TONI PIKOOS**

A

new year typically turns our minds to change. And if you've made a resolution around changing your appearance, you're not alone. Around 43 per cent of adults in the UK set a goal to lose weight last year.

For many, these aims of 'new year, new me' may also extend to more extreme methods of appearance alteration, such as cosmetic procedures or plastic surgeries.

But when does this common, widespread desire for self-improvement or enhancement become something more sinister? For around three per cent of the general population, the drive to fix or change one's physical appearance becomes a constant – a condition known as body dysmorphic disorder (BDD).

Individuals with BDD see themselves as having serious defects or flaws in their bodies, that to other people would seem slight or potentially even nonexistent.

Take Rebecca*, a 36-year-old woman who strongly believes she looks like a 'moon-face' because she can't help but stare, into the mirror, at acne scars that cover her skin.

Or Tyson*, the 17-year-old who spends hours at the gym each day to build up his muscle mass, because he feels he looks like a 'toothpick.'

Both Tyson and Rebecca have been reassured countless times by their families, friends and medical professionals that the way they see themselves doesn't match how they're perceived by others, but they just don't believe them. Seeing is believing, right? But what happens when your eyes deceive you?

A LONG OBSESSION

BDD is not a new condition. It was first described by Italian psychiatrist Enrico Morselli back in 1891, long before we were glued to our TikTok feeds. He described the 'dysmorphophobic' (a former term for BDD) as a person who "in the midst of his daily affairs, in conversations, while reading, at a →

ILLUSTRATION: SAM FALCONER

→ table, in fact anywhere and at any hour of the day, is suddenly overcome by the fear of a deformity that might have developed in his body.”

It's believed that BDD is caused by a complex interplay of biopsychosocial factors, including a genetic contribution, differences in brain structure and function, as well as a history of adverse childhood experiences like bullying, abuse or neglect, which can lead an individual to feel ashamed of themselves and their body. This predisposition is often then unmasked or exacerbated by societal pressures on physical appearance. Indeed, research supports the notion that attractive people often gain societal advantages, such as being perceived as more trustworthy, healthy, confident and intelligent. In turn, this can lead to a greater chance of finding a romantic partner, being hired for a job and even attracting a higher salary.

This often plays on the minds of people with BDD, leaving them feeling like they're less able to succeed in life. While we can't ignore that these advantages of beauty exist in our society, the pursuit of beauty at all costs can be damaging to both our physical and mental health.

UNREAL PERFECTION

While BDD predates the development of social media, it has certainly had an influential role in increasing the prevalence and severity of the disorder. The emphasis on sharing the 'perfect' selfie, the use of filters and various methods of augmenting or enhancing an image, and powerful algorithms that ensure users are fed content that they (or their disorder) are most interested in, is a perfect storm for enhancing one's focus on their appearance.

Frequent social media use and photo editing has been linked to an increased risk of developing BDD, appearance comparison, and interest in undertaking surgical and non-surgical cosmetic procedures. This relationship occurs in a number of ways. Firstly, our perceptions of attractiveness and beauty are often affected by our 'visual diet'. When we're

spending extended periods consuming curated content that showcases the best angles, lighting, makeup and outfit choices, and potentially artificial enhancements through the addition of filters, our perception of beauty can begin to skew towards highly idealised and edited images.

In turn, the viewer feels more pressure to align with this newly formed beauty ideal, and may seek to do so through applying filters themselves, or seeking out cosmetic procedures to better meet this standard. Unfortunately, the positive effects of the filter on one's self-image only last as long as the filter is applied and, once removed, or once the individual sees themselves in a mirror in the real world, they can feel less attractive or acceptable.

There is also mounting pressure to create a 'personal brand' online, which can extend beyond posting the 'perfect' picture, to also achieving the most aesthetic feed, the right captions, hashtags and themes. This can contribute to a lack of authenticity, and a growing discrepancy between the 'online self' and the 'real self'. Some people speak about mounting social anxiety in their day-to-day lives from their social media use. They're fearful that they might unintentionally 'catfish' others who have become accustomed to seeing them a certain way in the online world. Thus, personal brands and polished online personas can contribute to embarrassment and shame around one's true appearance and personality.

Once a person develops BDD, the disorder is often maintained by unhelpful patterns in thoughts or behaviours. For example, engaging in excessive behaviours to check,

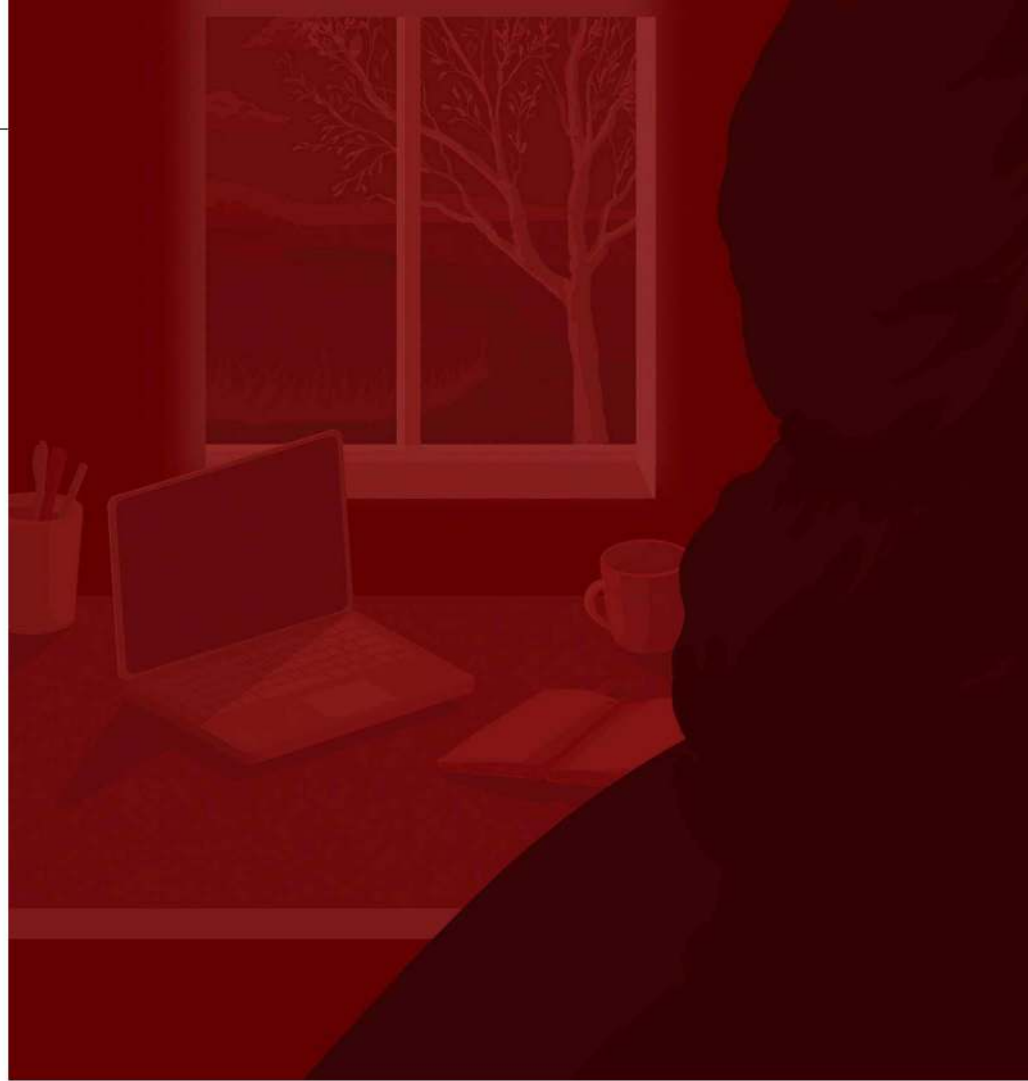


ILLUSTRATION: SAM FALCONER



“PERSONAL BRANDS AND POLISHED ONLINE PERSONAS CAN CONTRIBUTE TO SHAME AROUND ONE’S TRUE APPEARANCE”

camouflage or change their physical appearance. This can be spending lengthy periods examining oneself in the mirror or taking photos from various angles; covering up with loose clothing, hats, scarves or glasses; and beauty treatments, new hairstyles, and cosmetic procedures.

