BBC

JAMES WEBB WHAT IT'S DISCOVERED SO FAR (HINT: THERE'S A LOT)

Science Focus

The enormous
POP QUIZ OF THE YEAR

The Universe's
MOST VIOLENT EXPLOSIONS

This year's
BIGGEST DISCOVERIES

END OF YEAR Q&A

SPECIAL ISSUE

Do video games make you smarter? ***Are we done with NFTs?***

How do I build a perfect snowman? *Is it good for your brain to avoid the news?*

Where is the contraceptive pill for men? ***Is the metaverse a fad?***

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This was Sylvia's promise to you...

A generation ago, a woman named Sylvia made a promise. As a doctor's secretary, she'd watched stroke destroy the lives of so many people. She was determined to make sure we could all live in a world where we're far less likely to lose our lives to stroke.

She kept her promise, and a gift to the Stroke Association was included in her Will. Sylvia's gift helped fund the work that made sure many more of us survive stroke now than did in her lifetime.

Sylvia changed the story for us all. Now it's our turn to change the story for those who'll come after us.

Stroke still shatters lives and tears families apart. And for so many survivors the road to recovery is still long and desperately lonely. If you or someone you love has been affected by stroke – you'll know just what that means.

But it doesn't have to be like this. You can change the story, just like Sylvia did, with a gift in your Will. All it takes is a promise.

You can promise future generations a world where researchers discover new treatments and surgeries and every single stroke survivor has the best care, rehabilitation and support network possible, to help them rebuild their lives.

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Find out how by calling 020 7566 1505
or email legacy@stroke.org.uk
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Rebuilding lives after stroke

Stroke Association

Why do lift rides with strangers feel so awkward? →p69

FROM THE EDITOR

Usually, I like to end the year by focusing on the positives, and this year I've really got my work cut out for me. That said, there has been a lot to feel hopeful about – and you'll find most of it inside this issue. First and foremost, the James Webb Space Telescope (JWST) produced its first images. Piece by piece, the JWST has been filling in the gaps in our knowledge, providing data that shines a fresh light on how stars, black holes and planetary systems work. To discover what we've learned so far, head to p44.

Back here on Earth, there was also much to be excited about. We saw the first launch of the Artemis mission, the programme that will put humans back on the Moon. The tech developed to fight COVID, mRNA vaccines, was spun into a potent vaccine that fights malaria, a disease that affects some 280 million people every year. Plus, palaeontologists discovered a dig site that was buried on the day that the asteroid which wiped out the dinosaurs hit Earth – a find that will tell the story of one of the most momentous days in the planet's history. Head to p20 to get a round-up of the year's key science stories.

Another positive has been our podcast, *Instant Genius*: it's brought us all kinds of science stories we might not have discovered otherwise. This year, we found out that one of the founders of the Medical Detection Dogs charity had her life saved by a dog, that you can hear astronomical data, and that what you think about your health can have a significant effect on your wellbeing. Don't miss out – come and find us on your favourite podcast app.

Enjoy the issue!

Daniel Bennett, Editor

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COVER: DANIEL BRIGHT THIS PAGE: BBC X2, PAUL WILKINSON, NASA, DANIEL BRIGHT

ON THE BBC THIS MONTH...

The Royal Institution Christmas Lectures
Okay, it's a tradition that's more than a century old, and has been presented by the likes of David Attenborough and Carl Sagan. But this year we're excited just because it's being hosted by Prof Dame Sue Black, a forensic scientist who's been involved in some of the UK's most high-profile criminal investigations.
BBC Four
28-30 December
Also available on iPlayer

The Documentary: Living In Space
With the Artemis programme, the idea of an off-planet settlement moves a step closer to reality. David Baker explores what we'd need to build a working community on another celestial body.
BBC World Service
10 December, midday

The Secret Genius Of Modern Life
We take technology like bank cards and GPS for granted – they're almost mundane. But powering these now ubiquitous technologies is some mind-blowing science. Hannah Fry tells the story of the science and engineering that shaped the modern world as we know it.
BBC Two
Thursdays, 8pm
Also available on iPlayer

CONTRIBUTORS

DR KATE DARLING
Kate, a researcher at MIT's Media Lab, studies how technology intersects with society. This month, she asks if we're really going to let robots into our homes. → p30

DR STUART CLARK
The images released from the JWST have been jaw-dropping. But what do they actually tell us that we didn't know before? Astronomer and author Stuart finds out. → p44

PROF LISA FELDMAN BARRETT
As a neuroscientist, Lisa studies how our brains (and bodies) create emotion. We asked her whether it might be better for our grey matter if we skipped the news once in a while. → p66

DR MERAV OZAIR
NFTs have lost their buyers millions. So are we finally done with this idea, or is the system here to stay? Merav, a leading expert in NFTs, cryptocurrency and blockchain, explains all you need to know. → p63

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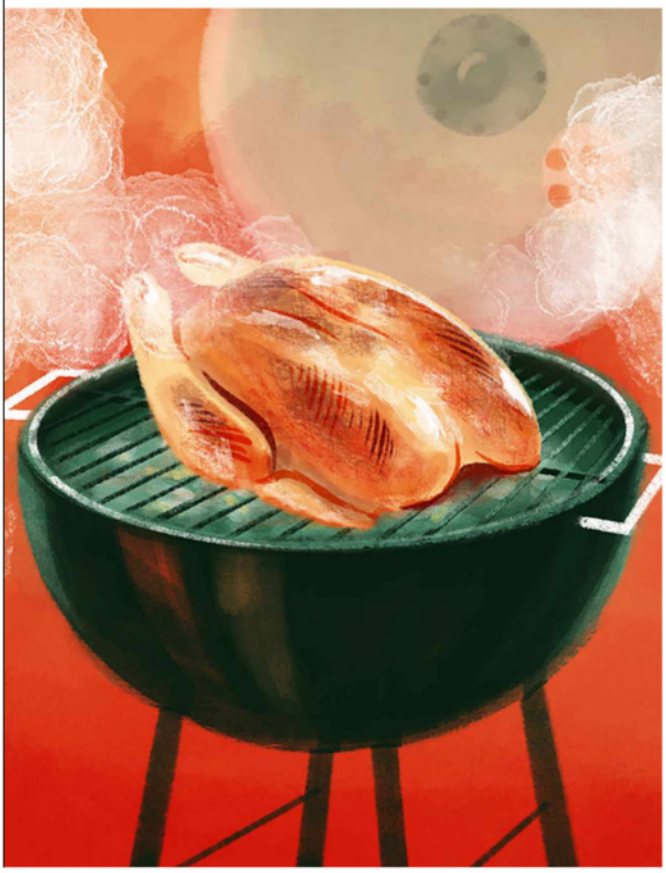

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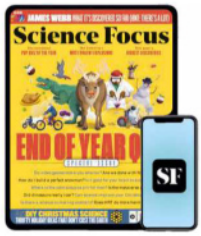

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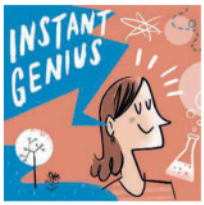

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EYE OPENER

Textbook landing

HOKKAIDO, JAPAN

Ignore what your eyes seem to be telling you about this image: flying squirrels can't take off from the ground. What this sequence shows is the way a flying squirrel sweeps upwards as it comes into land, after launching and gliding down from a spot higher in the canopy.

What's most unusual about this isn't the squirrel's flight path, though. It's the fact we can see it at all. Normally, this species of flying squirrel, *Pteromys volans orii*, only comes out at night. But after a pair of Ural owls began hunting in the Hokkaido forest during the winter of 2021-2022, the squirrels became more active during the day to avoid the new nocturnal predators.

The change in behaviour gave photographer Tony Wu a chance to capture these elusive rodents swooping through the dense trees, a feat they achieve by extending the furry membranes – called patagia – that connect their wrists to their ankles.

TONY WU/NATUREPL.COM

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EYE OPENER

Beat the heat

LANGLEY RESEARCH CENTER, VIRGINIA, USA

This structure might be the key to landing experiments, equipment and possibly even people on Mars. And it's inflatable. But it's not for cushioning the impact of hitting the planet's surface; it's for surviving the heat of atmospheric re-entry.

NASA is developing it as an alternative to the rigid heatshields currently used to protect payloads as they pass through a planet's atmosphere. The bigger the heatshield, the more heat it can absorb as it generates drag to slow the craft for a safer landing. The problem is, a rigid heatshield's dimensions are constrained by the size of the rocket it has to fit inside. An inflatable shield, however, can be stowed for launch, then inflated to a larger size when it's deployed.

This one is six metres wide when inflated, and if all goes well, it'll have undergone its first test (by re-entering Earth's atmosphere from low orbit) by the time you read this.

NASA/GREG SWANSON

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CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

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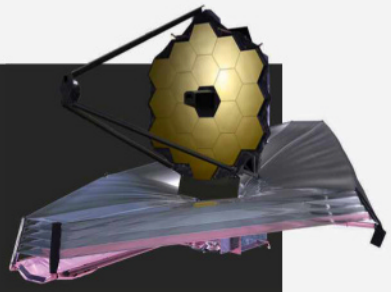
LETTER OF THE MONTH



Ode to the JWST

After reading lots of articles in your excellent magazine about possible explanations for the beginning and end of the Universe as we know it, I wondered if my little ode might amuse?

Where do we go from here?
When 15 billion years go by,
Will we freeze, or will we fry?
Should we worry, should we care?
One thing's for sure: we won't be there.
Or will we?
Will the James Webb Telescope,
Reveal a multiverse of hope?
Where we will leap from
world to world,
Our other lives to be unfurled.
Pi in the sky?
Recurring, again, and again,
and again...

Kay Hunting, via email

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a year's subscription to **Earthwatch Book Club**. For £10 a month, Earthwatch sends out a book every other month for readers, and then there is an online live Q&A with the author the following month. The carefully selected books feature a range of topics, including conservation, nature and the environment. Subscribers have access to recommended books, as well as offers on events. **earthwatchbookclub.com**

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Earthwatch Book Club

Rewilding for the future

Prof Adam Hart made a good point about what era do you aspire to rewild to (August, p42), but I suggest that the only genuine way to rewild is to leave an area totally undisturbed and accept what you get, even if it is unattractive. After millennia it will be full of new species we can't even imagine.

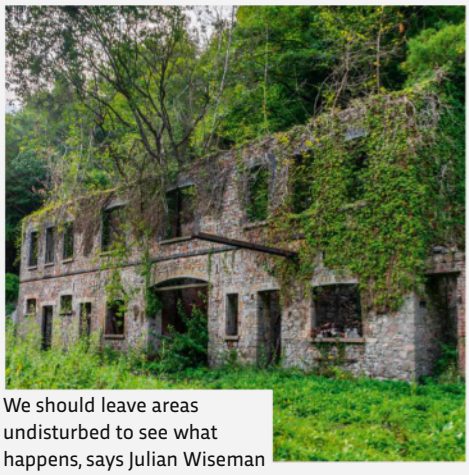
Julian Wiseman, via email

A question of biology

In your article about first contact, it was written: "...we won't share the same biology or the same brain" (October, p60). As far as I am aware, the Universe contains the same elements, and all life forms on this planet are carbon-based. From a chemistry point of view, am I right in thinking that the only other element which can chemically combine in the same way as carbon is silicon? Presumably, silicon-based life would be possible, and if so, why silicon and not carbon? Why should life on other planets not be carbon-based?

Geoff Todd, via email

That's a great observation. Yes, the chemical elements are the same everywhere in the Universe. So, extraterrestrial life may indeed be based on carbon, but that doesn't



We should leave areas undisturbed to see what happens, says Julian Wiseman

RESEARCH SHOWS THAT DELICIOUSNESS AND STRUCTURAL INTEGRITY OF A SANDWICH PLUMMETS WHEN YOU HAVE OVER FOUR FILLINGS"

DR STUART FARRIMOND, P85

There could be silicon-based life on other planets, as imagined here in this artist's impression

NASA, ALAMY, LEI CHEN/YAN LIANG/BEAUTYOFSCIENCE.COM/CALTECH

necessarily mean the biology will be the same. For example, perhaps the molecule carrying those alien genes will be different from DNA. Until we understand the origin of life on Earth, or see examples of alien life, we have no real idea how similar – or different – it will be. It seems prudent to assume it will be different, because what we do know about life on Earth is that evolution has taken many twists and turns to get where it is today. It seems highly unlikely that those same twists and turns will be replicated on a distant planet. Similarly, since brains evolve to 'cope' with the environment in which we live, a brain evolving on another planet may well be different from ours. As for silicon, it can bond to four neighbouring atoms in the same way that carbon does, which is why some people have speculated about silicon-based life. But those bonds are not as strong as for carbon, so the molecules would not be as robust.

Dr Stuart Clark, astronomy writer

Helping me understand

Thank you, Hayley Bennett, for your explainer article on the vagus nerve (September, p82). My husband just had a vasovagal syncope episode which was very scary, but this has helped me to understand it more. Thank you!

Shelley Röstlund, via Twitter

You are very welcome, Shelley. I'm glad to be of use! I hope your husband has recovered from his fainting episode.

Hayley Bennett, science writer

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DISCOVERIES

“The first launch of the Artemis 1 SLS rocket is a landmark moment”

Sue Horne, head of space exploration at the UK Space Agency **p14**

The Orion capsule, as seen in this artist’s impression, successfully launched on an SLS rocket on 16 November

NASA/JPL

SPACE

WE HAVE LIFT-OFF!

The UK’s Goonhilly Earth Station is tracking Artemis 1’s Orion capsule, putting British space science firmly on the map **p14**

SLEEP

SNOOZE SOUNDLY

Recurring nightmares can be reduced by sound therapy **p16**

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ANCIENT JOURNEY

Oldest-ever DNA found in the UK reveals hints of how people migrated here from Europe **p17**

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BIRDS FOR THE BRAIN

Watching birds and listening to birdsong boosts mental wellbeing **p18**

HEALTH

RAPID GAINS

Just 10 minutes of exercise a week could stave off the Grim Reaper **p19**

SPACE

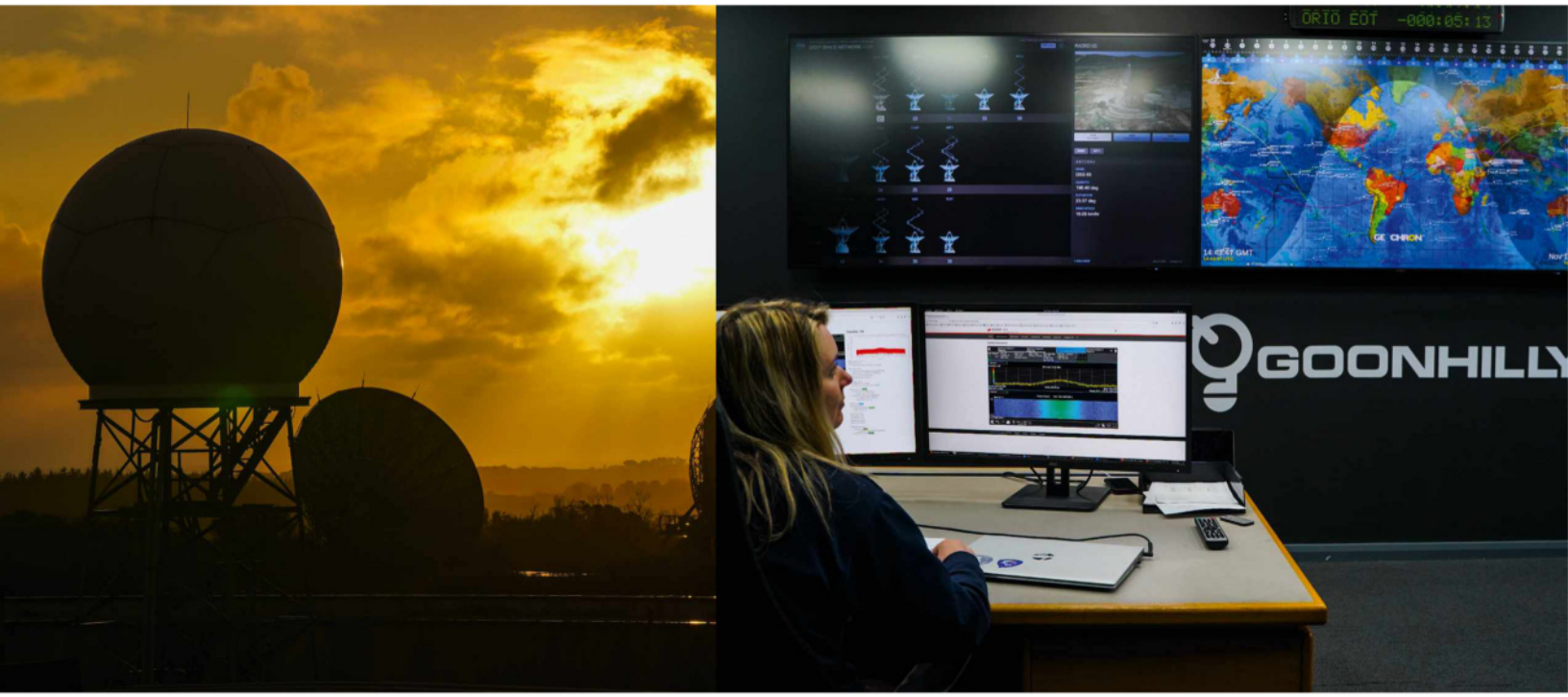
THE UK'S GOONHILLY EARTH STATION HAS STARTED TRACKING THE PATH OF NASA'S ARTEMIS 1

The collaboration is the first of several missions ushering in an exciting new era for UK space science

ABOVE Artemis 1 blasts off from the Kennedy Space Center

NASA's Artemis 1 mission successfully got underway on 16 November, with the Space Launch System (SLS) rocket sending the uncrewed Orion capsule on its journey to the Moon. The mission is the first of a series that will culminate with the space agency aiming to put humanity back on the lunar surface for the first time in more than 50 years.