Many of these are common, everyday behaviours that people engage in for self-expression or enhancement. However, when we take these behaviours to the extreme, they can contribute to a hyperfocus on appearance. One study compared the mirror-gazing patterns of individuals with and without BDD, and found that even healthy individuals who spent more than 10 minutes looking at themselves in the mirror developed an increased awareness of their ‘flaws’ and heightened distress

levels. People with BDD experienced this heightened distress even when they looked at themselves briefly, for around 25 seconds. These findings support the notion that BDD sufferers display different patterns of visual processing when looking at faces, often focusing on fine details or individual features rather than the big picture. Similarly, if someone without BDD looks at themselves for long enough, they too begin to see themselves in parts instead of a whole. This is one explanation for why the ‘Zoom effect’ and the sharp increase in video calls during the COVID-19 pandemic led to growing self-image distress for many individuals.

EXTREME MEASURES

In an effort to feel better about themselves, people with BDD often seek out beauty and cosmetic treatments at much higher rates than the general population. Around 70 per cent of BDD sufferers have sought cosmetic interventions before, and they comprise up to 15 per cent of all patients undertaking cosmetic procedures. These high rates make sense – for Rebecca, concerned about scars on her face, dermatological treatments like chemical peels and anti-wrinkle injections feel like the obvious solution. Unfortunately, the research suggests that while most people seeking cosmetic procedures are satisfied with the treatment outcomes, the same is not true for patients with BDD. In up to 91 per cent of cases, they don’t experience any change in their symptoms, meaning they continue to worry about the treated area or engage in methods to hide, check or cover up their ‘flaws’.

Sometimes, the worries shift following a cosmetic procedure. Beforehand, an individual may have been →



→ concerned about their ‘hook nose’, which after a rhinoplasty (nose job) develops into a new concern that their nose now looks surgically enhanced, and that others may judge them for having had surgery. In other cases, BDD symptoms actually deteriorate following a procedure, and can leave a person who was already feeling self-conscious and vulnerable even worse off.

For the cosmetic practitioner, there’s an ethical and professional imperative to identify BDD in their patients before administering a procedure, as there have been cases of people with BDD taking out legal action, making complaints or requesting compensation for procedures that didn’t meet their expectations.

It can be disappointing to learn that cosmetic surgery may not be the solution to an intense and distressing preoccupation with physical appearance. But the good news is that effective, evidence-based treatments exist. The National Institute for Health and Care Excellence suggests that first-line treatment for BDD should involve cognitive behavioural therapy with exposure and response prevention (CBT-ERP), and the addition of psychiatric medication for moderate to severe cases.

CBT for BDD involves identifying the unhelpful and rigid assumptions and expectations we may place upon ourselves and our appearance (“I must always look presentable when I leave the house”, for example, or “Nobody could ever love me with a nose this size”), and learning new ways of either disengaging from these thoughts, or developing more flexible and helpful thought processes (for example, “I would like to find a partner who is

attracted to me for my values, interests and passions – not what my nose looks like”).

The addition of ERP involves gradually exposing the patient to situations, environments or people that may typically be avoided, while at the same time trying not to engage in compulsive behaviours. For example, Rebecca may work on being able to leave the house without wearing heavy makeup to cover up her skin, by gradually removing a makeup product from her routine each day. Tyson may be working on reducing his workout schedule, or being able to go to the beach with friends without covering himself up with a t-shirt. These exposure exercises are designed to help the individual learn that what they fear most (being judged or ridiculed for their appearance) might not happen. Through exposure, rather than avoidance, they can begin to live more productive, fulfilling and joyful lives.

Current estimates show that with CBT-ERP, up to 70 per cent of people with BDD experience a significant reduction in their symptoms, rising to 80 per cent when combined with medication.

If you’re reading this and feel like you might be spending a bit too much time worrying about your appearance, there are some things you can try:

- **MIRROR HYGIENE** Set some limits around how much time you spend looking at your reflection. Spending more than 10 minutes looking at yourself, when not for a particular purpose, like putting on makeup or shaving, can lead to distress. Don’t avoid the mirror, but try to keep it to an ‘as needed’ basis.

- **ENGAGE IN NON-APPEARANCE-RELATED INTERESTS** BDD is often associated with a hyperfocus on appearance, often at the expense of other activities. By spending time engaging with friends, family and activities you enjoy, your self-esteem broadens and you can identify that your strengths are greater than just your looks.

- **SOCIAL MEDIA DETOXES** Take a look at your social media and notice how much of the content you’re consuming involves highly edited images, or content promoting fitness, beauty or cosmetic treatments. Unfollow or hide content that makes you feel more self-conscious, or set some limits around when and for how long you engage with social media.

- **CUT BACK ON REASSURANCE SEEKING** Try not to discuss your appearance with others – asking for feedback about your appearance can leave you feeling worse regardless of whether the answer is positive or negative. Focus the conversation on more interesting topics.

So, as 2024 begins and we think about the people we would like to be for the year ahead, consider whether goals around appearance align with your true values. Perhaps 2024, instead of being a year of chasing after the perfect body, may be the year to uncover a broader sense of self-worth that can withstand the inevitable challenges of ageing and development that we’ll all go through – whether we like it or not! **SF**

*Names and descriptions do not reflect real clients.

by **DR TONI PIKOOS**

Toni is a clinical psychologist who studies and works with patients that experience body dysmorphic and eating disorders. She co-founded ReadyMind, which aims to help cosmetic surgeons assess their patients’ mental health, and shares her work and advice on Instagram, @thebddtherapist.

ILLUSTRATION: SAM FALCONER

“THROUGH EXPOSURE, RATHER THAN AVOIDANCE, THEY CAN BEGIN TO LIVE MORE FULFILLING AND JOYFUL LIVES”

Email your questions to
questions@sciencefocus.com
 or submit on X (formerly Twitter) at
 @sciencefocus

YOUR QUESTIONS ANSWERED

KATRINA SHERMAN, VIA EMAIL

IS THE MOON SHRINKING?

The Moon is shrinking, by about 50m (164ft) in radius over the last several hundred million years. Scientists discovered this by analysing images of thrust faults (known as scarps) on the lunar surface. The images were taken by Apollo astronauts and, more recently, NASA's Lunar Reconnaissance Orbiter. Researchers found that the epicentres of some shallow moonquakes, detected by seismometers left on the Moon during the Apollo era, seem to be associated with these thrust faults.

They also found that the Moon has an inner core that's about 500km (310 miles) in diameter and partially molten, but much less dense than Earth's core.

The Moon is tectonically active because its interior is still cooling and contracting. The Moon's crust is very brittle, so as the interior shrinks, the crust breaks apart, resulting in scarps as portions of crust are pushed over others. At least some lunar scarps are cracks and wrinkles formed by that slow contraction. All the evidence suggests this process is still going on today, although the stresses on the Moon due to Earth's gravity (tidal forces), have a greater effect on the occurrence of moonquakes.

Are there any consequences for Earth (or humans) from the shrinking Moon? Not really. This rate of shrinking is almost imperceptible, being equivalent to a change in the Moon's radius by about one quintillionth (10^{-18}) of a per cent per year. So, the Moon's apparent size in the sky won't change noticeably due to lunar shrinking

over Earth's expected lifetime. Also, the Moon isn't shrinking due to loss of mass, so the gravitational force between Earth and the Moon will remain the same.

This doesn't mean that the evolution of the Moon won't affect Earth in the future, though. Due to tidal forces between Earth and the Moon, the size of the Moon's orbit is





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Biology



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LIAM DUTTON
Meteorology



DR ALASTAIR GUNN
Astrophysics

increasing by about 3.8cm (1.5in) per year. As it recedes from us, the Moon's orbital period increases and Earth's rotation slows down. Every century, that process adds about 2.3 milliseconds to the length of a day on Earth.

But, again, this effect is almost imperceptible. The change in the Moon's apparent size due to its recession from us is vanishingly small and is completely dwarfed by the monthly change in size due to its elliptical orbit around Earth.

A receding Moon will eventually have severe consequences for Earth, however. Ocean currents would be disrupted, meaning many aquatic species would probably cease to exist. And Earth itself would become unstable and begin to wobble, disrupting the planet's seasons and causing devastating variations in climate. It's not something you need to worry about

"THE MOON ISN'T SHRINKING DUE TO LOSS OF MASS, SO THE GRAVITATIONAL FORCE BETWEEN EARTH AND THE MOON WILL REMAIN THE SAME"

right now, however. This won't happen until many billions of years from now.

That said, the fact that the Moon is tectonically active will have consequences for human exploration. Shallow moonquakes can cause strong seismic shaking, so the location of thrust faults may determine the selection of sites for long-term lunar bases. **AG**

GETTY IMAGES, NASA/JPL ILLUSTRATION: HARRIET NOBLE

STEPHEN LONG, WALLASEY

WHY DO CATS WIGGLE BEFORE THEY PONCE?

Like so much of cat behaviour, no one really understands what's going on.

Big cats, such as lions and tigers, also butt-shimmy before pouncing, so it's a behaviour that our domestic felines must have inherited from their wild cat ancestors. One theory is that it presses the

hindlimbs into the ground, giving the cat more

traction to propel it forwards when it pounces. It could also be a warm-up move to ready the muscles or heighten the senses, or it could be a sign of excitement.

Or all of the above. Or something else entirely. That's cats for you! **HP**



MYRTLE MORALES, VIA EMAIL

WHY DOES JUPITER SPIN SO FAST?

Jupiter is the fastest rotating planet in the Solar System; one day lasts just 10 Earth hours, despite its circumference being almost 11 times larger. The reason for this lies in the planet's mass. As the planets condensed from the disc of material surrounding the infant Sun, they naturally conserved angular momentum. Just as an ice skater performs faster pirouette spins by drawing their arms towards their body, a proto-planet spins faster as it contracts under gravity. All the gas giants have high mass and consequently fast rotation rates, Jupiter being the most massive and hence fastest. **AG**



NATURE'S WEIRDEST CREATURES



THE BURMESE NARROW-HEADED SOFTSHELL TURTLE

One warm June night in 2019, a solitary turtle clambered out of her large fishpond and up the tiled ramp to a specially created spawning area. The stones and the plants there had been removed, and the sand had been raked, sieved and sprinkled with water. It was just the way she liked it. When your species is Critically Endangered, nothing is too much trouble for the scientists who care for you. Using

her hind legs and webbed feet, she then excavated a chamber, deposited 112 spherical, rigid, grape-sized eggs, covered them with sand and went on her way.

Little is known about the ecology of the Burmese narrow-headed softshell turtle, so when scientists at the Pearl River Fisheries Research Institute in Guangzhou, China, had the chance to try breeding them in captivity, they were keen to try.

Adult Burmese narrow-headed softshell turtles have flexible, leathery, slate-coloured carapaces that are around a metre (3.3ft) long. This makes the aquatic species one of the largest freshwater turtles in the world. They have stripy necks, pointy heads and short snouts. Numbers are declining because of habitat destruction and because the reptiles are taken from their freshwater homes in



Myanmar and Thailand, and transported to China, where they're illegally sold for food.

The turtle doesn't breed readily in captivity, but the Chinese scientists had experience with other related species, so they prepared the site and set up a surveillance camera. The two adult turtles, who were accidentally captured and rescued from the Mekong River, had lived in the pond for 25 years alongside carp and tilapia. To help get them in shape, the big fish were removed, and small fry were added for the carnivorous reptiles to eat.

The hard work paid off. Over the next few months, the female returned to spawn four more times. She laid a total of 564 eggs, which were excavated by the scientists, and transferred into sand-filled plastic boxes, maintained at a constant temperature and humidity.

Sixty-five days after each clutch was laid, 39 per cent of the eggs hatched successfully and the scientists rejoiced as they welcomed around 200 new Burmese narrow-headed softshell turtles into the world. Each weighed about the same as a tablespoon of butter and had a shell that was just over 3cm (1in) wide.

When the scientists last reported on them, in a 2022 academic paper, 180 juveniles were still alive. They lived in plastic tanks in a greenhouse, where they dined on live fry and had increased their body weight 15-fold.

It'll be years before the youngsters reach adulthood, but the story is already a success. Scientists now know something about this unique turtle's breeding biology. The plan is to continue to learn and breed more. The hope is that, as numbers of the turtle decline in the wild, numbers in captivity will grow, and that one day these turtles and their descendants could be released back into their native rivers to restore the wild population. **HP**

JOEL SARTORE/PHOTO ART/NATUREPL.COM X2, GETTY IMAGES

APRIL STRICKLAND, YARMOUTH

HOW DO I GET RID OF MY NECK HUMP?

As a result of the COVID-19 pandemic, working from home has become the norm for many office workers. Although working from home does have its benefits, one major drawback is the potential to develop poor posture. This can lead to neck, back and shoulder discomfort, and sometimes the development of a neck hump. This is often because home office setups lack proper ergonomics, which increases slouching, hunching and straining to view computer screens.

While the odd slouch may do you no harm, prolonged periods of poor posture place excessive strain on the neck and upper back muscles. Over time, this can cause the head to tilt forward, leading to a structural change in the spine and the development of a hump-like curvature in the upper spine, known as kyphosis.

Fortunately, there are effective ways to combat this. Besides ensuring ergonomic home offices, research supports a combination of exercises designed to stretch the pectoral muscles and strengthen the trapezius and rhomboid muscles in the back. (Always check with a doctor before starting new exercises if you don't already exercise regularly.)