Shortly following the launch, the Goonhilly Earth Station based in Cornwall picked up radio signals being sent from the mission's Orion capsule as it detached from the SLS launch rocket to begin its mission in earnest. The huge radio communications facility is now tracking the trajectory of the spacecraft as it makes its 25-day journey to the Moon and beyond, and is feeding data directly to NASA scientists in the US.



During its mission, Orion will travel within 100km of the lunar surface before being flung out by gravitational effects into an orbit around 70,000km beyond the Moon. It will then loop back and return to Earth, before splashing down off the coast of Baja California. For the entirety of its 2,000,000km round trip, it will be under the watchful eye of Goonhilly.

The radio communications facility will also be tracking the progress of six of the 10 CubeSat miniature satellites launched by Orion.

"Witnessing the first launch of the Artemis 1 SLS rocket is a landmark moment for the global space community, as we prepare to return humans to the Moon," said Sue Horne, head of space exploration at the UK Space Agency (UKSA).

"The rocket will place the Orion spacecraft in orbit around the Moon, which we will be able to track in the UK from Goonhilly Earth Station in Cornwall. The Artemis programme marks the next chapter of human space exploration, and we look forward to continued involvement as it comes to life," she added.

If everything goes to plan, NASA aims to send a crewed mission around the Moon as part of Artemis 2 in early 2024. In 2026, it then plans for Artemis 3 to land astronauts on the lunar surface for the first time since 1972.

Looking even further ahead, plans to build the Lunar Gateway – a small space station in orbit around the Moon – are currently slated for 2027. Again, UK science is involved in this mission. Researchers from Imperial College London are building a sensor that will monitor cosmic and solar rays to investigate their effects on astronauts and equipment, while commercial enterprise Thales Alenia Space UK is developing the ESPRIT refuelling module, which will enable the spacecraft to safely refuel while in orbit.

"I've been in this sector for 12 years now and I've seen it grow significantly in that time," said Andrew Kuh, manager of exploration and technology at the UKSA.

"That's through diversifying into parts of space that we didn't do so much before, such as launch, but also through increased investment in areas like Earth observation and telecommunications, where there's this huge potential still for more growth.

"I think we have a really good story to tell about how space can play a role in improving our fortunes as a country."

ABOVE LEFT
The antennas at Goonhilly Earth Station in Cornwall

ABOVE RIGHT
Operators at Goonhilly track the Orion spacecraft

"We have a really good story to tell about how space can play a role in improving our fortunes as a country"

GETTY IMAGES X3

SLEEP

RECURRING NIGHTMARES CAN BE REDUCED BY SOUND THERAPY

The treatment helped people have more positive dreams

Whether it's being unprepared for an exam, realising you are naked in public, or having your teeth suddenly fall out, around 1 in 20 of us are troubled by recurring nightmares. As well as being distressing, these nightmares can negatively affect sleep and lead to poor health. Now, help may be on the way, as sleep scientists at the University of Geneva have devised a method of cutting down the frequency of bad dreams using sound therapy.

Currently, those suffering from recurrent nightmares are prescribed 'image rehearsal therapy' – a form of treatment that involves patients changing the negative narrative of the recurring dream into a more positive one and then mentally rehearsing the scenario throughout the day. While this is effective in some cases, it doesn't always help.

In an attempt to improve the effectiveness of the treatment, the researchers recruited 36 patients undergoing image rehearsal therapy. They asked half of them to listen to a soothing sound while going through their positive dream scenarios, then had them wear a headband that played the same sound to them as they slept.

Both groups experienced a drop in the frequency of their nightmares, but the effect was more pronounced in those that were played the soothing sound. They also experienced more joyful dreams.

"We were positively surprised by how well the participants respected and tolerated the study procedures, for example, performing image rehearsal therapy every day and wearing the sleep headband during the night," said lead researcher Lampros Perogamvros.

"We observed a fast decrease of nightmares, together with dreams becoming emotionally more positive. For us, researchers and clinicians, these findings are very promising both for the study of emotional processing during sleep and for the development of new therapies."

The researchers now plan to trial the sound therapy treatment on larger scales, with a wider range of individuals, to further establish its efficacy.

ON THE PODCAST
Listen to an episode of the *Instant Genius* podcast about night disorders at **bit.ly/sleep_disorder**

THE FOUR STAGES OF SLEEP

It all starts when you shut your eyes

NREM STAGE 1
- Transition period between wakefulness and sleep
- Lasts around 5 to 10 minutes

NREM STAGE 2
- Body temperature drops and heart rate begins to slow
- Brain begins to produce sleep spindles
- Lasts approximately 20 minutes

NREM STAGE 3
- Muscles relax
- Blood pressure and breathing rate drop
- Deepest sleep occurs

REM SLEEP
- Brain becomes more active
- Body becomes immobilised
- Dreams occur
- Eyes move rapidly

GETTY IMAGES, TRUSTEES OF THE NATURAL HISTORY MUSEUM

HUMANS

OLDEST HUMAN DNA EVER FOUND IN THE UK REVEALS TWO DISTINCT POPULATIONS MIGRATED HERE FROM EUROPE

The remains of the ancient Britons were discovered in caves in Somerset and North Wales and date back more than 13,500 years

At least two genetically distinct groups of people made their way to Britain at the end of the last ice age, an analysis of the oldest human DNA discovered in the country has found.

To make the discovery, researchers from University College London, the Natural History Museum and the Francis Crick Institute analysed the remains of two ancient humans using radiocarbon dating and genome sequencing techniques.

One, a female unearthed from Gough's Cave in Somerset, was found to have lived around 15,000 years ago. She belonged to a group known for their use of stone tools and production of cave art, that moved through northern Europe around 16,000 years ago.

The other, a male found in Kendrick's Cave, North Wales, lived around 13,500 years ago and belonged to a group known as western hunter-gatherers, who migrated to Britain around 14,000 years ago from the Near East.

ABOVE The ancient human remains found at two cave sites in the UK

Around 17,000 years ago, as the last ice age was coming to an end, the climate in the UK began to warm. As temperatures increased, the glaciers that covered much of the country began to melt. The increasingly favourable conditions led to groups of Palaeolithic humans making their way to the UK from the continent.

"The period we were interested in, from 20,000 to 10,000 years ago, is part of the Palaeolithic – the Old Stone Age. This is an important time period for the environment in Britain, as there would have been significant climate warming, increases in the amount of forest, and changes in the type of animals available to hunt," said Dr Sophy Charlton, formerly of the Natural History Museum but now a lecturer in bioarchaeology at the University of York. "There are very few human remains of this age in Britain; perhaps around a dozen individuals from six sites."

As well as differing genetically, the two groups also differed culturally, having different diets and ritualistic practices.

"Chemical analyses of the bones showed that the individuals from Kendrick's Cave ate a lot of marine and freshwater foods, including large marine mammals," said study co-author Dr Rhiannon Stevens, from University College London.

"Humans at Gough's Cave, however, showed no evidence of eating marine and freshwater foods, and primarily ate terrestrial herbivores such as red deer, bovids – such as wild cattle called aurochs – and horses."

In Kendrick's Cave, decorated animal bones were found alongside the human remains, while Gough's Cave contained cups made from modified human skulls – an indication of ritualistic cannibalism.

> **"The Old Stone Age is an important time period for the environment in Britain"**

Studies of remains from other areas in the UK and across Europe are now needed in order to help fill out the picture further, the researchers say.

"Finding the two ancestries so close in time in Britain, only a millennium or so apart, is adding to the emerging picture of Palaeolithic Europe, which is one of a changing and dynamic population," said Mateja Hajdinjak, a postdoctoral research fellow at the Francis Crick Institute.

GETTY IMAGES

HEALTH

WATCHING OR LISTENING TO BIRDS CAN HELP BOOST MENTAL WELLBEING, EVEN FOR THOSE WITH DEPRESSION

Worldwide study using smartphone app uncovers mood-boosting effect of birds and birdsong

Here's an easy way to make yourself feel a bit chirpier: seeing or listening to birds can improve our mental wellbeing, a study carried out at King's College London has found.

The finding is based on data collected by a smartphone app named Urban Mind that was developed by King's College London, landscape architects J&L Gibbons and the arts foundation Nomad Projects. The app was downloaded by almost 1,300 volunteers from the UK, the European Union and the USA. Each day, the volunteers were sent three notifications by the app and asked

Creating good habitats for birds could also boost our mental health

"There is growing evidence on the mental health benefits of being around nature"

whether they could see or hear birds nearby, followed by a short questionnaire designed to assess their mental wellbeing. The researchers found that the volunteers' wellbeing was better when they could see or hear birds, compared to when they could not.

"There is growing evidence on the mental health benefits of being around nature and we intuitively think that the presence of birdsong and birds would help lift our mood," said lead researcher Ryan Hammoud, from King's College. "However, there is little research that has actually investigated the impact of birds on mental health in real-time and in a real environment."

The app also collected information on existing diagnoses of mental health conditions and found that the mood-boosting effect was even seen in those who were diagnosed with depression.

"The term 'ecosystem services' is often used to describe the benefits of certain aspects of the natural environment on our physical and mental health," said co-researcher Prof Andrea Mechelli, of King's College London.

"However, it can be difficult to prove these benefits scientifically. Our study provides an evidence base for creating and supporting biodiverse spaces that harbour birdlife, since this is strongly linked with our mental health."

HEALTH

GETTING JUST 10 MINUTES OF VIGOROUS EXERCISE A WEEK CAN HELP YOU LIVE LONGER

Fitness tracker study shows that getting several bursts of intense activity throughout the week can reduce the risk of cardiovascular disease and cancer

These days we are all busier than ever. For lots of us, finding the time to squeeze in a decent workout is becoming increasingly difficult. However, significant health benefits can be seen from getting as little as 10 minutes of vigorous exercise a week, a study carried out at the University of Sydney has found.

The team analysed UK Biobank data recorded on more than 70,000 adults aged between 40 and 69, without cancer or cardiovascular disease. Each participant was asked to wear an activity tracker that measured how much they moved over seven consecutive days.

The researchers then followed the participants' health records for an average of almost seven years, looking for associations between the volume and frequency of vigorous activity, and death from all causes, cancer and cardiovascular disease.

The team found increasing health benefits as the volume and frequency of vigorous activity increased, but significant benefits were seen even with small amounts of exercise.

Participants who undertook no vigorous activity were found to have a 4 per cent risk of dying within five years. This was halved to 2 per cent for those taking 10 minutes per week and halved again to 1 per cent for those taking 60 minutes or more.

"The results indicate that accumulating vigorous activity in short bouts across the week can help us live longer," said study author Dr Matthew Ahmadi of the University of Sydney, Australia.

"Given that lack of time is the most commonly reported barrier to regular physical activity, accruing small amounts sporadically during the day may be a particularly attractive option for busy people."

WHAT COUNTS AS VIGOROUS ACTIVITY?

Vigorous exercise is defined by the NHS as any activity that makes you breathe hard and fast. Anyone engaging in these activities will not be able to say more than a few words at a time without having to pause to catch their breath. Examples include swimming, running, riding a bike up a hill and walking up a flight of stairs.

2022 IN SCIENCE

This year, the news headlines have been dominated by UK politics, the energy crisis and the Ukrainian war. But there have been some fascinating scientific discoveries too. Here's the proof...

WE NOW KNOW MORE ABOUT THE DAY THE DINOSAURS DIED

In March, palaeontologists led by Robert DePalma were digging in the Hell Creek region of North Dakota in the US, when they found a fossilised dinosaur leg. That in itself was not unusual, as the region has long been known to be rich in fossil deposits. But this particular dinosaur, a *Thescelosaurus*, is believed to have been killed in the asteroid strike that wiped out the dinosaurs around 66 million years ago.

This makes it unique in the fossil record. In fact, until just a few years ago, no fossil had been found that lived even *around* the time of the impact. While debris and ash from the event shows up in core samples as a thin layer of dark sediment known as the KT (or K-Pg) boundary, no fossils had ever been found in the layers immediately below that, which represent a million years or so of evolution.

Dinosaurs could therefore, in theory, have died out thousands of years before the impact. But in 2013, DePalma was digging in an area of Hell Creek when he unearthed fish fossils buried in the same stratum as microtektites. These are beads of glass that form when molten rock is blasted into the air by an asteroid impact and then rains back down, solidifying as it falls. DePalma realised he had stumbled upon a geological snapshot of the extinction event itself and has since found many more fossils at the top-secret site, which he has named Tanis. He published his results in 2019 and caused an uproar in palaeontology circles.

But the discovery of the 'dino drumstick' in March is perhaps even more game-changing.

Around 66 million years ago, an asteroid smashed into what is now the Yucatán Peninsula. The impact threw dust and debris into the atmosphere, leading to widespread climate change that altered the path of Earth's evolution

It was found among fossilised debris that is believed to have been washed there in a huge wave of water after the asteroid smashed into what is now the Yucatán Peninsula.

"The 1.5m-thick surge deposit is temporarily constrained by the presence of ejecta – chemically and radiometrically shown to be associated with the Chicxulub impact – through the two main packages of sediment in the surge deposit," said University of Manchester palaeontologist Prof Phillip Manning, who is DePalma's PhD supervisor. "The limb of the *Thescelosaurus* is still relatively 'inflated', given the muscle mass of the limb is constrained by the skin envelope that shows little sign of decay, collapse or breakdown. This dinosaur may have died before the impact, but not more than a few days before. But given other soft tissue is found in the surge deposit, it seems likely that the animals were at least interred by this event."

DePalma and his team suggest that the leg was ripped from the dino's body by rocks and trees that were carried along by the wave, to eventually be deposited some 3,000km from the impact site.

Not all are convinced that the fossil can really be dated quite that accurately, and studies are ongoing. But if DePalma is right, we've gone from the idea of a dino-destroying asteroid first being mooted in the 1970s, to uncovering an actual victim of that impact, in less than 50 years – and that's truly remarkable.