The trapezius, which covers the upper back and facilitates shoulder movements, works alongside the rhomboid muscles situated beneath it to stabilise the shoulders and maintain proper posture.

The pectoral muscles are large chest muscles that are essential for arm and shoulder movement. When they become overly tight, they can contribute to a neck hump by pulling the shoulders forward and rounding the upper back.

1. WALL PEC STRETCH This exercise is great for strengthening the entire back to provide spinal support.

How to do it Stand diagonally facing a wall, with your elbow and forearm resting on the wall at chest height at a 90° angle. Turn your body away from the wall to feel a stretch in your chest. Hold for 30 seconds on each side.

2. SUPERMAN This exercise is great for strengthening the entire back to provide spinal support.

How to do it Lying on your stomach, extend your hands in front of your head and lift both arms and legs up toward the ceiling – you're now in Superman mode. Hold for 3 seconds and repeat 10 times.

3. BENT-OVER ROW This exercise targets the rhomboids, trapezius and other muscles in the upper back.

How to do it Hold a barbell or a dumbbell in each hand, then bend forward at the waist, lift the weight(s) towards your chest, and squeeze your shoulder blades together. Repeat 10-12 times.

4. REVERSE FLY This is another exercise that's great for helping to strengthen the upper back and improve posture.

How to do it Stand with feet shoulder-width apart, with a dumbbell in each hand. Bend forward at the waist, and lift the dumbbells out to each side. Squeeze your shoulder blades together at the top of the movement, then lower the dumbbells. Repeat 10-12 times.

5. NECK AND SCAPULAR RETRACTIONS

Other research has found that neck and shoulder (scapular) retraction exercises can help correct a neck hump posture and alleviate neck pain.

How to do it For neck retractions, sit or stand upright, pull your head back and slightly upwards (as if you're trying to give yourself the biggest double chin) and hold for a few seconds. Repeat 10-12 times. For shoulder retractions, squeeze your shoulder blades together with your arms at your sides, look upwards, hold for 5-10 seconds, then relax and repeat 10-12 times.

With these exercises in your back pocket, you can help keep the hump at bay. Remember to take regular screen breaks and stay active, even with simple stretches and movements, as this helps counteract the sedentary nature of desk work and allows your muscles to relax. **HMH**



ASHTON MAHONEY, VIA EMAIL

WHY IS THE PINK LAKE IN AUSTRALIA PINK?

Australia is home to several pink lakes that have attracted tourists and scientists alike. One of the most famous is Lake Hillier in Western Australia, but pink lakes exist around the world, from Senegal to Spain.

What these lakes have in common is salinity – the pink colour is caused by salt-loving microbes that produce red pigments to aid photosynthesis. Lake Hillier's pink waters are caused by *Salinibacter ruber*, a bacterium that produces the pigment bacterioruberin. Other pink lakes harbour the algae *Dunaliella salina*, which makes beta-carotene. Sadly, commercial salt harvesting has caused some pink lakes to lose their vibrant colour. **CA**



TERENCE WILKINS, VIA EMAIL

WHY DO WE LIKE COLLECTING THINGS?

One important reason is because it's fun. No matter what else is going on in your life, from difficult relationships to unsatisfying jobs, if you're a collector, you can set yourself clearly defined, obtainable goals.

You can enjoy the 'hunt' as you search for the next item on your wish list, then feel the thrill of adding it to your collection, which you can showcase to others.

In fact, the social side of collecting is key to its appeal. Collectors often form communities and share knowledge or compete with each other, which can foster a strong sense of belonging. Of course, the

internet has made it easier for these kind of communities to thrive. Collecting can also be an expression of other forms of belonging. Just think of the football fan who collects match programmes or other memorabilia as an extension of their affiliation to a particular team.

Other collectors are motivated by nostalgia, whether collective or more personal. For instance, people who collect particular items from the past are often driven by the notion that they're preserving aspects of bygone eras – think of the person collecting antique guns or Victorian postcards. Additionally, each item in their collection might contain a multitude of personal memories, such as from the trip where it was first acquired.

Other psychologists argue for even deeper psychological motives behind collecting – they say the collection can act as compensation for a lack of loving human relationships; or that it can be a way that some people cope with existential anxieties (the collection lives on even after the collector has gone).

You might be wondering whether collecting is the same as hoarding; it's not. Hoarding tends to be uncontrolled, problematic and indiscriminate and it's recognised as a psychiatric disorder. Collecting, by contrast, involves careful and deliberate curation. **Q**

ADAM SUTHERLAND, RIPON

WHAT IS THE REMINISCENCE BUMP?



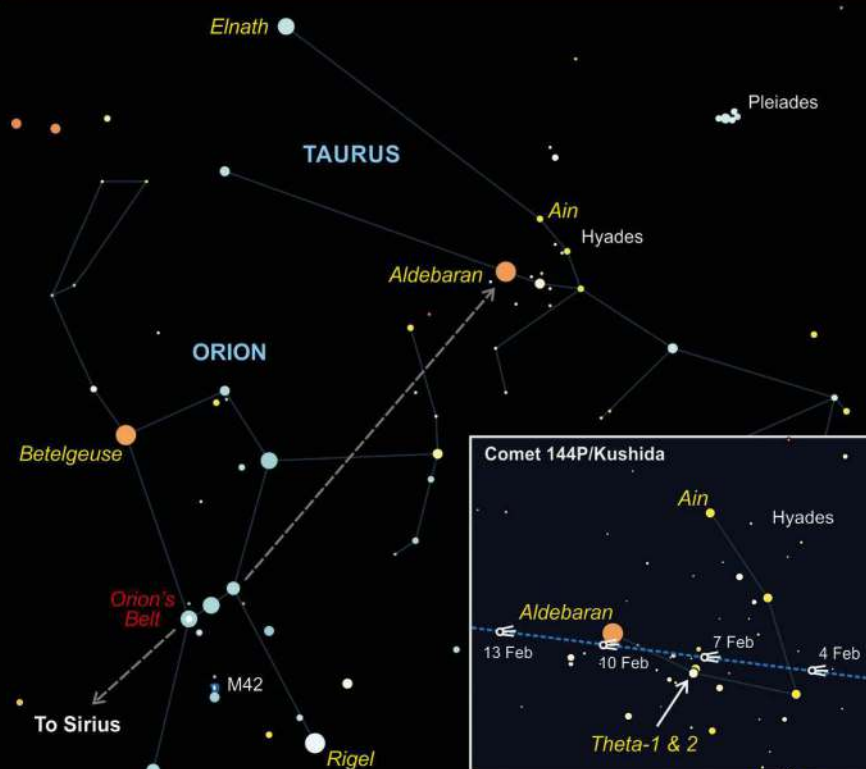
The 'reminiscence bump' is a quirk of autobiographical memory – the memories you hold of the things that have happened in your life to date. Generally speaking, our memories are better for more recent events – you're more likely to remember what you did yesterday, than what you did on this day a year ago. But the reminiscence bump breaks this rule: it describes the way that we tend to have a particularly good memory for events that occurred during our teenage years and early adulthood, compared with more recent times.

Psychologists have shown the reminiscence bump at work in various ways. For instance, if you're in your thirties or older, you're more likely to remember significant public events that occurred when aged between 10 and 30 years old, and to remember more details about those events. What's more, if I asked you to name your favourite footballer, you'll probably name a player from that same period. Ditto for your favourite band or film. You can test this out with different generations of your family.

There are a few theories for why we show a reminiscence bump. One has to do with the way that so many of our experiences in our teens and twenties are formative – they become entwined in our developing sense of who we are – making them highly memorable. A related theory states that there are a lot of first-time experiences when we're young – from our first kiss or first trip abroad, to our first concert or football match – and the novelty of these experiences makes them highly memorable.

A more mundane explanation is that our mental fitness and memory capabilities reach their peak in the second and third decades of life, thus giving us particularly good recall for that period. **Q**

ASTRONOMY FOR BEGINNERS



HOW TO SEE THE HYADES STAR CLUSTER

WHEN: JANUARY-FEBRUARY

Go outside on a clear, dark night and look towards the south to locate the three stars of similar brightness in a line forming Orion's Belt. This distinctive arrangement is an excellent signpost for finding other sky targets. Follow the line it makes down and left as seen from the UK, to arrive at bright Sirius, the Dog Star, the brightest star in the night sky. Follow the belt line in the opposite direction to arrive at Aldebaran, a star marking the red eye of Taurus, the Bull. The bull's face is represented by the sideways V-shaped pattern of stars next to Aldebaran: the Hyades open cluster.

The Hyades is the closest open cluster to Earth, an open cluster being a group of stars formed out of the same gas cloud. It's 153 light-years away from us, a little over twice the 65 light-year distance of red-giant Aldebaran.

Although Aldebaran looks to be part of the Hyades cluster, this is just a line-of-sight effect. If you have keen eyesight or the use of binoculars, look along the mid-point of the southern arm of the

Hyades and you'll find the lovely double star, Theta-1 and Theta-2 Tauri. Again, these stars aren't linked by gravity, their double nature is simply a line-of-sight effect. In reality, Theta-1 is 152 light-years away from us, and Theta-2 157 light-years.

The southern arm of the Hyades marks the approximate passage of a faint comet during early February. To see comet 144P/Kushida you'll need at least a small telescope or possibly large binoculars. Although dim, the comet's movement along this part of the sky does make it easy to find, so if you have access to a telescope give it a go. It'll probably look like a faint smudge; its apparent movement along the southern arm of the Hyades is obvious from one night to the next. **PL**



by PETE LAWRENCE

(@Avertedvision)

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

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In 1872, President Ulysses S Grant and the 42nd US Congress enacted a law making Yellowstone the first national park, not just in America, but the entire world.



At over 8,900km² (2.2 million acres), the park is huge, stretching across Wyoming, Montana and Idaho. It's home to all sorts of wildlife including bears, wolves and bison.



The park is well known for its geothermal features, including its supervolcano and the world-famous geyser Old Faithful, which has over 1,000,000 recorded eruptions.

Yellowstone National Park. Natural Wonder. Existential Threat?

From the striking features of Iceland, to the picturesque landscapes of Indonesia, volcanoes play a key role in shaping the world around us. Volcanic eruptions offer glimpses of incredible forces at work deep beneath our feet; forces with the means to create continents, but equally capable of unleashing catastrophic levels of destruction. There are around 1,500 active volcanoes on Earth, 170 of which can be found in the United States. Among these, few have captured our imaginations, or provoked our collective sense of existential dread like Yellowstone. So, does the threat from the supervolcano live up to the hype?

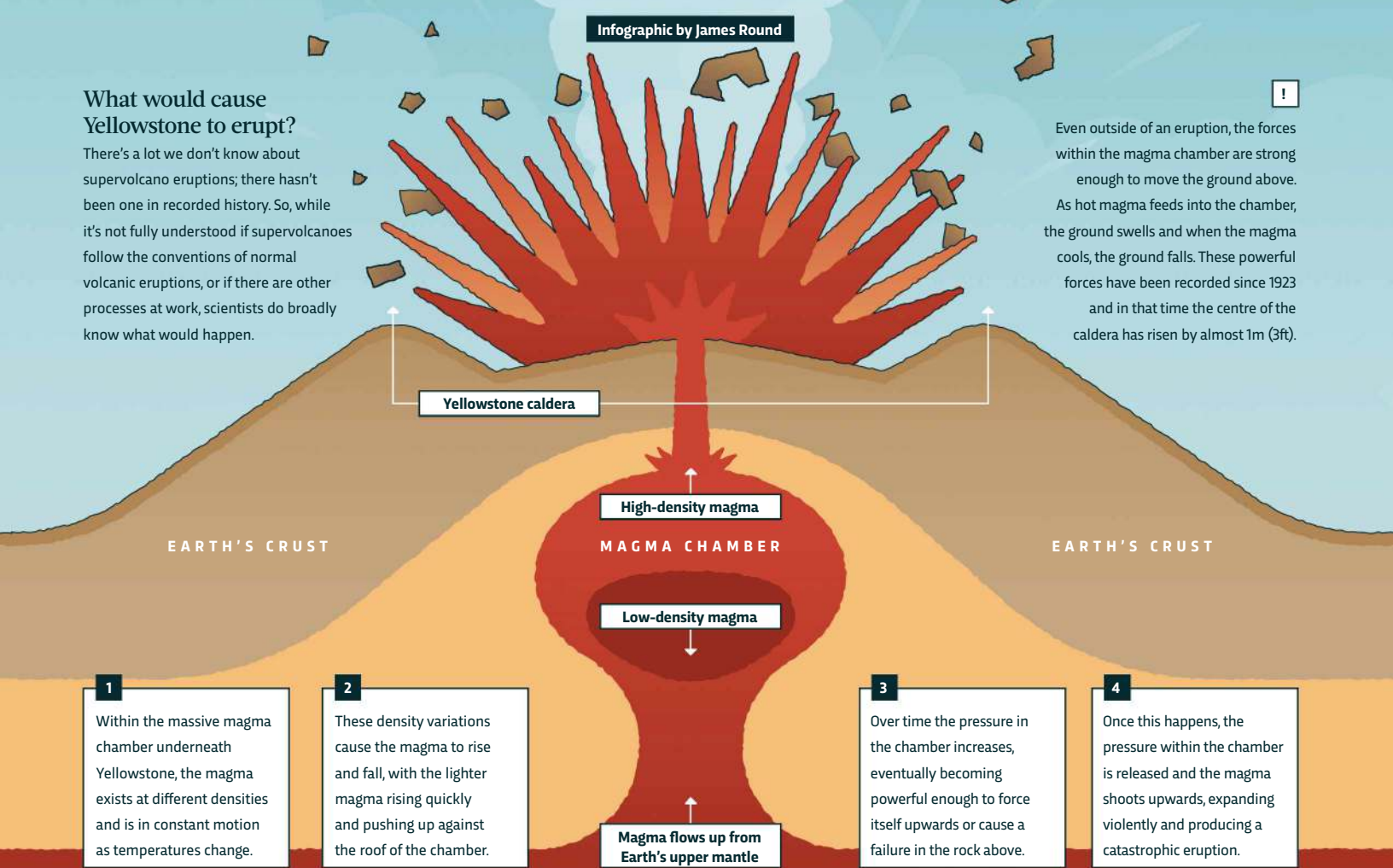
Infographic by James Round

What would cause Yellowstone to erupt?