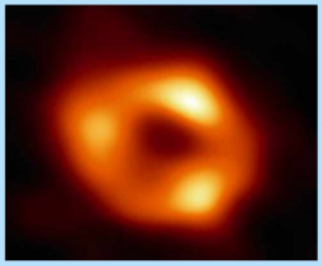
GETTY IMAGES, AERWINS, ESO/EHT COLLABORATION

HOVERBIKES ARE HERE

Unveiled at the Detroit Motor Show, Aerwins Technologies' XTURISMO Hoverbike is the new form of transport we never knew we needed. It runs on a hybrid powertrain, can reach speeds of up to 100km/h (60mph) and has a range of around 40km (about 25 miles). Yours for just $555,000 (£465,000 approx).

THE MILKY WAY'S CENTRAL BLACK HOLE IS SUPERMASSIVE

In May, the Event Horizon Telescope revealed the first-ever picture of Sagittarius A*, the black hole that lurks at the centre of the Milky Way. The eerie Eye of Sauron-like image shows the central black hole surrounded by a ring of matter colourised in orange, and is the most compelling evidence to date it is a supermassive black hole, EHT researchers say.



THE EFFECTS OF CLIMATE CHANGE MAY NOW BE IRREVERSIBLE

This year saw the publication, in stages, of the sixth report by the UN's Intergovernmental Panel on Climate Change (IPCC) – a report which both made for disheartening reading for many climate scientists, and in some ways offered a glimmer of hope.

Why disheartening? Because the sixth report confirmed what scientists have been saying for years: that human activity, particularly in the form of emissions of greenhouse gases, is responsible for the warming seen in the past few centuries, and that unless such emissions are radically reduced, we will soon bring about our own and our entire ecosystem's destruction.

The report concluded that 1.5°C of global warming over the next couple of hundred years is already 'baked in' – it is too late to do anything about that. This makes the goals outlined in the landmark 2015 Paris Agreement – when nations agreed to keep warming below 2°C, and hopefully below 1.5°C – that much harder to meet. To compound the problem, the IPCC report was followed later in the year by the COP27 summit, described by Prof Dann Mitchell, a climate scientist at the University of Bristol, as "a complete failure, other than some commitment on loss and damage. But we knew it would be."

And the glimmer of hope? The IPCC's sixth report was broader in approach than previous studies – looking in-depth for the first time at the role played in warming by short-term greenhouse gases such as methane, for instance.

"Reducing carbon emissions is always the best approach: stop the problem at its source," said Mitchell. "But we know from decades of trying that this isn't working so well, so we need other approaches to help with this. Methane is important, but it's so short-lived – that's why we haven't been so bothered when compared with carbon dioxide."

"One key thing was constraining climate sensitivity," Mitchell continued. "The more important IPCC working groups showed potential adaptation pathways to mitigate the impacts."

Those potential adaptation pathways outlined in the IPCC report are the other things we can do in terms of combating climate change and mitigating its worst effects, rather than simply reducing carbon emissions. This would include taking measures such as switching to a more plant-based diet (to reduce methane emissions), taking steps to curb both population growth and financial inequality, and striving to develop means by which we might remove CO_2 that's already in our atmosphere, rather than simply preventing it being released.

SCIENTISTS CURED 100 PER CENT OF CANCER PATIENTS IN A SMALL TRIAL

In a small study at the Memorial Sloan Kettering Cancer Center in New York, all 14 colorectal cancer patients treated with an experimental drug were cured, without the need for chemotherapy. The drug works by blocking the activity of specific proteins on the surface of white blood cells. The team now hopes to run a larger trial on a more diverse range of patients.

WE MAY RESURRECT THE THYLACINE WITHIN THE NEXT DECADE

Geneticists based at the University of Melbourne announced their 10-year plan to genetically resurrect the thylacine in August. Also known as the Tasmanian tiger, the iconic marsupial has been extinct for nearly 100 years after being hunted out of existence by European settlers. The researchers plan to genetically edit stem cells taken from the fat-tailed dunnart – the thylacine's closest living relative – to create and raise embryos using IVF techniques.

THE LARGE HADRON COLLIDER IS BACK ONLINE

In April, CERN's atom smasher fired up for run three after being shut down for more than three years for maintenance and upgrade work. This time the collision energy has been ramped up to a world-record 13.6TeV for another four-year run. Ongoing experiments include further probing of the Higgs boson, an investigation of antimatter and a search for dark matter candidates.

SPROUTING COSY FEATHERS HELPED DINOSAURS SURVIVE FREEZING VOLCANIC WINTERS

Researchers at Columbia University found evidence that dinosaurs' feathery insulation allowed them to survive the Triassic-Jurassic Extinction that killed off many reptiles 200 million years ago. Fossilised footprints of feathered dinosaurs found in a part of China known to have experienced freezing temperatures indicate that the dinos living there were able to tolerate the cold.

THE MALE PILL IS GETTING CLOSER

A contraceptive pill for males developed at the University of Minnesota proved 99 per cent effective in preventing pregnancies in mice. The key compound, dubbed YCT529, works by shutting off a protein that controls sperm production, and has no observable side effects. Human trials are expected to begin next year.

WE'RE STILL FIGURING OUT LONG COVID

While cases of coronavirus fell sharply after an initial surge earlier in the year, cases of long COVID still stubbornly persist. According to the ONS, there are currently more than two million people suffering from the illness in the UK. Symptoms vary from person to person but include fatigue, brain fog, joint and muscle pain and shortness of breath. It is still unknown exactly what causes long COVID, and there is currently no cure.

HUMANITY IS ON TRACK TO WALK ON THE MOON AGAIN

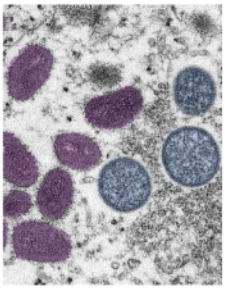
NASA's Artemis 1 Moon rocket was successfully launched from Kennedy Space Center on 16 November. The launch went off without a hitch, and the Orion capsule separated from the Space Launch System rocket around eight minutes later. The capsule then entered lunar orbit where it will remain until it eventually returns to Earth to splash down in the Pacific Ocean.

GETTY IMAGES X2, CERN

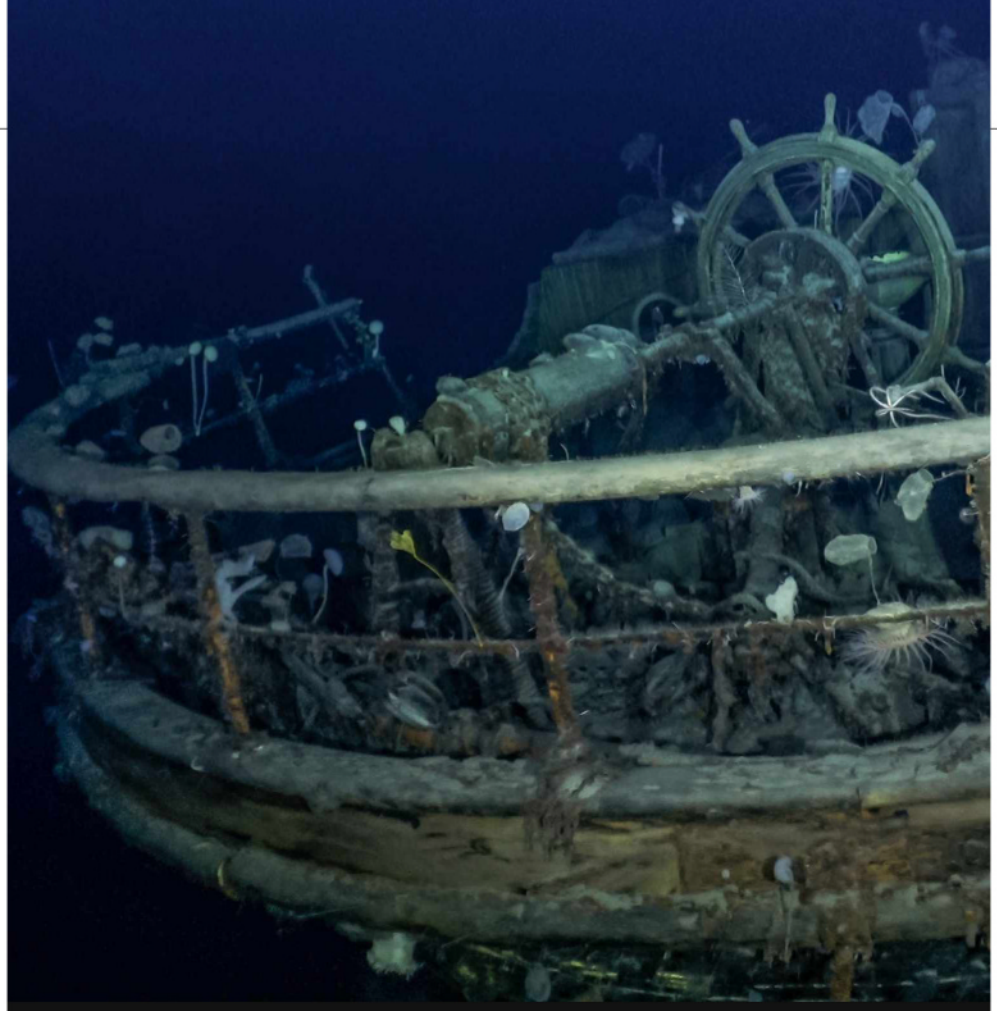
WE CAN LOOK EVEN DEEPER INTO SPACE

This year saw a raft of spectacular images released by NASA's spanking new James Webb Space Telescope. Since July, the telescope's scientific team has released a stream of images of distant galaxies and nebulae that are sharper and deeper than any that came before them. See more on p44.

MONKEYPOX DIDN'T TAKE HOLD IN THE UK



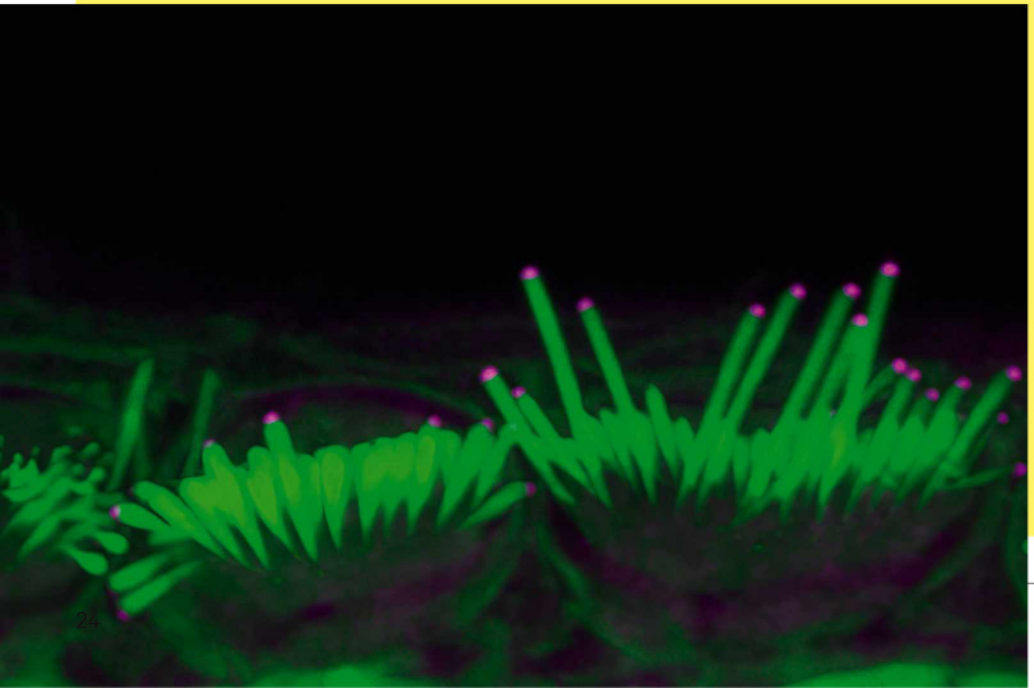
Concerns were raised about a new virus threat sweeping across the country when cases of monkeypox infection were confirmed in England in May. Like COVID, it is a zoonotic disease – meaning it can spread from animals to humans. Symptoms include a high temperature, headache and an unpleasant blistery rash, but the infection can be treated with antiviral medication. As of October, there have been 3,650 cases in the UK.



THE *ENDURANCE* HAS BEEN SITTING AT THE BOTTOM OF THE WEDDELL SEA FOR 107 YEARS

The wreck of the *Endurance*, the lost vessel of famed Antarctic explorer Sir Ernest Shackleton, was located by an expedition team put together by the Falklands Maritime Heritage Trust in March. It was found sitting 3km beneath the surface of the Weddell Sea off the coast of Antarctica. The ship has lain there since 1915 when it was abandoned by its crew after becoming trapped in pack ice.

FALKLANDS MARITIME HERITAGE TRUST/ENDURANCE22, NASA, SALK INSTITUTE, GETTY IMAGES



WE'RE GETTING CLOSER TO REVERSING HEARING LOSS

Researchers at the Salk Institute identified a protein that can help to regrow the tiny hair cells in the inner ear, known as stereocilia, which are responsible for detecting sound. Experiments carried out in mice showed that delivering the protein to stereocilia triggered their regrowth and improved or even restored hearing.

WE CAN (PROBABLY) SAVE THE WORLD FROM ASTEROID IMPACT

In September, NASA's DART mission successfully changed the orbital velocity of a small asteroid called Dimorphos by crashing into it, confirming that astrophysicists' best ideas about how to protect planet Earth from an asteroid strike do actually work.

Dimorphos, the smaller component in a binary asteroid system that also includes the larger Didymos, was never any threat to Earth – its orbit doesn't bring it close enough. It does, however, come close enough that getting a spacecraft to reach it wasn't an insurmountable problem, and it also just happens to be roughly the same size and shape as the sort of asteroids whose orbit may eventually put them on a collision course with Earth.

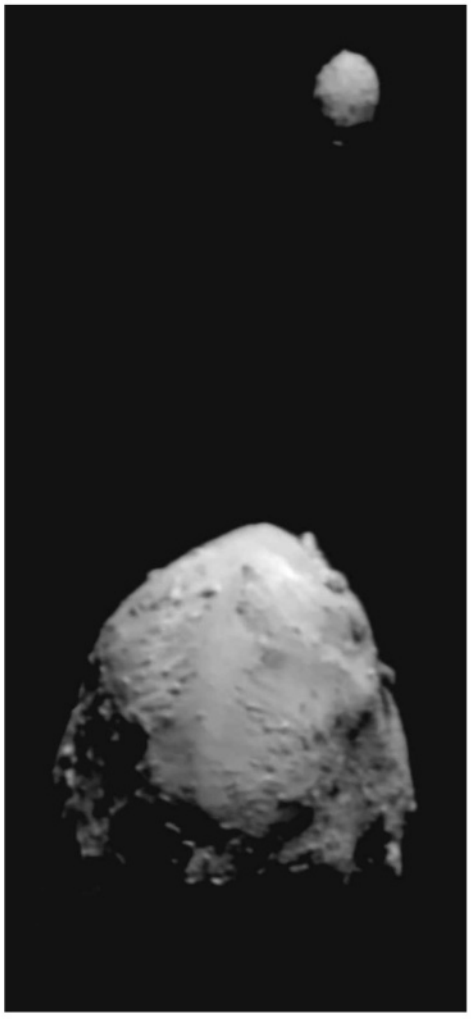
For these reasons, Dimorphos was chosen as the target for the DART mission. The name stands for 'Double Asteroid Redirection Test', and the goal was to see if the path of the asteroid could be changed by crashing a spacecraft into it, and so decreasing its orbital velocity (slowing it down).

This was no easy task: only one craft had ever been successfully landed on an asteroid before (Deep Impact, in 2005). As DART team member Prof Alan Fitzsimmons, from Queen's University Belfast, told *BBC Science Focus*: "The maths involved is pretty straightforward – if you hit something fast enough it will move! The unknown is exactly how much, which DART spectacularly showed us. Getting a spacecraft travelling at over six kilometres per second to hit a small 160m asteroid that's millions of kilometres away, when you've never directly seen the asteroid in a telescope? That's much tougher!"