There's a lot we don't know about supervolcano eruptions; there hasn't been one in recorded history. So, while it's not fully understood if supervolcanoes follow the conventions of normal volcanic eruptions, or if there are other processes at work, scientists do broadly know what would happen.

!

Even outside of an eruption, the forces within the magma chamber are strong enough to move the ground above. As hot magma feeds into the chamber, the ground swells and when the magma cools, the ground falls. These powerful forces have been recorded since 1923 and in that time the centre of the caldera has risen by almost 1m (3ft).



1 Within the massive magma chamber underneath Yellowstone, the magma exists at different densities and is in constant motion as temperatures change.

2 These density variations cause the magma to rise and fall, with the lighter magma rising quickly and pushing up against the roof of the chamber.

3 Over time the pressure in the chamber increases, eventually becoming powerful enough to force itself upwards or cause a failure in the rock above.

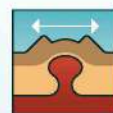
4 Once this happens, the pressure within the chamber is released and the magma shoots upwards, expanding violently and producing a catastrophic eruption.



Beneath Yellowstone's beautiful landscapes is a huge chamber of hot magma, believed to be roughly 80km (50 miles) long, 40km (25 miles) wide and 8km (5miles) deep.



The Yellowstone supervolcano has erupted three times: 2.1 million, 1.3 million, and 640,000 years ago. That's an average of about 725,000 years between eruptions.



The previous eruptions caused the Yellowstone caldera to form, a 70 x 45km (43 x 28 mile) cauldron-like hollow and the largest volcanic system in North America.

There are plenty of volcanoes in the US that pose a greater threat than Yellowstone...

In 2018, the US Geological Survey released the National Volcanic Threat Assessment, which found 20 volcanoes that were deemed more hazardous than Yellowstone, located in three parts of the United States.

Alaska



There are over 130 volcanoes in Alaska; more than any other US state. Of the 54 that are considered active, four are classed among the ten most hazardous volcanoes in the US, including Redoubt Volcano and Akutan Island.

Hawaii



Hawaii is home to six active volcanoes. These include Kilauea, which has been erupting almost continuously since 1983 and is considered the most hazardous volcano in the US, and Mauna Loa, the largest active volcano on the planet.

Western United States



Among the 20 volcanoes deemed more hazardous than Yellowstone are Mount St Helens and Mount Rainier in Washington, Mount Shasta and the Lassen Volcanic Center in California, and Mount Hood and the Three Sisters in Oregon.

...And there are existential threats far greater than a supervolcano that we should be worried about.

Life on Earth has always faced threats from a variety of natural phenomena, but the future is also filled with some terrifying new dangers. Below are some possible threats, as well as an estimated likelihood* of them leading to an existential catastrophe during the next century.

Asteroid strike -1 in 1,000,000



While there are no known asteroids that pose a threat to Earth, it's possible that one has evaded detection.

Supervolcano -1 in 10,000



Earth's history is filled with examples of volcanic destruction, including at least one mass extinction.

Nuclear war -1 in 1,000



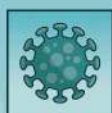
One nuclear blast wouldn't pose an existential threat, but the risk of a global nuclear war certainly could.

Climate change -1 in 1,000



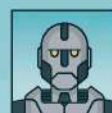
The changing climate could have devastating consequences for life on Earth over the next century.

Engineered pandemic -1 in 30



As our understanding of biology increases, so too do the risks posed by human-made viruses.

Artificial intelligence -1 in 10



Our greatest and most pressing existential threat is that posed by the rapid advancement of AI.

What would happen if Yellowstone erupted?

During the eruption, huge amounts of volcanic material would be ejected into the atmosphere, before falling back to Earth as a deadly rain of splintered rock, glass and ash that would devastate large parts of the United States, with consequences felt around the world.

-700km (435 miles) from eruption

Denver, Colorado

At this distance the devastation would be apocalyptic, with over 1m (3ft) of ash covering everything in sight, collapsing buildings, destroying infrastructure and causing people to suffocate.

-1,800km (1,120 miles) from eruption

Chicago, Illinois

This far from Yellowstone would see a few inches of ash deposited – enough to damage buildings and infrastructure, block roads, destroy agriculture and cause respiratory problems for millions.

-3,000km (1,860 miles) from eruption

New York, New York

On the other side of the US, a few millimetres of ash would fall. But even this small amount can be dangerous; the abrasive particles can cause skin and eye inflammation, and breathing problems.

-7,400km (4,600 miles) from eruption

London, UK

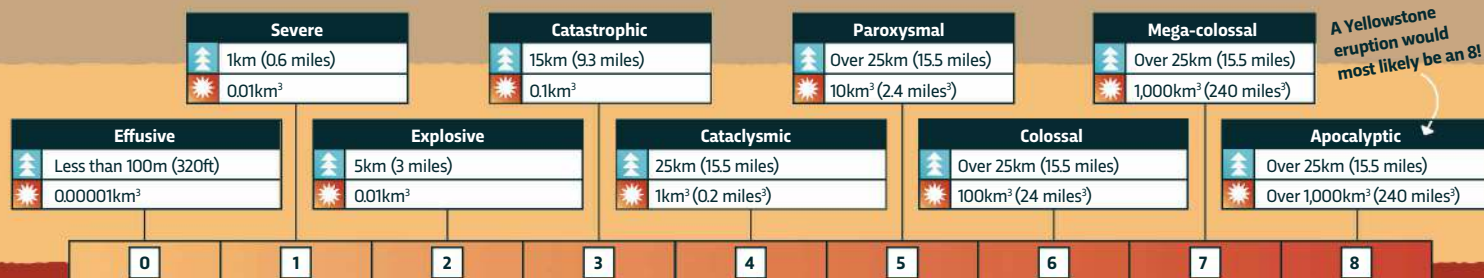
Even the UK wouldn't be safe from the eruption's effects. Dust and gases from the volcano would linger in the atmosphere for years, causing temperatures to fall, crops to fail and supply chains to collapse.



Can we quantify the scale of a volcanic eruption?

Created by the US Geological Survey in 1982, the volcanic explosivity index provides a means to measure the explosiveness of a volcanic eruption by looking at a variety of factors and qualitative observations.

Plume height
Ejecta volume



* Existential threat estimates are taken from *The Precipice* (2020) and are presented with a large amount of uncertainty. However, they do represent a well informed order of magnitude relative to each other.

DEAR DOCTOR

HOW DO I STOP TAKING THINGS PERSONALLY?

Most of us strive for self-respect – to see ourselves in a positive light, to be proud of who we are. Any comments or experiences that undermine those feelings of self-worth can be uncomfortable and it's only natural to want to avoid them. But the thing is, whether your self-worth really is being undermined is, to a large degree, subjective. Much of it comes down to your perception of what someone said or did.

When you take things personally, you're interpreting these situations as saying something significant and negative about you as a person. Say your boss picks holes in your sales report, and you come away feeling like this means she thinks you're a poor member of staff. Or, two of your friends cancel your planned get together at the pub and you interpret this as meaning they're bored of you. Psychologists have a term for this way of thinking: personalisation.

But the reality is that your boss might view you very highly. It's just you made some mistakes in the report and she wanted to point these out so that you do better next time. Similarly, in the case of your friends cancelling, perhaps they both felt unwell that weekend or they just changed their minds.

In both examples – and others that we all experience – there's another process at work that psychologists call mind reading. This is when you assume to know what other people are thinking about you, when you can't really know without asking them directly. In the examples above, if you

assume your boss thinks you're useless or you assume your friends think you're boring, then you're engaging in mind reading.

One simple way to avoid engaging in personalisation and mind reading is to challenge your negative assumptions of what's happened. When you find yourself taking a situation personally, try to think of other interpretations that are less focused on you – especially in the sense of saying anything deep or fundamental about you.

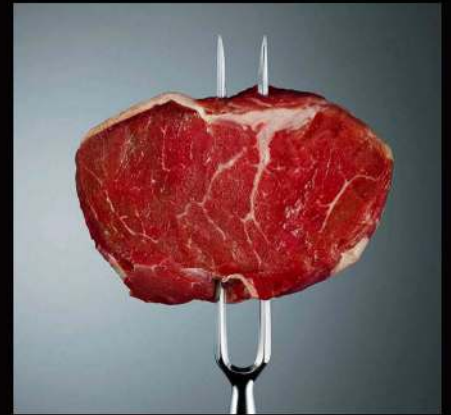
When you do this, it might help to try to put yourself in other people's shoes and see things from their perspective. For instance, it can be tricky to give negative feedback in a tactful way. But the fact your boss took the time to give you feedback at all means they care enough to want to help you improve. When it comes to your friends – maybe it's because your friendship is so strong that they felt able to cancel at late notice. And can you honestly say you've never backed out on plans, sometimes just because you felt tired or not in the mood?

Wanting to be proud of yourself is healthy. But pride comes in different forms – if you take pride in the idea that there's something inherently exceptional about you ('hubristic pride'), it's bound to make you more sensitive and prone to taking things personally. Try instead to take pride in your efforts, good intentions and achievements ('authentic pride'). This shift in focus will also help you become less sensitive and less inclined to take things personally **Q**



MELISSA MCBRIDE, SANDWICH

WHY DO I SLEEP SO WELL AFTER EATING RED MEAT?



The effect of red meat on sleep is a complex and controversial topic; some people report worse sleep while others claim they sleep better. One reason eating red meat can make you sleepy is because it's high in fat and protein. These require a lot of energy for your body to break down, which can leave you feeling tired and lethargic.

But don't let this sensation fool you into eating red meat close to bedtime, as research suggests late-night eating may hinder your ability to drop off. This is because an active digestive system isn't conducive to a restful state and can cause disruptions to your natural body clock, as well as sleep apnea and acid reflux.

Red meat also contains the amino acids tryptophan and tyrosine, which are precursors for serotonin, dopamine and melatonin – chemicals responsible for regulating your body clock and making you sleepy. But a recent study found that eating meat actually decreases sleep duration and quality, and that this effect gets worse the more meat is eaten. Scientists believe this is because red meat contains other amino acids that compete for absorption in the brain, meaning there's less tyrosine and tryptophan available to be converted into sleepy chemicals. Hence, their sleep-inducing effects may be reduced.

Ultimately, the impact of red meat on sleep varies from person to person. It may depend on things like the specific amino acid composition of a meal, different sleeping patterns, and differences in metabolism and responses to nutrients. **HMH**

DAVINA ORR, VIA EMAIL

CAN YOU TELL WHEN YOU'RE ABOUT TO BE STRUCK BY LIGHTNING?

Lightning is one of the most spectacular displays that nature has to offer. But while it may be enjoyable to watch, it's something that you would never want to be struck by. To understand why, you need to know what lightning is and what causes it.

Inside a thunderstorm (cumulonimbus) cloud, ice crystals and hail bounce around and collide with each other. This leads to the bottom of the cloud having a negative charge. But the top of the cloud and the ground it below both have a positive charge.

Eventually, the negative and positive charges build up so much, that a huge spark of electricity – lightning – is released, and hits either other clouds nearby or something on the ground.

The charge carried by a bolt of lightning is so intense that it has a temperature of 30,000°C (54,000°F) – that's five times hotter than the surface of the Sun. If you were struck by lightning, not only would you be electrocuted, but you would also be badly burnt.

So how can you tell if you're about to be struck by lightning? As the electrical charge starts to build up in the air, your hair – even long hair – would stand on end.

If you're outdoors in an open space, experts advise that the best thing to do is crouch down with your hands on your knees and your head tucked between them. Never seek shelter under a tree, as trees are more

likely to be struck and often catch fire, split and send sharp debris flying outwards.

The safest option of all, is to make sure you check the weather forecast beforehand, so you're never caught out. Then, as soon as you hear thunder, put yourself out of harm's way by seeking shelter in a building or car, and making sure that all the windows and doors are closed. **LD**

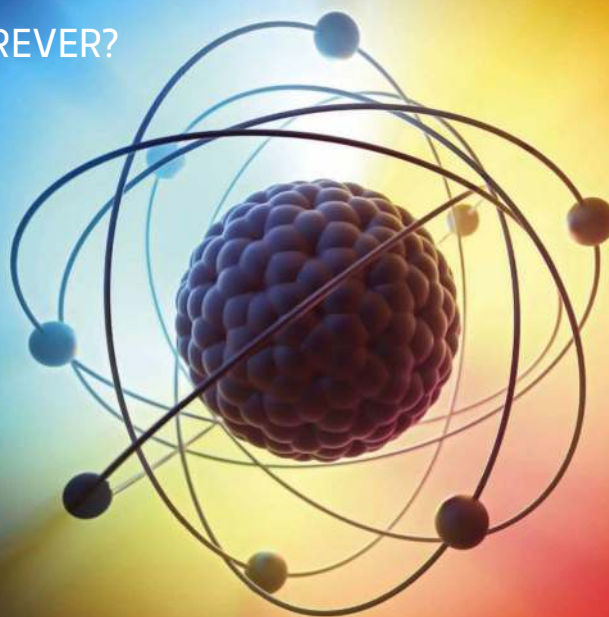


QUESTION OF THE MONTH

BRIAN SHIMELL, BANSTEAD

DO ELECTRONS LIVE FOREVER?

The 'standard model' of modern particle physics includes the inherent law that electric charge, like energy and mass, is conserved. Although theoretically an electron could decay into a photon and a neutrino, doing so would violate this principle. So, assuming electrons obey the law of charge conservation, they do indeed live forever. Experimental searches have so far found no evidence for spontaneous electron decay. This gives scientists an estimate for the minimum lifetime of the electron; it's about 6.6×10^{28} years – this is 66,000 'yottayears'. Since this is about 5 quintillion times the age of the Universe, even if electrons don't live forever, they may as well do! **AG**



WINNER

The winner of next issue's Question of the Month wins a pair of paperback popular science books: *The Biggest Ideas in the Universe*, by Sean Carroll and *The Art of Stargazing* by Dr Maggie Aderin-Pocock.