Not only did DART get there and crash into the smaller asteroid as planned, subsequent observations revealed that the impact had indeed slowed Dimorphos down, reducing its orbital velocity by between 1.75 and 2.54cm per second. This in turn makes it more susceptible to Dimorphos's gravity, pulling it closer to its parent and reducing its orbital period from roughly 11.9 to 11.4 hours.

That might not seem a lot, but such changes increase gradually over time, and scientists have calculated that if a Dimorphos-like asteroid was hurtling towards Earth, decreasing its orbital velocity by as little as two centimetres per second, some 10 years before the projected impact, would be enough to shift the rock onto a non-Earth-threatening trajectory.

So that's mission accomplished for DART, then – and great news for life on Earth. "But there's still a long way to go," said Fitzsimmons. "Over the next few decades we need to discover all the near-Earth asteroids out there, so we know which ones we need to worry about. We'll also need to test other defence technologies, because asteroids come in all shapes and sizes."



BRAIN CELLS IN A DISH CAN PLAY VIDEO GAMES

In what must be one of the most bizarre studies of the year, brain cells grown by Melbourne-based Cortical Labs learnt how to play the retro video game *Pong*. The system, named 'DishBrain', was created using human stem cells and neurons extracted from the brains of embryonic mice. It was trained using a simple electrical feedback system designed to correct its wrong moves.

HURRICANE IAN WAS THE COSTLIEST STORM FOR 30 YEARS

In late September, the southeast coast of the US was battered by Hurricane Ian. At the peak of the storm, wind speeds reached 250km/h (155mph), flood waters reached 4.5m (15ft) and an estimated 1.7 million people were forced out of their homes. Repairing the damage is estimated to cost up to $42bn (£35bn approx) – the largest sum since Hurricane Andrew in 1992.

EARTH NOW HOLDS MORE THAN EIGHT BILLION HUMANS

On 15 November, the United Nations announced that the world population reached eight billion – that's one billion more than just 12 years ago. The staggering growth in numbers is due to improvements in medicine, hygiene and nutrition, along with persistently high levels of fertility, said the UN researchers.

COMMENT

CONTENT MODERATORS PAY A PSYCHOLOGICAL TOLL TO KEEP SOCIAL MEDIA CLEAN

We should be offering more support to the people who help to protect us from distressing online content

DR JULIA SHAW
(@drjuliashaw)
Julia is a psychological scientist at University College London, the author of multiple best-selling books, and the co-host of the hit podcast Bad People *on BBC Sounds.*

Content moderators are the unsung heroes of the internet. They work in a growing field which upholds the social media infrastructure of today. But keeping us safer, by constantly seeing and filtering the worst content online, takes its toll. Can people really cope with this constant barrage of horror?

One of the main handbooks for psychologists, the *DSM-5*, includes 'indirect exposure to aversive details' in the category of post-traumatic stress disorder. In extreme circumstances this can result in what is often called 'secondary trauma'.

Secondary trauma can happen when people, such as first responders, deal with victims in distress. It can also occur after seeing or reading distressing content. Among others, those who work in content moderation for social media companies, in medicine or psychology, and in social work, can all relate to how unhelpfully memorable horrible cases can be.

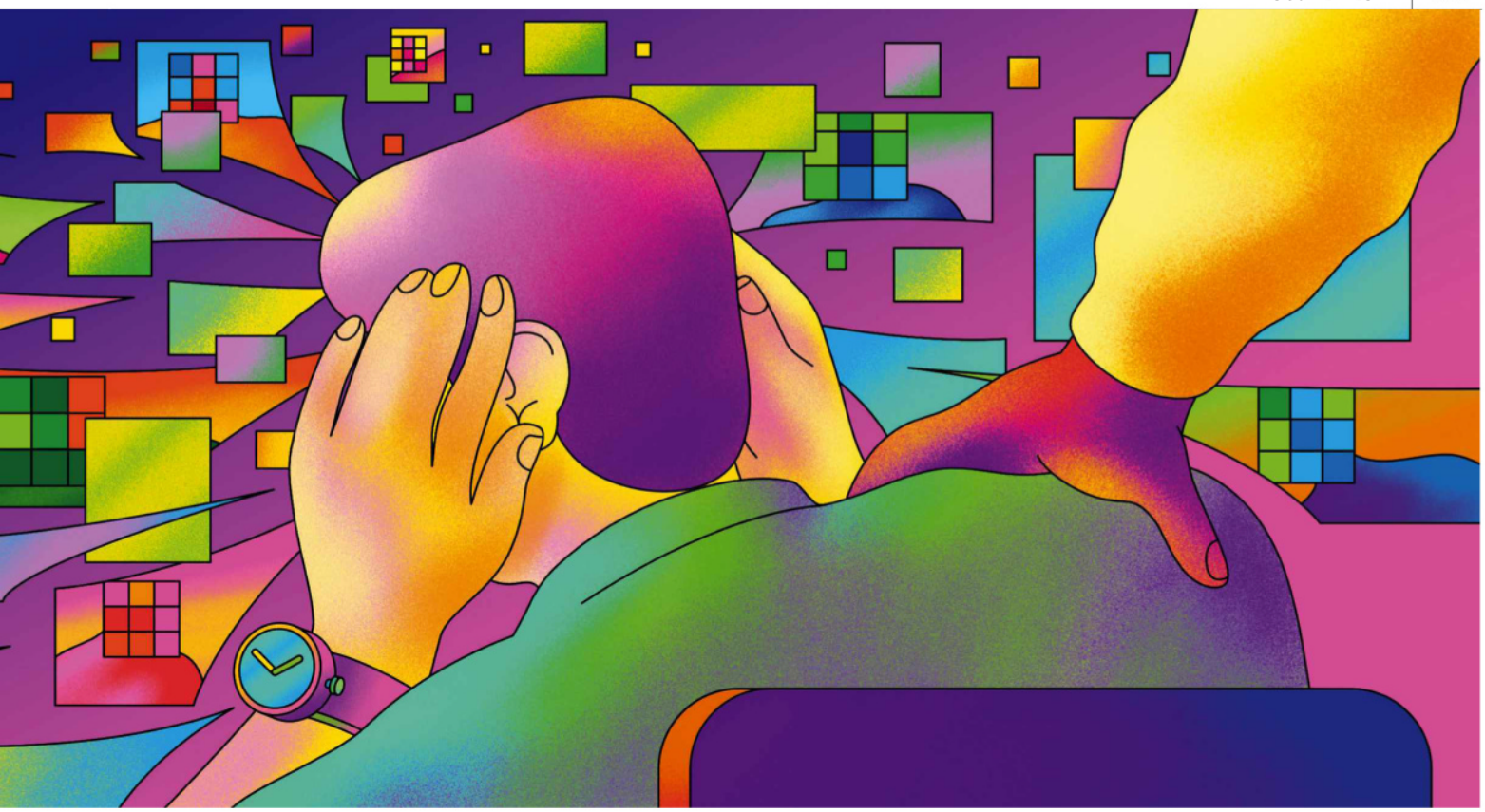
Personally, I have had flashbacks as the result of my work as a criminal psychologist. The most intrusive were after a case where I had an unusual amount of access to video content, including zoomed-in shots of highly emotional victim statements.

Among the first to study the specific impact of violent videos was a team led by stress and trauma researcher, Arija Birze. In 2022, the team published the results of two studies in which police, lawyers, judges, psychiatrists, law clerks and court reporters were interviewed.

In the first study, they found that in criminal justice settings, violent videos increase 'novel emotional proximity'. It's harder to stay unaffected when you can see every second of emotion in hyper-realistic detail. This is because, compared to photos, being able to see dynamic facial expressions leads to more activation of the parts of the brain responsible for empathy and emotional memory.

They also found what they named 'perpetual visibility'. Before cameras and high-res footage, most of the intimate details of a crime would have been unknowable, imperceptible, or fleeting. Details like the look on a victim's face while being attacked were previously limited to our imaginations. But now we are seated in the front row, sometimes even closer than the actual witnesses.

ILLUSTRATION: SCOTT BALMER



“The negative effects of violent content are cumulative, and compassion fatigue can develop”

The researchers also found that people were often blindsided by the violence. It can be impossible to be fully prepared for graphic images, even if you know they are coming. Added to this is an almost complete lack of training for many people dealing with these shocking videos.

It makes sense that the psychology of victims and perpetrators is prioritised, but the wider psychological fallout of these crimes also needs to be considered. Particularly because those in criminal justice and content moderation often need to watch video evidence over, and over, and over.

Unfortunately, in a second study, the researchers found that organisations have failed to keep up with the rise in disturbing video content. Criminal justice professionals are typically only offered help when they are so affected they can no longer do their jobs. Many don’t even get offered help then.

Because of this, people over-rely on colleagues who are themselves struggling, which can create what the researchers call an intense ‘trauma contagion’. This means that some people who are traumatised are amplifying each other’s suffering.

Interventions have been developed for content moderators, with mixed success. For example, in 2022 a group of researchers added positive content to breaks. Between distressing posts, they were shown pictures of cute baby animals and awe-inspiring landscapes. These kinds of pictures have been shown to decrease stress in other research settings, but here it had the opposite of the intended effect. This might be due to ‘affective contrast’, the happy images made the negative seem even worse.

It seems that the negative effects of violent content are cumulative, and compassion fatigue can develop over time. That’s when people have spent so much time helping safeguard others that they get burned out and their emotions become flat.

For professionals who regularly deal with distressing video content, in addition to organisations providing formal support, taking a break from the content can help. It’s also important to regularly zoom out. People who focus on general aspects of crimes and content, compared to specific details, are less likely to have flashbacks.

As technologies develop and new ones emerge, research needs to consider how to ensure people who keep us safe remain psychologically healthy.

BBC SOUNDS

Listen to Dr Julia Shaw on the *Bad People* podcast, available on BBC Sounds.

COMMENT

HOW COLD WAR PARANOIA LED TO A NEW EXPLOSIVE PROBLEM

The search for secret nuclear tests on the dark side of the Moon led to the discovery of the most violent detonations in the Universe

The first instrument to detect a gamma-ray burst (GRB) was watching for the end of the world. What it ended up seeing was quite possibly the end of someone else's.

In the 1960s, during the Cold War, the US military deployed a group of satellites called Vela to monitor Earth and nearby space for the characteristic flash of high-energy radiation (gamma rays and X-rays) that would give away the location of secret nuclear weapon tests, even if they were carried out behind the Moon.

The first events Vela observed, however, looked nothing like the kind of flash a nuclear bomb would

produce, and seemed to be coming from deep space. For years afterwards, experts debated their nature and origin: where could these spectacular bursts of radiation be coming from? Some argued they were extraordinarily bright explosions outside our Galaxy. Others thought they were some kind of ultra-powerful solar flare from stars close by.

The debate about their distance was eventually won through a clever argument that had little to do with the bursts themselves. Observers had noticed that the bursts were appearing all over the sky, with no concentration in any particular direction. Polish astronomer Bohdan Paczyński pointed out that left only two options. One: they're very close by, presumably arising from nearby stars; or two: they're so far away that they must be in distant galaxies.

In both cases, they'd appear everywhere, either because the clump of stars around us is too small a piece of the Milky Way for any of the Galaxy's structure to affect the distribution, or because on the largest scales in the cosmos, there's no structure big enough to stand out. It would be like if you saw a fuzzy image of yellow dots on a green background, and you didn't know if you were looking at a close-up of the petals on a bunch of yellow flowers, or an aerial shot of yellow bushes in a field. If it were anything in the middle, you'd see the shape of the bush, or a clump of bushes. But from close enough in or far enough away, the yellow is scattered pretty much everywhere.

In the case of GRBs, we had good reason to think they weren't that nearby, which left cosmological distances as the only possibility.

GRBs are now thought to have two origins. A 'short' GRB is caused by two neutron stars colliding. A 'long' GRB occurs when a massive, rapidly rotating star collapses on itself, creates a supernova and, in the process, causes energetic jets of radiation to shoot out through the poles of the stellar remnant. Long GRBs made the news in early October when what may have been the brightest burst ever recorded lit up the cosmos with so much power that it temporarily blinded several satellites and altered radio wave transmission by disturbing the Earth's ionosphere.

Officially dubbed GRB221009A, it also created a striking set of concentric rings in X-ray images, due to the way the light from the explosion bounced off layers of cosmic dust. Preliminary analyses of the burst suggest the star was so massive that it became a black hole after the explosion, and follow-up observations have found an optical-light afterglow that appears to be associated with the supernova.

We don't know if the star was orbited by any planets before it went off. If it was, they would have been destroyed by the supernova, if not the burst itself. But a GRB can cause devastation far beyond its own solar system. Some estimates suggest that a planet in the path of the burst could be virtually destroyed, even at a distance of 200 light-years, and impacts on an atmosphere could be felt even farther away than that. There have been hints that GRBs millions of years ago could have changed the chemistry of Earth's atmosphere enough to set off mass extinctions.

"A gamma-ray burst can cause devastation far beyond its own solar system. Some estimates suggest that a planet in the path of the burst could be virtually destroyed, even at a distance of 200 light-years"

Should we be worried? Probably not. Of the 1,700 or so recorded GRBs, the closest was a billion light-years away. And as far as we can tell, no nearby stars are massive enough to be a threat, and we don't have reason to believe there are any close neutron star pairs in danger of colliding soon, either.

As astronomers, we're grateful for GRBs: they help us learn exactly how and why stars explode in such a spectacular way. They also give us a useful probe of the cosmic material between us and them, by shining a very bright backlight on it.

Some theorists have even suggested that GRB221009A's most energetic photons might only have reached us with the help of exotic hypothetical particles called axions. As we keep watching for new GRBs, we'll gather more data that will help answer some of these questions, and fortunately, we don't have to get a close-up look.

DR KATIE MACK
(@AstroKatie)
Katie is a theoretical astrophysicist. She currently holds the position of Hawking Chair in Cosmology and Science Communication at the Perimeter Institute for Theoretical Physics.

NERISSA ESCANLAR ILLUSTRATION: MATT HOLLAND

COMMENT

ROBOT COMPANIONS ARE ON THEIR WAY, BUT DON'T WORRY, THEY WON'T REPLACE HUMANS

Don't be surprised if robots purchased to provide home security quickly become part of the family

Multinational tech giant Amazon recently released a household robot named Astro. The robot, currently available by invitation only, puts Amazon's virtual assistant, Alexa, into a dog-sized body with wheels that roams around your living space. Astro's primary function is home security. But, just like real dogs have gone from guarding our property to being part of the family, the role household robots play may eventually become one of companionship.

Futurists have long promised the arrival of robots in our homes, but so far, few have made it. Single-task devices, such as robot vacuums, are popular, as are virtual assistants. But Hollywood's vision of all-purpose robot aides remains elusive.

"Even if companies like Amazon put steps in place to protect user privacy, home security simply isn't the ideal application for a robot like Astro"

DR KATE DARLING
(@grok_)
Kate is a research scientist at the MIT Media Lab, studying human-robot interaction. Her book is The New Breed *(£20, Penguin).*

There are a few reasons why the home robot landscape is still so barren. One is cost, another is expectations. Science fiction, pop culture and misleading product promotion videos have given consumers the impression that robots are more capable than the current state-of-the-art can deliver. Furthermore, reliable, safe and useful robots are difficult to make, which means they're expensive – more expensive than most people are willing (or able) to pay.

These barriers, although real, are temporary. Development costs are decreasing and interactions with robots will improve as the technology develops. For example, recent breakthroughs in language learning models will soon enable much more satisfying conversations with AI agents. But the main challenge is figuring out what home robots are for. After all, consumers need a reason to want them.

Amazon is pitching Astro as a home security robot. Owners can use Astro to snoop around while they're out, connect it to other security devices and even have it patrol for intruders. And Astro isn't alone: last year, Amazon announced a flying drone that pairs with its security system to monitor your home.

This selling point is worrisome. Robots, equipped with cameras, microphones and sensors, have the ability to send information back to their manufacturers. This data can be shared with law enforcement, advertisers and other third parties. Many robots also use facial recognition, which is known to embed racial biases. But even if companies like Amazon put steps in place to protect user privacy, home security simply isn't the ideal application for a robot like Astro.

Named after the dog in the classic sci-fi cartoon *The Jetsons*, Astro is also built to interact on a social level. It has animated eyes, makes adorable sounds and has killer dance moves. It's no small feat to design these features, so why go to the trouble? Today, social robots that are predominantly intended as companions still lack a major market because people don't see why they would want one. But for those of us who work in human-robot interaction, it's clear: people can value a robot primarily for its companionship.

Take Jibo, a social robot launched in 2017. When the Pixar-lamp-reminiscent robot couldn't make it commercially, many people who had a Jibo were devastated. They wrote letters, formed communities, and grieved the loss of their robot friend. The response showed that a home robot, initially purchased as a novelty item, could become much more. But as of yet, there hasn't been a critical mass of people exposed to these sorts of devices.

If you worry that this means replacing your human friends, consider pets. Animals are our companions – not as a replacement for other people, but as a supplement. And interestingly, before dogs became our snuggle buddies, they had a different job. It turns out that a guardian for the home was an easier sell than convincing people they needed a four-legged friend. Over time, dog-ownership moved away from this practical justification and canines became part of the family.

Similarly, the use for home robots may change over time, as people purchase them for practical reasons and discover a companionship they didn't anticipate. These relationships could be useful: loneliness, a major societal concern, is correlated with early mortality and a slew of mental and physical health problems. Neither animals nor robots can fix societal issues, but they might help people feel a little less alone.

That said, dogs don't tell others your secrets, so one can only hope that companies are willing (or compelled) to pivot away from mass data collection. It's a tall order to ensure that the technology benefits society rather than corporate interests, but whether we like it or not, the era of robot companions is definitely coming.

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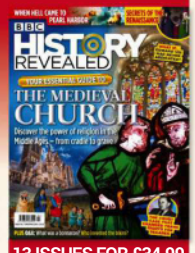

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CHRISTMAS WISHLIST

Okay, so it's hard to get in the Christmas spirit when energy prices are nearing the point where it might be more efficient just to set the cash on fire, and the economy looks like it's been shoved down the stairs in some grisly act of mercy. But that doesn't stop us daydreaming does it? Here's our wishlist of gifts that have driven us to distraction as we near the festive period

A futuristic VR experience

The reaction to the metaverse and the world of VR has been lukewarm to say the least, but that doesn't stop my curiosity getting the better of me. With Facebook, now rebranded as Meta, determined to create a virtual world that we'll all apparently be obsessed with, I am ready to dive in headfirst. To do this, I need a VR headset, and the Meta Quest Pro seems like the best choice. Yes, it's an eye-watering price, but the company is promising the latest and greatest specs. Maybe this will allow me to live out the ultimate virtual Christmas, complete with trees, decorations and glitchy avatars.

Meta Quest Pro
£1,499, meta.com
Alex Hughes, staff writer

A super-light camera

I am hoping that Father Christmas hears my plea for a Canon EOS R10 mirrorless camera. This new model is super-light, and much more portable than my old dSLR.

The controls are simple to operate, and will be familiar to anyone who has used a Canon dSLR in the past, as well as being relatively easy to use for someone who's just starting out in photography or graduating from a smartphone camera.

Even though it is the budget option in Canon's updated mirrorless collection, it has an impressive range of specs, including facial recognition, autofocus tracking and 4K video, and shares a lot of its features with the more expensive R7.

Plus, with the nifty R-mount adapter, I can use all my old lenses on this model, saving Santa a small fortune.

Canon EOS R10
£999.99, store.canon.co.uk
James Cutmore, picture editor

Renter-friendly smart home tech

Smart home tech is becoming increasingly renter-friendly. Take this camera which requires no wiring, or even Wi-Fi to work. You can stick the Arlo Go 2 anywhere and then connect to it via the camera's own 4G connection (which you'll have to pay for separately). This makes it perfect if you want it to keep watch over a garage, caravan or shed that's set away from your home's Wi-Fi network. Arlo's also got some similarly smart wireless doorbells to deal with visitors at the front of the house. You may need to buy a subscription for the best features.

Arlo Go 2 and Arlo Essential Wire-free Doorbell
£279.99 and £179.99, arlo.com
Daniel Bennett, editor

A tyre saviour

As I approach my 'middle years', I have decided to reacquaint myself with bicycles in an effort to stave off the cruel passage of time. But, to be completely honest, things haven't gone to plan. I seem to get a puncture every time I ride, so a device like this handy portable air compressor would be incredibly useful for me to keep moving and might even help me resist the temptation to throw my bike into the nearest ditch.

At only 124mm in length and 545g in weight, you can keep it in your bag wherever you go. It will also pump up car tyres, so it's perfect for keeping in the glovebox for emergencies.

Xiaomi Portable Electric Air Compressor 1S
£44.99, mi.com
James Cutmore, picture editor

A cinema in a box

This projector has been living rent-free in my head all year. I have a mortgage to pay, a leaky boiler to fix and an energy bill close to the GDP of Micronesia, but these trivial demands are all that stand between me and my one desire: this home cinema in a box. The Aura is an ultra-short-throw 4K device. That means it can sit snugly against a wall and beam its image upwards – there's no need to place the projector on the other side of the room and clear everything out of its way. There's a suite of Harman Kardon tweeters and woofers inside, providing Dolby surround sound, while an Android OS onboard gives me access to all those TV apps holding me back from financial freedom.

XGIMI AURA projector
£2,399, uk.xgimi.com
Daniel Bennett, editor

A computer for my bike

Whether you are serious about cycling and want to optimise your performance, or are more of a hobbyist looking for something to keep you motivated on your Sunday ride, chances are you've eyed up a dedicated bike computer at some point. As with a lot of bike-related kit, the price can lean into "how much?!" territory, but for a couple of hundred quid, you could do a lot worse than the Garmin Edge Explore 2. It's easy to set up and use, gives excellent navigation and has a reliable touchscreen and a battery that is unlikely to let you down mid-ride.

Garmin Edge Explore 2
£249.99, garmin.com
Jason Goodyer, commissioning editor

A techy hairdryer

Rather than blasting your hair with hot air which can damage the structure of each strand, the Zuvi Halo hairdryer combines infrared light with a warm breeze, making the drying process a gentler and more energy-efficient experience. I've got curly hair that can be prone to dryness and frizziness when I use a normal hairdryer, but I'd rather not sit around with wet hair for hours in the winter (especially when I can't afford to put the heating on). I'm hoping that this innovative hairdryer, which comes with a diffuser for curls, as well as a nozzle for styling, will give me the shiny, smooth coils that I crave.

Zuvi Halo
£329, zuvilife.com
Alice Lipscombe-Southwell, managing editor

A professional recording device

During lockdown, with conventional recording studios out of bounds, lots of musicians and podcasters turned to home studio setups to satisfy their creative urges – a trend that has continued apace post-pandemic.

Top of the shopping list is a high-quality microphone. But with a dizzying number of options out there, choosing the right one can be a bit of a minefield. A good place to start is the Rode NT-USB. It's well put together, sounds open and natural and comes with a sturdy stand and detachable pop filter. All you need is a laptop loaded with your favourite recording software and you're ready to go.

Rode NT-USB
£169, rode.com
Jason Goodyer, commissioning editor

A retro-looking radio

My old digital radio went to the electronics heaven in the sky, so I am keen to get hold of a new one. This pint-sized radio picks up FM, DAB and DAB+, but can also be used as a wireless Bluetooth device so you can stream your favourite music and podcasts direct from your phone. Plus, it charges up using a USB-C cable, so it's completely wireless too, making it a great option for taking on your travels (even if you're going no further than the end of the garden). The problem is, I don't know which of the four colours I like best!

Roberts Rambler Mini
£99.99, robertsradio.com
Alice Lipscombe-Southwell, managing editor

A way to experience space through photos

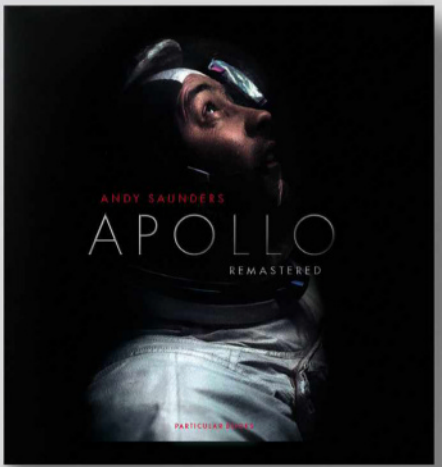
December 2022 marks the 50th anniversary of the last time humans went to the Moon. In this coffee-table book, science writer and NASA image expert Andy Saunders has raided the archives, and painstakingly restored and polished some rarely seen Apollo mission imagery.

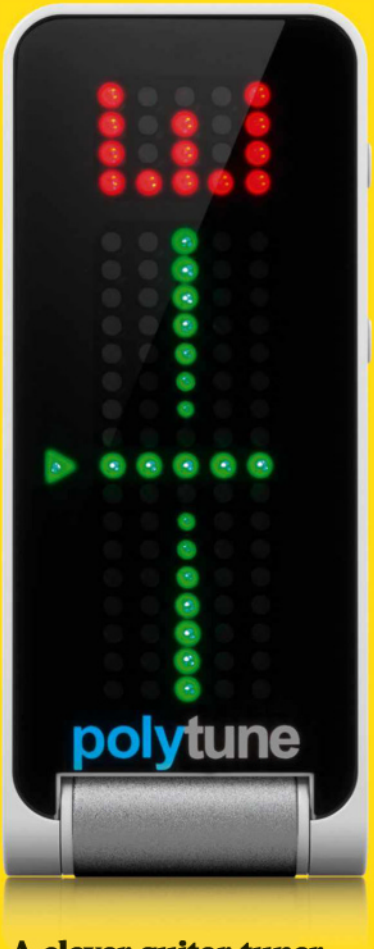
The result is a beautiful photography book, full of crisp and clean images that look like they could have been taken yesterday.

Starting off with the earliest NASA space missions, the book takes you on a journey through every Apollo space mission, sharing interesting insights and commentary along the way.

One of the highlights for me is the amount of pictures of sleeping astronauts during the hazardous Apollo 13 mission. Quite how they managed to snooze so well when they were in such danger amazes me.

Apollo Remastered
£60, penguin.co.uk
James Cutmore, picture editor





A clever guitar tuner

Okay, so any experienced guitarist worth their salt can tune their instrument to itself. But nothing beats the ease and convenience of a decent chromatic tuner, especially for beginners or those playing in bands that need to get up to concert pitch as quickly as possible. This one is about as natty as they come. Simply clip the unit to your headstock, pluck a string and then let the KITT-from-Knight-Rider-style display guide you to perfectly pitched plucking. There are similar tuners on the market, but this one gets my vote due to its clean, minimalist design, along with a bright, easy-to-read display that stands out on even the darkest of stages.

TC Electronic Polytune Clip
£45, tcelectronic.com
Jason Goodyer, commissioning editor

A health tracker for my loved ones...

Luckily my mum doesn't read this magazine, but as she settles into retirement I worry about her health. With fall detection, a heart rate monitor and temperature sensors, it's almost irresponsible *not* to wear the new Apple Watch. There's the latest 8 model, which adds additional motion sensors and a temperature sensor to the mix. These mean you get more accurate fitness data, crash detection (your phone will call the police if it believes you're in an accident) and cycle tracking. The same is true of the more affordable SE, only it doesn't have the temperature sensor. Ultimately, the watch can't diagnose health conditions, but it will provide data that you can show your doctor if you have concerns.

Apple Watch 8 and SE
From £419 and £259,
apple.com

Daniel Bennett, editor

Headphones that are all about style

In-ear headphones have never worked for me. For whatever reason, any squishy earbuds that are meant to fit snugly in my ear canals instantly fall out, leaving me chasing them down the road.

The brand Nothing has released a pair of earbuds that I'm eyeing up this Christmas. Known as the Nothing Ear (stick), they have a feather-light, ergonomic design that I'm hoping will comfortably fit my odd-shaped ears.

They come in a thin, stylish case that you rotate to open. They cost a fairly reasonable £99, have up to 29 hours of listening time, and come with an impressive audio performance that will be perfect for runs and my commute.

Nothing Ear (stick)
£99, nothing.tech

Alex Hughes, staff writer

Shoes that care for the environment

I've been on the hunt for a new pair of running shoes for a while now. While there are plenty of big brands vying for my attention in this domain, it's the lesser-known Allbirds that have won me over this Christmas.

The fabric of these shoes is made using eucalyptus trees, certified by the Forest Stewardship Council. But while their small eco-footprint is the big selling point, they are also optimised to be long-lasting running shoes that are flexible and comfortable to boot. I won't be running over the Christmas period, as I'll be weighed down by turkey and stuffing, but these trainers are sure to pay off in the new year.

Allbirds Tree Dasher 2
£125, allbirds.co.uk
Alex Hughes, staff writer

All the kitchen gadgets that I could ever want

Ignore the naysayers, an air fryer really does make your food crispier than an oven while saving you money too. There are plenty of options out there, but this, the Inspector Gadget of air fryers, is our choice: it can slow cook, steam and pressure cooker as well as fry. On top of that, it can prove dough, steam bake, dehydrate, roast, and even make yoghurt.

The rack system means you can prep multiple dishes at once (maybe some rice cooking below some chicken breasts) and there's a temperature probe inside for ensuring that joints of meat are the perfect temperature. Ultimately, this is a great piece of kit if you want to save on energy while cooking. If it could peel an onion, you'd have to pay it a wage.

Ninja Foodi MAX 15-in-1 SmartLid Multi-Cooker
£299.99, ninjakitchen.co.uk
Daniel Bennett, editor

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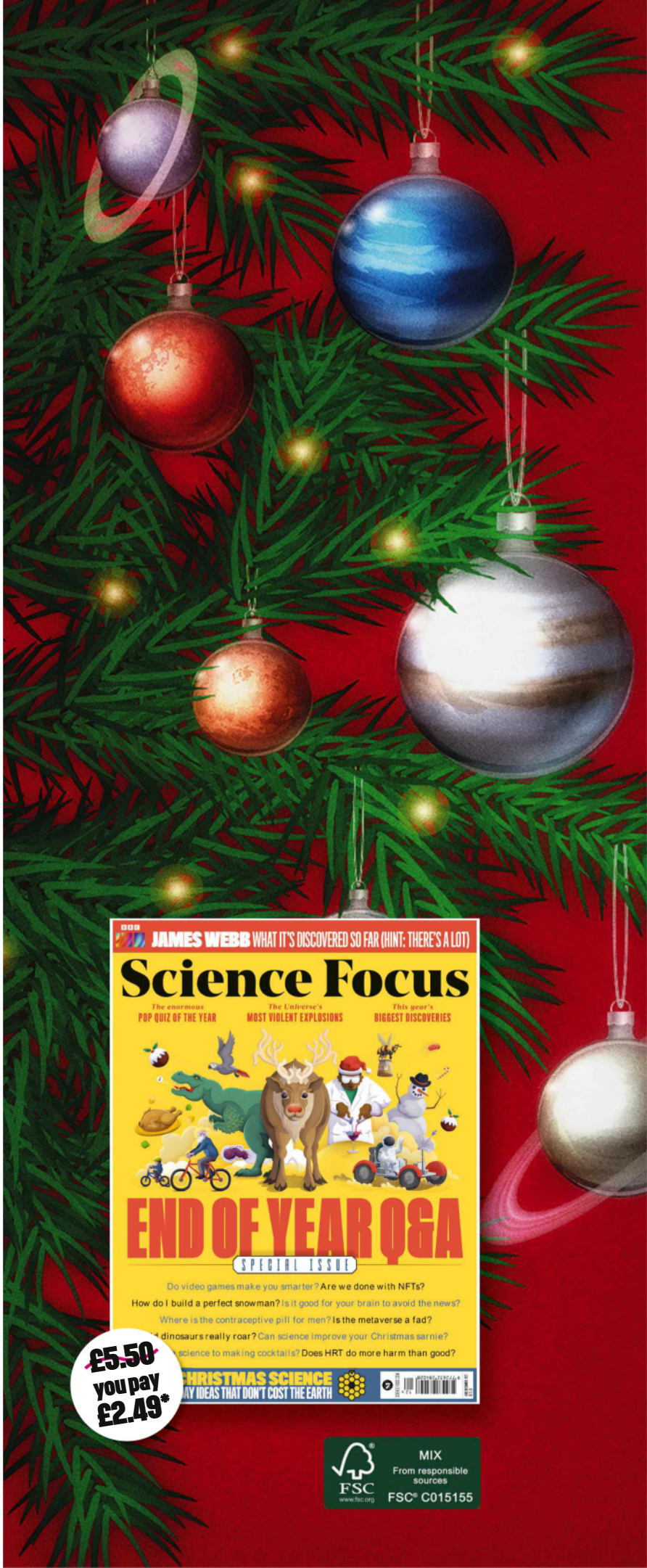


JAMES WEBB'S FIRST YEAR IN SPACE

WORDS: DR STUART CLARK

IN JUST A FEW SHORT MONTHS, THE JAMES WEBB SPACE TELESCOPE HAS IMAGED THE UNIVERSE AS NEVER BEFORE. HERE ARE ITS BIGGEST DISCOVERIES SO FAR

The first images beamed back from NASA's James Webb Space Telescope (JWST) have stunned the world this year. Launched on Christmas Day 2021, it took a month to arrive at its destination in space, a gravitational sweet spot 1.5 million kilometres further out into the Solar System. It then underwent an extraordinary sequence of deployment, unfurling a tennis-court-sized sunshield and unfolding a segmented mirror measuring 6.5 metres in diameter before any further work could take place.