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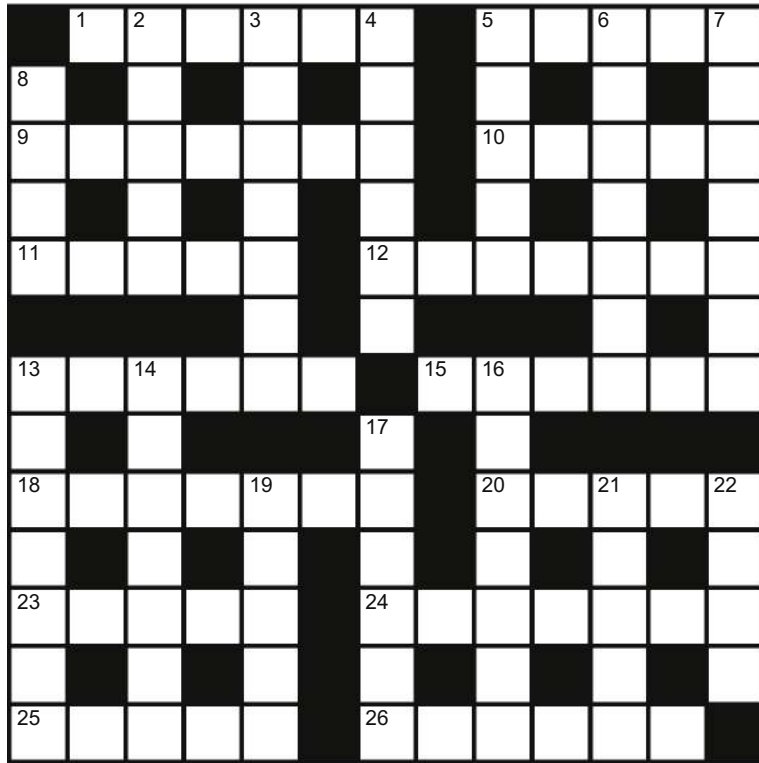
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CROSSWORD

PENCILS AT THE READY!



ACROSS

- 1 Happy to be told not to start (6)
- 5 Musical game (5)
- 9 Zero about strange lab being sweet (7)
- 10 Villain in Cairo, guessing (5)
- 11 Peculiar, losing American trinket (5)
- 12 Resentment one controlled in ship (7)
- 13 Group has right to my last drink (6)
- 15 Crime making one fly in a panic (6)
- 18 Walks with small monsters (7)
- 20 Quiet chat about material reinforcement (5)
- 23 Insinuate – like a rascal? (5)
- 24 Choose diamonds first, then mountaineering gear (3,4)
- 25 Sodium, sulphur and aluminium in one's nose (5)
- 26 Festival involved a steer (6)

DOWN

- 2 Unending regalia for an organ (5)
- 3 Old bait used daily (7)
- 4 Dig up doctor by the border (6)
- 5 She's often heard at Christmas (5)
- 6 Artist's unrestrained glee acquiring registered company (2,5)
- 7 In a severe way at the back? (7)
- 8 Endlessly obstruct some countries (4)
- 13 Graduate isn't worried about old supporter (7)
- 14 Concerning a rugby player - so wrong (7)
- 16 Ruler sends me back with reporters (7)
- 17 Hope for a bit of a church (6)
- 19 True alloy always conceals it (5)
- 21 Wit upset church more than once (5)
- 22 Tramp sees a sharp increase (4)

CAUTION: HOT SURFACE

What the recent volcanic eruption in Iceland reveals about the geological activity beneath it



PLUS

PLANET 9

Everything you need to know about the Solar System's as-yet-unknown resident

THE COSMOS DEFIES COMMON SENSE

Life, the Universe and everything is not what it seems. An expert explains why

ON SALE 15 FEBRUARY



GETTY IMAGES

**BETTER
LIVING
THROUGH
SCIENCE**

TO YOUR HEALTH!

Sobering science tells us that no amount of booze is good for our health. So should we rethink the way we drink?

During Dry January in 2023, the World Health Organization (WHO) issued a statement about alcohol that poured warm, stale lager on the idea that any amount of booze is good for you. There's no such thing as a safe drink, it said.

Issued in *The Lancet Public Health*, the statement reminded us that "alcohol is a toxic, psychoactive and dependence-producing substance and [was] classified as a Group 1 carcinogen by the International Agency for Research on Cancer decades ago." Sobering stuff, and a surprise for those of us who toast our health with the occasional tippie.

Everyone knows that drinking to excess is linked to a cocktail of ill health effects: damaged livers, hearts and mental health, plus increased risk of cancer. But most drinkers have also heard that, in small doses, alcohol bestows certain protective effects, such as cutting your risk of hardened arteries and reducing insulin resistance.

Of course, 'moderate drinking' is a subjective measure. In the UK it means 7-14 units of alcohol a week (14 units is about six pints of beer or a bottle and a half of wine). In Belgium, guidelines say that 21 drinks a week for men and



14 drinks a week for women is "low risk". So why has the WHO decided that any amount of booze is a bad idea?

Well, the WHO statement didn't appear in a vacuum. It partly resulted from a discussion about whether there's a 'threshold' at which alcohol becomes carcinogenic, explains Dr Jürgen Rehm, from the University of Toronto, whose work looks at the harm of alcohol and other drugs on public health.

"While even [the alcohol] industry doesn't deny that alcohol is a carcinogenic substance, there had been discussions about a potential threshold," he says. "That led to a re-evaluation of the evidence and a reiteration of the statement from the International Agency for Research on Cancer that there's no lower threshold."

In other words, just a single drink a week increases your risk of cancer. This echoes what other researchers have found in recent years. "There are a number of studies on breast cancer, which demonstrate risk from less than one drink a day," says Rehm.

And it's not just cancer. In 2021, scientists at the University of Oxford found that no amount of alcohol is safe for brain function, tracking the loss of grey and white matter in the brain with increasing amounts of alcohol intake.

In 2022, researchers also dismissed the idea that light drinking is good for the heart. Using data from over 300,000 people in the UK Biobank, they found that even a few drinks increases the risk of hypertension and coronary artery disease.

They also found that while light drinkers seemed to have a lower risk of heart disease than teetotal people, it wasn't the hooch that was helping. Instead, the study found that light drinkers were more likely to engage in other healthy behaviours, such as exercising and not smoking. It was those things – not the occasional glass of shiraz – that offered the benefits.

There's one more interesting point to emerge from these and other studies. In most cases, the health risks from alcohol increase the more you drink.

"Many risk curves with alcohol are exponential," Rehm says. "That means that health gains from reducing from four to two drinks a day are, by far, larger than reducing from two to zero drinks."

Nothing is life is risk-free, so if you enjoy the occasional drink then perhaps you're happy with the risk. "I personally wouldn't mind about the risk of three glasses [a week]," Rehm says, "unless you're genetically vulnerable for cancer."

For anyone cutting back after a very merry Christmas, it's natural to wonder whether Dry January should become a more permanent change. A growing body of evidence is clear: less is best. **SF**

TAKEAWAY ADVICE

There's no such thing as a beneficial amount of alcohol. So anything you can do to cut down your intake will help your health

by IAN TAYLOR

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

"WHILE LIGHT DRINKERS SEEMED TO HAVE A LOWER RISK OF HEART DISEASE THAN TEETOTAL PEOPLE, IT WASN'T THE HOOCH THAT WAS HELPING"



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