Once everything was powered up and online, operators began the painstaking job of commissioning the instruments and making sure everything was working correctly.

The JWST is the largest telescope ever launched into space. It works at infrared wavelengths of light. These are rays that have a longer wavelength than the light we can see with our eyes. We generally perceive infrared radiation to be heat, which is why so-called 'thermal cameras' are infrared in nature.

Finally, on 11 July 2022, we got to see its first images. And they were breathtaking. Giant celestial landscapes of dust and gas were revealed, as were the deepest reaches of the Universe. There were huge, interacting galaxies, and dying stars in their final throes of life.

But the images themselves, however mind-blowing, are just the tip of the iceberg. Behind them are mountains of data that are set to reshape our understanding of the Universe. From the deepest realms of the cosmos all the way home to the celestial backyard of our Solar System, there is not a single domain of the Universe that the JWST cannot make a meaningful investigation.

In truth it is still early days for the actual results. Astronomers around the world are still getting used to the data that is now streaming down to Earth. But it is very clear that the JWST looks set to fulfil every science promise and then some.

NASA/ESA/CSA/STScI

THE EARLY UNIVERSE

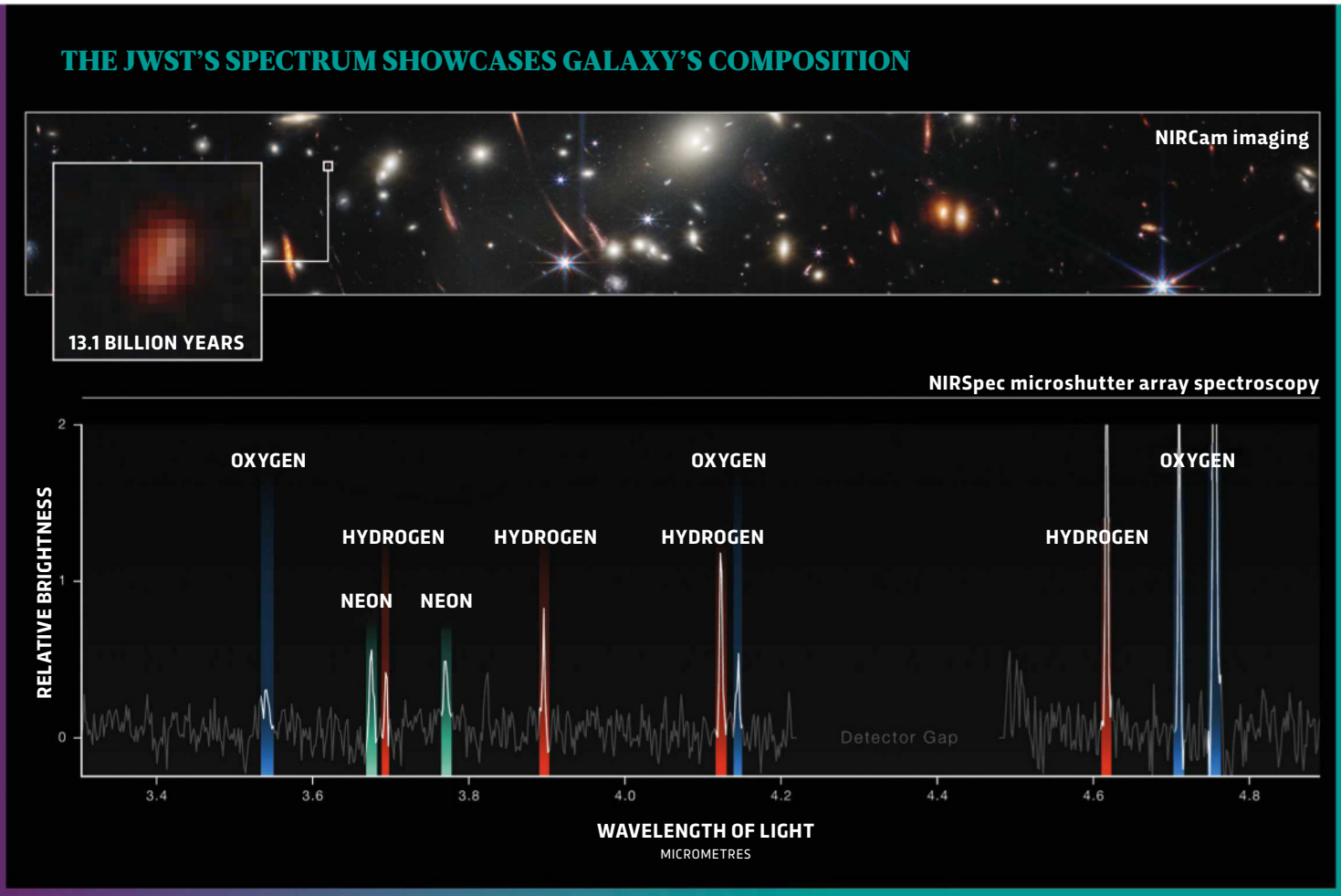
One of the JWST's science objectives is to look into the distant reaches of the Universe to see how the first galaxies were born. It can do this because light takes billions of years to cross our cosmos. When the JWST collects this light, it is seeing those objects as they looked billions of years ago. To reflect this fact, astronomers refer to distances in light-years, which is the distance light can travel in a year. And the first image to be released by the team highlighted this point. It was unveiled on 11 July 2022 by US President Joe Biden, speaking from the White House, and it was a 'deep field' image. Deep fields came to prominence in 1995 when the Hubble Space Telescope peered at a single patch of sky for 10 consecutive days, starting on 18 December. The selected patch was little more than a tiny speck, about one 24-millionth of the whole sky. Yet Hubble revealed around 3,000 previously unknown objects, mostly galaxies that are billions of light-years away. Centred around the galaxy cluster SMACS 0723, the JWST's deep field spans a similarly minuscule patch of sky.

"It's the equivalent to having a grain of sand and holding it at arm's length, while standing on Earth. That grain of sand will blot out a small sliver of the sky, and yet there are thousands of galaxies and features that we've never seen before just in that one image," says Caroline Harper, head of space science at the UK Space Agency.

SMACS 0723 itself is 4.6 billion light-years away. Its mighty gravitational field acts like a magnifying glass to more distant galaxies behind. Where the gravitational field is the strongest, it distorts the background galaxies into great arcs. In one case, the light from a distant galaxy was measured to have been travelling through space for 13.1 billion years before being collected by the telescope.

As the Universe expands, it stretches the light that is being emitted. The JWST's main target galaxies are so far away that the stretching has transformed the visible light from their stars into infrared. So by collecting those wavelengths, astronomers can compare the JWST's observations directly with the visible light images of closer galaxies from Hubble and other observatories. This will reveal the way galaxies evolve through cosmic time, growing larger and building up into the shapes we see today.

Perhaps the most amazing thing about the JWST's first deep field image is not just the number of galaxies, but the speed with



which it can take such images – just hours, rather than days. In fact, it cannot help but detect galaxies almost everywhere it looks.

"The one big feature that jumps out with all the data is the fact that there's just so many galaxies. Everywhere you point – particularly in the near-infrared – you don't even have to integrate for very long, and you're gonna have like 200 galaxies all over the place," says Sarah Kendrew, an instrument and calibration scientist for the European Space Agency.

It is not only galaxy clusters that are serving as magnifying glasses. The JWST's image of a pair of galaxies, catalogued as VV191, was taken so that the scientists could analyse how light from one of the pair changed as it passed through the other. The analysis will betray the characteristics of the dust in the intervening galaxy.

Astronomers noticed that the telescope had also captured the faint arc of an even more distant galaxy, distorted by one of the galaxies they were studying. Because the lensed galaxy's shape depends on the mass of the lensing galaxy, they now have a way of measuring the mass of the galaxy that they did not have before.

NASA/ESA/CSA/STSCI X3

PREVIOUS PAGE The first image released by the JWST, unveiled by US President Joe Biden at the White House, is a deep field image of the galaxy cluster SMACS 0723

FAR LEFT This galaxy emitted its light 13.1 billion years ago. It was captured by the JWST's microshutter array, part of its NIRSpec instrument. This is so sensitive that it can observe the light of individual galaxies that existed in the early Universe

ABOVE The Cartwheel Galaxy formed when a small, unseen galaxy passed through it. This sent a shockwave rippling outwards triggering the star formation captured here by the JWST's MIRI and NIRCam instruments

LEFT Composite image from the JWST and Hubble, showing two galaxies catalogued as VV191

NASA/ESA/CSA/STSCI/JUDY SCHMIDT X2

GALAXIES AND BLACK HOLES

One of the first images released by the JWST was of a small group of galaxies known as Stephan's Quintet. This collection of galaxies features four galaxies that are so close to one another that they are gravitationally interacting. The fifth galaxy in the grouping merely appears close. In reality, it is much closer to us and just happens to lie in the same line of sight.

Together, the quartet of interacting galaxies form a 'laboratory' in which astronomers can study the way galaxies interact and merge with each other. Such mergers are thought to have been exceptionally common in the early Universe, where they were the principal route for galaxies to grow into the gigantic star cities we see around us today. The mergers are also thought to be responsible for the growth of supermassive black holes, an example of which now lies in the centre of every galaxy.

The JWST studied Stephan's Quintet with its NIRCam and MIRI instruments. In particular, the MIRI images came as a surprise because the shapes of the galaxies were not what astronomers were expecting.

The Phantom Galaxy M74 also provided the MIRI instrument with another stunning success. Located 32 million light-years away, M74 is a spiral galaxy that we see almost exactly face-on. It is a favourite for studying the giant spiral arms that give spiral galaxies their name. But no one has seen it so clearly before. The spiral arms of the galaxy, where star formation is taking place, can be seen for the first time reaching down into the very centre of the galaxy.

As well as the brand-new discoveries that everyone hopes the JWST will make, collaborations will also be a major focus, combining the telescope's new observations with those from other observatories in order to unlock a greater understanding of the celestial objects being studied.

For example, the observations of M74 are part of a larger effort to target 19 nearby star-forming galaxies. These galaxies have already been imaged by Hubble and various ground-based observatories. The JWST's observations will allow astronomers to more accurately pinpoint star-forming regions, measure the masses and ages of star clusters, and uncover the physical and chemical nature of the dust grains drifting through the galaxies.

LEFT Stephan's Quintet is a laboratory for studying gravitational interactions between galaxies. This image from NIRCam and MIRI contains more than 150 million pixels and is constructed from 1,000 separate image files

ABOVE At mid-infrared wavelengths, as seen by MIRI, the traditional shape of the galaxies disappears. This is because MIRI is not sensitive to starlight, which we traditionally use to define a galaxy's shape

What's the JWST looking for?

The JWST is the most technically advanced space telescope ever created. It's capable of capturing even the faintest traces of light and, in doing so, will reveal insights into our Universe unlike anything we've seen before.

The early Universe

Looking over great distances is also looking back in time, and the JWST will give us our best view yet of the Universe just after the Big Bang.

Black holes

The JWST will allow scientists to see black holes in a new way, and find out more about their temperatures and chemical compositions.

James Webb staring into Space

Infographic by James Round

Secondary mirror

The secondary mirror captures light that's been gathered by the primary mirror, and reflects it into the telescope's suite of scientific instruments. It's supported by three 7.6m-long struts that extend out from the primary mirror.

Primary mirror

Measuring 6.5 metres across, and made up of 18 different hexagonal segments, the JWST's mirror is the largest ever launched into space. Its impressive size allows it to collect lots of light, and see incredibly faint, distant objects.

Multilayer sunshield

The tennis-court-sized sunshield stops sunlight from interfering with the sensitive instruments onboard the telescope. It's made of a lightweight material with special thermal properties, called Kapton.

Integrated science instrument module

This module, located behind the primary mirror, houses the cameras and other scientific instruments that detect light from distant stars and galaxies: it's the heart of the JWST. These tools are further explained below.

MIRI: the mid-infrared instrument

MIRI has a camera and a spectrograph that works at wavelengths of 5 to 28 micrometres; wavelengths that our eyes can't see. This will reveal new details about distant galaxies, newly forming stars, and faintly visible comets.

NIRCam: the near-infrared camera

NIRCam is the JWST's primary imager. It covers the infrared wavelength range of 0.6 to 5 micrometres. NIRCam, like MIRI, is also equipped with a coronagraph that allows astronomers to take pictures of faint objects around a central bright object.

NIRSpec: the near-infrared spectrograph

Operating between 0.6 to 5 micrometres, NIRSpec will disperse light from stellar objects into a spectrum, so that they can be analysed to learn more about their physical properties, including temperature, mass, and chemical composition.

FGS/NIRISS: fine guidance sensor/near-infrared imager and slitless spectrograph

With a wavelength range of 0.8 to 5 micrometres, the FGS allows the JWST to point at its targets very precisely to ensure image quality, while the NIRISS will be used to investigate exoplanets.

Stars

In huge dust clouds across the cosmos, stars are born. the JWST will allow us to peer through the dust, and watch these stars form.

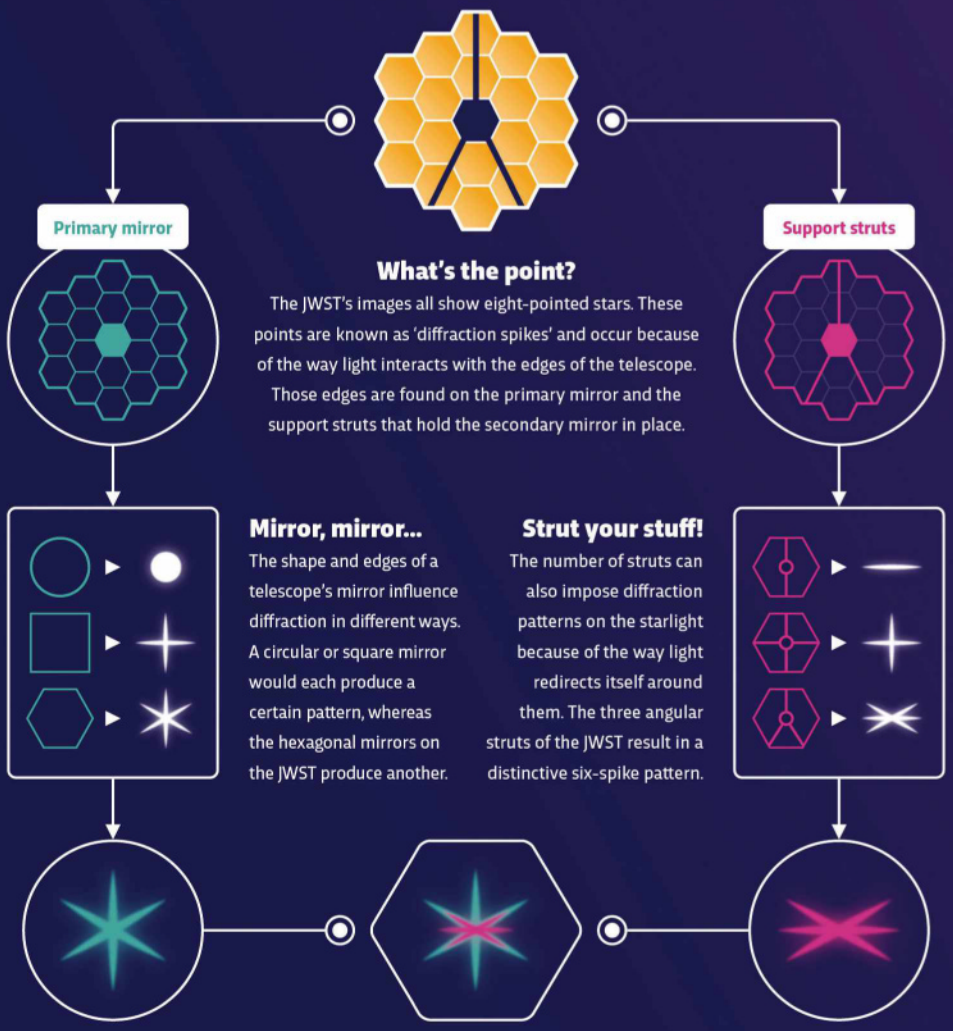
Planetary systems

There's so much we don't know about how planetary systems form and evolve. The JWST will help shine a light on these mysteries.

Exoplanets

The JWST can analyse distant worlds to reveal the chemicals in their atmospheres, and perhaps even discover signs of life!

Why do the JWST's images feature eight-pointed stars?



What's the point?

The JWST's images all show eight-pointed stars. These points are known as 'diffraction spikes' and occur because of the way light interacts with the edges of the telescope. Those edges are found on the primary mirror and the support struts that hold the secondary mirror in place.

Mirror, mirror...

The shape and edges of a telescope's mirror influence diffraction in different ways. A circular or square mirror would each produce a certain pattern, whereas the hexagonal mirrors on the JWST produce another.

Strut your stuff!

The number of struts can also impose diffraction patterns on the starlight because of the way light redirects itself around them. The three angular struts of the JWST result in a distinctive six-spike pattern.

Where is the JWST?

The JWST is stationed at a gravitational sweet spot called a Lagrange point

Here, the gravitational forces of two celestial objects balance out when other forces produced by the spacecraft's orbital motion are taken into account. In the JWST's case, it is at the second Sun-Earth Lagrange point, known as L2.

Being an infrared telescope, the JWST needs to be as cool as possible to work correctly, and at L2 it receives a constant amount of heat from the Sun. On the side facing the Sun, the temperature rises to about 110°C. The main telescope and instruments are protected from this by the sunshield, where the temperature remains around -233°C; about the surface temperature of Pluto.

L2 is located approximately 1.5 million kilometres from Earth, and it only took the JWST around 30 days to reach its destination. But the hard work was just beginning – back on Earth, scientists were working tirelessly to get the telescope up and running, and ready to bring in a new era of astronomy. Explore the timeline below to see some key moments from the JWST's departure, to when it shared its first incredible pictures with the world.

Lift-off!

The JWST launches from French Guiana

Fully deployed

The telescope completes the deployment of its mirrors and sunshield

Welcome to L2

The JWST reaches its final orbit around the second Sun-Earth Lagrange point

Photons incoming

The three-month process of aligning and preparing the telescope begins

Let's focus

NASA announces that the the JWST can capture crisp, focused images

Testing, testing...

Work begins to configure and calibrate the rest of the JWST's scientific instruments

Picture perfect

A new era of astronomy begins as the JWST shares its first images

Ready for science!

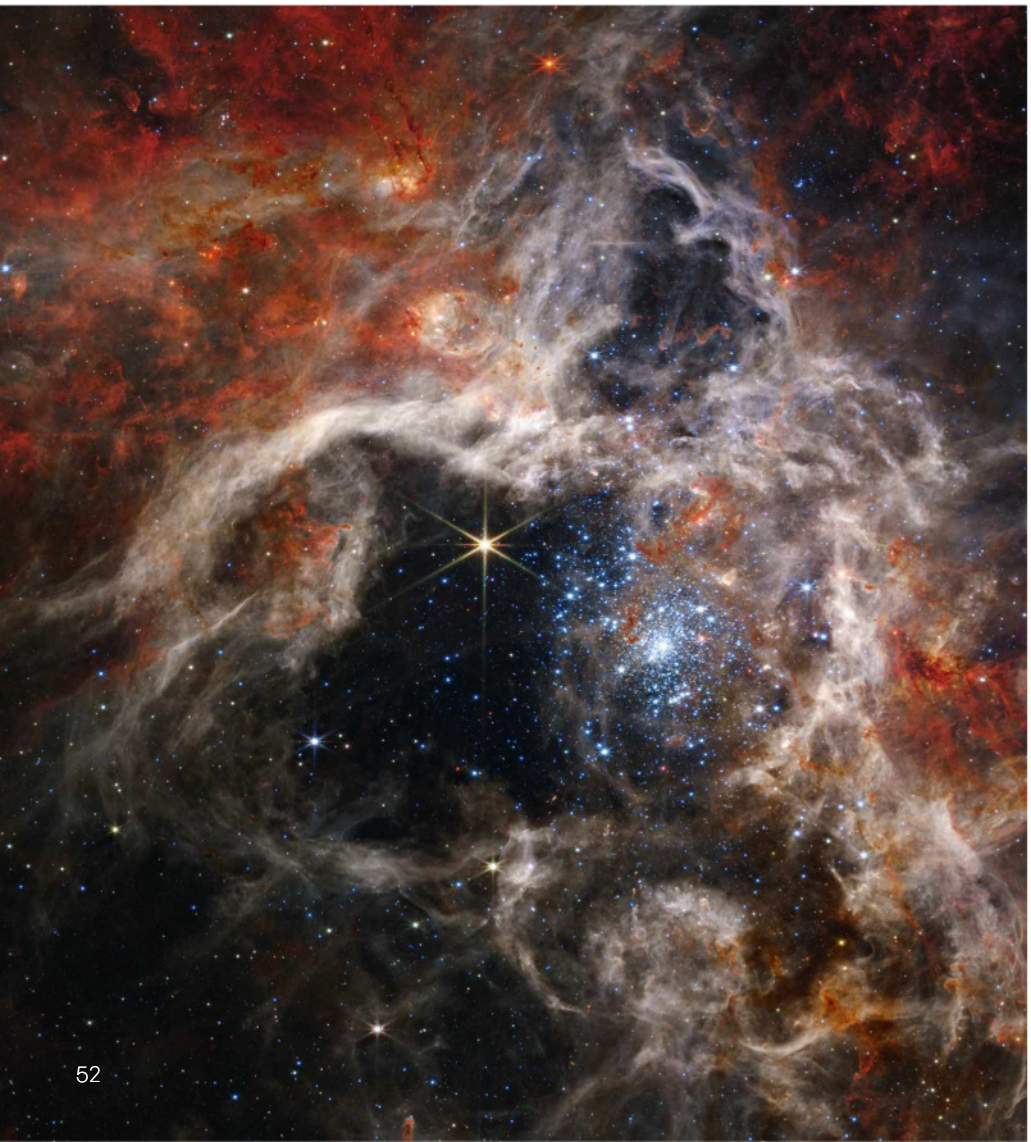
After months of testing, the JWST is ready to begin full scientific operations

DEC (2021) | JAN (2022) | FEB | MAR | APR | MAY | JUN | JUL

Timeline positions are approximate

ILLUSTRATION: JAMES ROUND

THE LIFE CYCLE OF STARS



One area in which infrared astronomy excels is looking deep into the clouds where stars are forming. This is because longer wavelengths are scattered less by atoms, molecules and dust grains. In effect, the very things that block our view of the stellar nurseries at visual wavelengths become almost transparent in the infrared.

Another image to be released from the JWST was NIRCam's view of the star-forming region NGC 3324 in the Carina Nebula, located 7,500 light-years away.

"The Carina Nebula is stunning. We know it's gas and dust being carved by starlight, but it looks like a landscape. The fact that you can now see inside it, using the infrared, is amazing. What's been private before is now visible in all its glory," says Harper.

At the time of release, it was dubbed 'the cosmic cliffs' because of the way the great gaseous cliffs appeared to resemble a mountain range. In reality, it was the edge of a giant cavity being gradually eroded by powerful ultraviolet light from newborn stars.

The stars are located off the top of the image but their action has blown a bubble in the surrounding material. The erosion can be seen taking place in this image because of the presence of what looks like steam coming off the landscape.

OPPOSITE TOP The 'cosmic cliffs' in the Carina Nebula

OPPOSITE BOTTOM NIRCam revealed young stars in the Tarantula Nebula

LEFT At wavelengths seen by MIRI, the Pillars of Creation take on an eerie look

This is actually hot gas, electrified by the stars' light, lifting off the denser surrounding matter. It is carrying some of the dust with it. The image spans roughly 12 light-years.

One of the most iconic pictures ever released by Hubble was of the Pillars of Creation. These are the star-forming regions in a much larger cloud of interstellar gas known as the Eagle Nebula. The JWST has now observed this same region using its NIRCam and MIRI instruments, to peer deeper into the massive stellar birthing ground than ever before.

One highlight of the new NIRCam image is the occasional bright orange features seen near the ends of the 'fingers'. These are shock waves produced by young stars inside that have just begun to generate energy by nuclear fusion. As those powerful processes began, huge jets of material are ejected at supersonic speeds that collide with the dusty cocoon surrounding each star, blowing this material away and revealing the newborn star to the Universe.

Shifting from the near-infrared image to MIRI's mid-infrared range reveals a similar but eerily different scene. Most of the stars have now disappeared because they are simply not that bright at these wavelengths. Instead, the dusty pillars are highlighted because of emissions coming from naturally occurring chemicals known as polycyclic aromatic hydrocarbons. But perhaps most excitingly, there are one or two instances where bright stars can be seen at the ends of the gaseous fingers. These are the young stars themselves, and each one could be attended by a solar system of planets.

"IT'S GAS AND DUST BEING CARVED BY STARLIGHT, BUT IT LOOKS LIKE A LANDSCAPE"

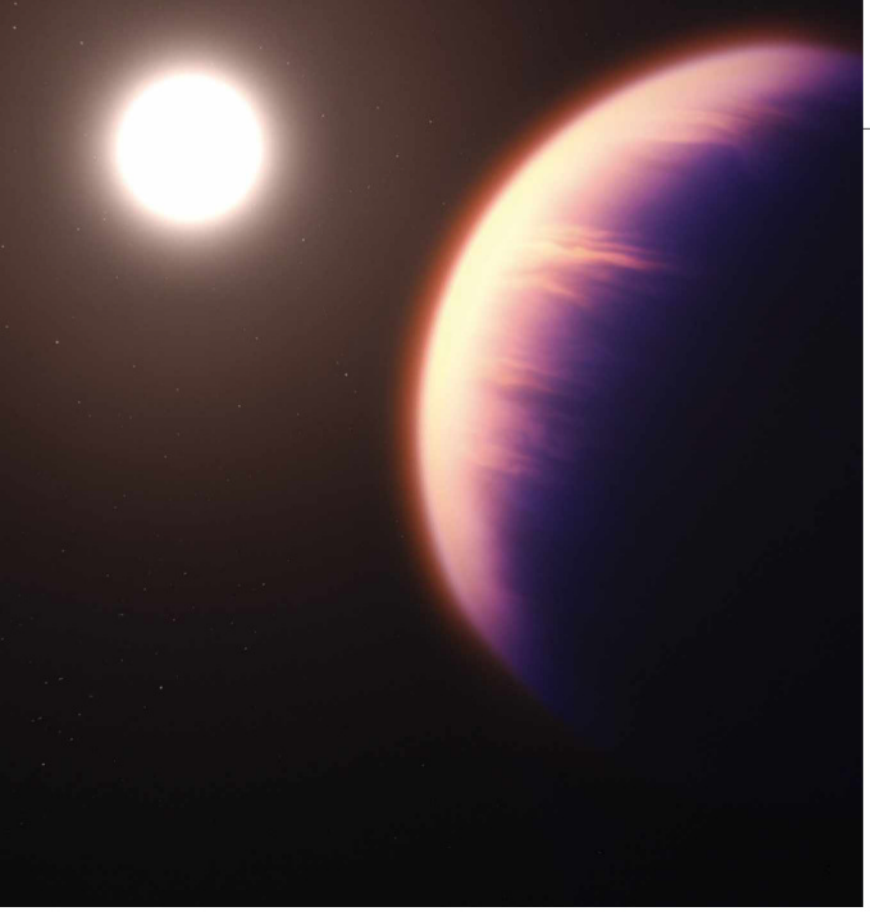
And even though the team behind MIRI had always had this observation in mind, the end result still took them by surprise. "We've planned to do it for all these years, we knew it would be exciting. But it's different when you actually see it, and you have the data. I think it's just really exciting," says Gillian Wright, the European principal investigator for MIRI.

By revealing more details than ever before, the JWST's new views of the Pillars of Creation will help researchers test their knowledge of star formation, and improve their computer models of the process. Understanding more about the precise number of young stars in these regions, and the spread of masses, along with the actual quantities of gas and dust that make up the nebula, is vital for understanding the way galaxies replenish their supply of stars.

At the other end of the stellar life cycle, the JWST has also been revealing the way stars die. Stars like the Sun swell to become red giant stars and then collapse into compact stellar corpses known as white dwarfs. In this collapse, they eject their outer layers to form a so-called (but woefully misnamed) planetary nebula. The JWST's image of the Southern Ring Nebula shows how beautiful this process can be.

For thousands of years before it became a white dwarf, the star would periodically eject shells of matter from its outer layers. What was left of the star would then contract and heat up, sparking a new round of energy generation that would set off a new round of pulsation, leading to the ejection of another shell of material. On and on this went until there was simply not enough remaining matter to squeeze the star's core sufficiently to spark nuclear fusion any more. At this point, it became a white dwarf. This is the fate that awaits our own Sun in around 4.5 billion years.

NASA/ESA/CSA/STSCI X3



EXOPLANETS

When it comes to planets beyond our Solar System, not even the JWST can deliver a detailed image. An exoplanet, especially one the size of Earth, is so small and dim compared to its central star that it will take a dedicated space mission using numerous space telescopes working together in clever ways to produce anything with any level of detail at all. Nevertheless, the JWST has managed to take one exoplanet image.

The planet is called HIP 65426 b. It is somewhere between six to 12 times the mass of Jupiter and orbits its star about 100 times further than Earth is from the Sun. To see the alien world, the JWST used devices called coronagraphs on its NIRCam and MIRI instruments.

A coronagraph blocks out the light from the central star, making the fainter surroundings easier to see. Its name comes from the fact that astronomers developed such an instrument to study the faint, outer atmosphere of our own Sun, which is called its corona. Now it can be used to see fainter objects such as exoplanets near distant stars.

Prof Sasha Hinkley, an astrophysicist at the University of Exeter, led these observations. "It was really impressive how well the Webb coronagraphs worked to suppress the light of the host star," he said when NASA released the image on 1 September 2022.

This is not the first direct image of an exoplanet ever taken from space, the Hubble Space Telescope had previously captured a direct image of a planet in orbit around the star Fomalhaut, but it is a proof of concept that the JWST can do this at infrared wavelengths.

But when it comes to exoplanet research, the JWST's biggest contribution is undoubtedly its ability to break down the light it receives into spectra. Spectra are a measure of how much light at each wavelength is being received.

A lot of science can be extracted from spectra, because atoms and molecules each like to interact with different wavelengths. This creates a pattern of dark lines in the spectra that are effectively like fingerprints, each one unique to a specific atom or molecule. The JWST is so important in this regard because molecules really like to interact with infrared wavelengths. Hence, an infrared spectrum of a celestial object can reveal its chemical composition.

This is exactly what astronomers did with the JWST's NIRISS instrument on the exoplanet WASP-96 b. The resulting graph showed the distribution of infrared light from 0.6 to 2.8 micrometres. WASP-96 b is notable because it often passes in front of its parent star. A small proportion of the star's light therefore passes through the exoplanet's atmosphere, where the constituent atoms and molecules absorb their preferred wavelengths. This shows up as a drop in the intensity at those wavelengths. In this particular case, the JWST showed that WASP-96 b contained water vapour in its atmosphere.

The planet is a 'hot Jupiter', so-called because it has a mass of around half that of Jupiter in our own Solar System, yet orbits so close to its star that a year lasts just 3.4 days. The results themselves are still preliminary because a computer model of the planet's atmosphere must be constructed. The model includes things like the abundance of various gases in the planet's atmosphere, and the height and thickness of any clouds in the exoplanet's atmosphere.

The next phase of this research is to extend this work to smaller and smaller exoplanets, eventually analysing Earth-sized worlds. This is more difficult, because smaller worlds have less dense atmospheres, but astronomers are optimistic.

"The JWST opens the door to smaller planets and cooler planets, more similar to our own Earth. And it will allow us to study giant planets in much more detail than we've ever had access to before," says Laura Kreidberg, an exoplanet expert from the Max Planck Institute for Astronomy, Germany. "I feel like we're at the very, very beginning of a really exciting journey."

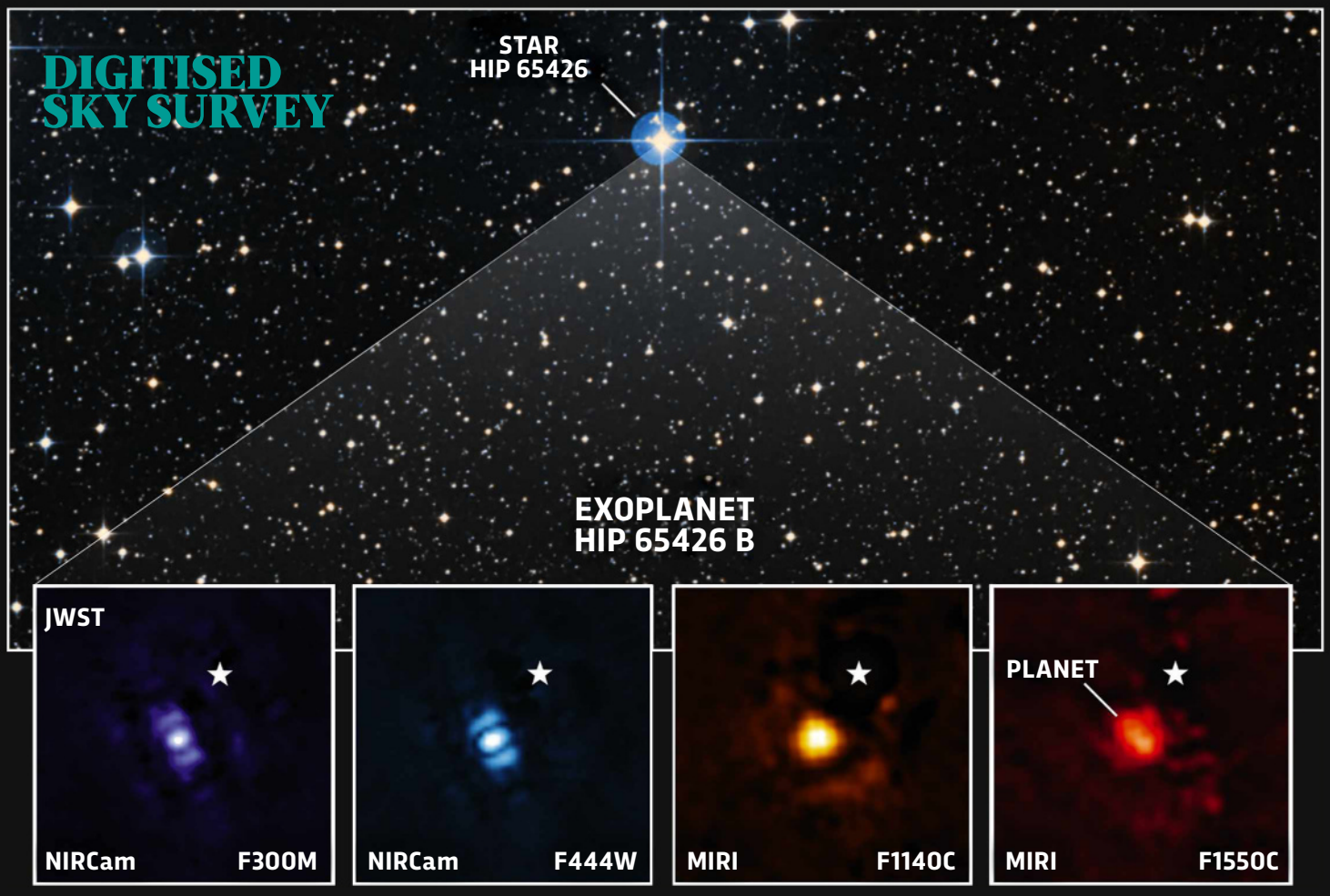
"WE'RE AT THE VERY BEGINNING OF A REALLY EXCITING JOURNEY"

LEFT This artist's impression shows what the exoplanet WASP-96 b could look like

RIGHT TOP The JWST took a direct image of exoplanet HIP 65426 b in different bands of infrared light using its NIRCam and MIRI instruments

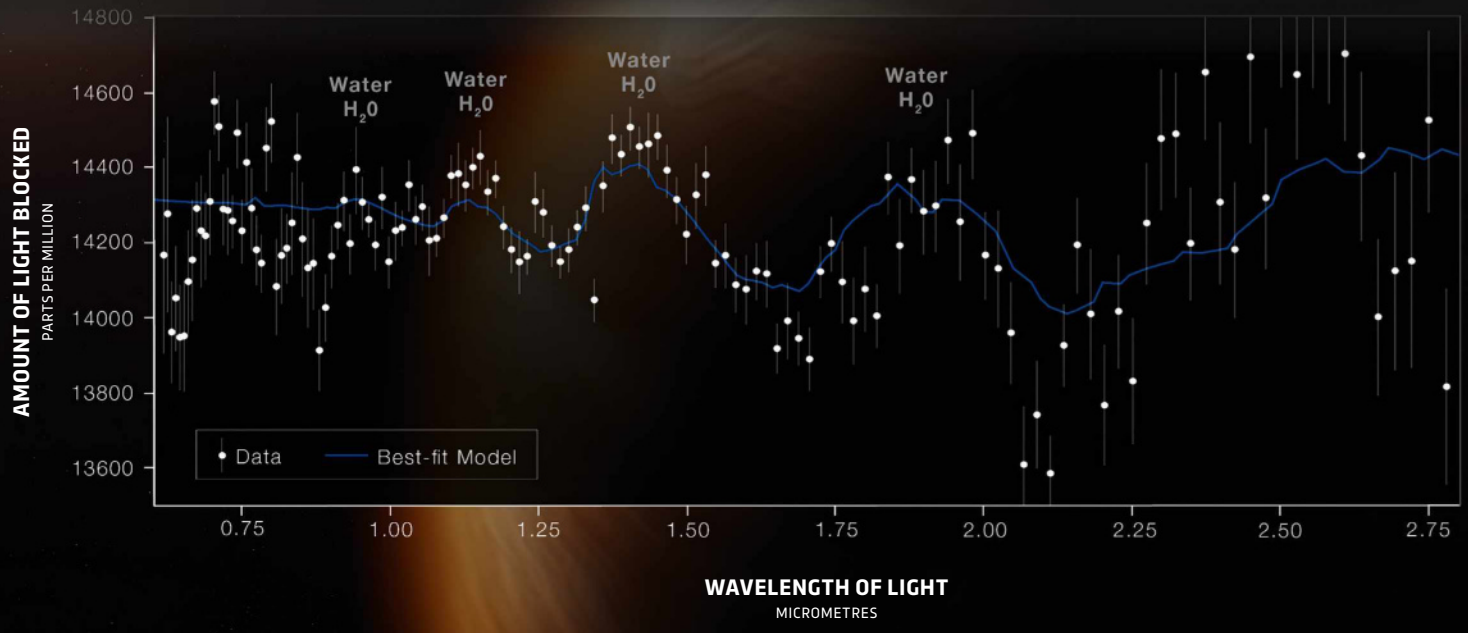
RIGHT BOTTOM Splitting the infrared light from star WASP-96 into a spectrum using the NIRISS instrument allowed the JWST to detect water vapour in the atmosphere of its planet WASP-96 b, as it crossed the face of the star

NASA/ESA/CSA/STSCI, NASA/ESA/CSA/JOSEPH OLMSTED/STSCI



ATMOSPHERE COMPOSITION

HOT GAS GIANT EXOPLANET WASP-96 B



PLANETARY SYSTEMS

It is not just planets around other stars that the JWST has been looking at. It has also been targeting some of the planets in our own Solar System. In its first released image of Jupiter, different wavelengths from the NIRCam instrument were combined to create an image where brightness represented altitude in the Jovian atmosphere. The higher a feature is, the more infrared light it reflects, so the brighter it appears.

Jupiter's Great Red Spot, for example, a storm system so large that it could engulf the entire planet Earth, is so high in the planet's atmosphere that it appears extremely bright at infrared wavelengths. The deeper cloud layers and hazes appear much darker by contrast. The auroras show up at the northern and southern poles of the planet in this image too. They are created when particles trapped in Jupiter's magnetic field are funnelled into the giant world's atmosphere, where they strike atoms and molecules and cause them to fluoresce.

The JWST also focused NIRCam on distant Neptune. Six times further from the Sun than Jupiter, Neptune is not seen in so much detail but the results are similar. A series of bright patches in the planet's southern hemisphere represent high-altitude methane-ice clouds, while a more subtle ring of brightness circling the planet's equator could portray a kind of 'jet-stream', a circulating band of atmosphere that powers Neptune's winds and storms.

One recent observational campaign that the JWST was well placed to assist with was the asteroid deflection test of Dimorphos. On 26 September, NASA's DART spacecraft intentionally crashed headfirst into the small asteroid in order to test our ability to deflect an asteroid should one be found to be on a collision course with Earth.

This image was taken around four hours after the impact and shows the enormous dust cloud that was ejected from the collision. Analysing the amount of material that was blown into space by DART will allow theoreticians to understand more about the interior composition and structure of Dimorphos, and asteroids in general. This knowledge will be crucial when designing a mission to deflect an asteroid for real. In the months after the collision, the JWST has continued to observe Dimorphos in order to gain as much insight as possible.

And it is still early days. The images that have been released so far are more like proofs of concept rather than full scientific results. They represent a promise from the astronomers involved that the telescope is working, and that the analyses, results and breakthroughs will follow.

"It's really fun and exciting at the moment. There's something new in everything the JWST touches," says Wright. "There's something you look at and you go 'wow!'" **SF**

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by **DR STUART CLARK** *(@DrStuClark)*

Stuart is an astronomy writer. His latest book is Beneath The Night: How The Stars Have Shaped The History Of Humankind *(£9.99, Faber).*

ABOVE
Cloud formations on Neptune shine brightly at near-infrared wavelengths, as seen in this NIRCam image

RIGHT
NIRCam shows Jupiter in a different light. The brightness of the features relates to how high they are in the planet's atmosphere

NASA/ESA/CSA/STSCI/JUDY SCHMIDT X2

“IT’S EXCITING. THERE’S SOMETHING NEW IN EVERYTHING THE JWST TOUCHES”

THE QUESTIONS THAT WE'VE BEEN PONDERING IN 2022

Q&A OF THE YEAR

ANSWERED BY *BBC SCIENCE FOCUS* EXPERTS

DOES PLAYING VIDEO GAMES MAKE YOU SMARTER?

GAMES DON'T ROT YOUR BRAINS. IN FACT THEY MIGHT BE SHARPENING YOUR COGNITIVE FACULTIES, ACCORDING TO AN UNPRECEDENTED, TWO-YEAR STUDY PUBLISHED EARLIER THIS YEAR

DR PETE ETCHELLS

Video games have been accused of many things over the years. There have been concerns that they make us isolated and antisocial, and in turn damage our mental wellbeing. We have worried that some games make us more violent, therefore damaging our physical wellbeing (literally). As scientists have become more adept at researching these topics, the best evidence has started to reveal that these sorts of worries are largely unfounded. Nevertheless, there persists a deep-seated idea that playing them rots your brain – it's easy to view them as an unproductive waste of time which displace other, more meaningful pursuits. But in reality, is the opposite the case? Could video games make us smarter?

For years, 'brain-training' games and apps have been touted as an easy and effective way to boost our cognitive abilities. The idea behind them is that by playing a series of quickfire puzzles that focus on things like memory or spatial awareness, over time our abilities in these areas will improve – and in theory, so will our general intelligence.

From a research perspective, the key issue has been in figuring out whether playing these sorts of games results in 'transfer' effects – namely, whether improving your skills on a given memory game brings about cognitive improvements more broadly.

PROF PETE ETCHELLS
Psychology expert

DR LISA FELDMAN BARRETT
Neuroscientist and psychologist

HOLLY McHUGH
Biology and health writer

JHENI OSMAN
Freelance science writer and presenter

DR MERAV OZAIR
Blockchain and cryptocurrency expert

DR STUART FARRIMOND
Food science and health expert

PROF STEVE BENFORD
Computer science expert

More specifically, scientists have tried to make a distinction between 'near' and 'far' transfer effects: near effects relate to whether playing one memory game results in improvements in other memory games, whereas far effects relate to whether playing that game results in a general improvement in cognitive abilities or intelligence. While some studies have shown that brain-training games result in near effects, these are generally weak, and other studies fail to find that same result. And as for far effects, there's no convincing evidence this happens.

However, one line of enquiry has compared brain-training games to run-of-the-mill video games, and this is where things get interesting. In a 2015 study comparing the brain-training game *Lumosity* with the first-person puzzle game *Portal 2*, researchers found that *Lumosity* players didn't show boosts in problem-solving and spatial skills, but *Portal 2* players did.

ILLUSTRATION: SAM BREWSTER

Along similar lines, a study of nearly 45,000 participants published in 2019 showed that while there were small cognitive benefits of playing brain-training games, these were negligible in comparison to the effects of video games in general.

More recently, in 2020, researchers based at the Karolinska Institutet in Sweden looked at data from some 9,000 American children and found that kids aged 9 or 10 who played video games for above-average amounts of time didn't show any differences in intelligence compared with those who played less. The study caught up with 5,000 of those children two years later and discovered that by the age of 12, the kids who played video games had 2.5 more IQ points than average. Elsewhere, studies in older populations have suggested that there are similar benefits. For example, a 2020 study of adults aged 60 to 80 showed that playing games like *Angry Birds* or *Super Mario 3D World* resulted in memory improvements over a four-week timespan.

Why off-the-shelf video games result in improvements in cognitive abilities over and above more targeted games isn't clear, and scientists are still trying to understand why this might be the case. One argument is to do with the amount of time invested: whereas brain-training apps tend to deliver mini-games over a short timespan, video games are immersive and often require sustained levels of attention and problem-solving. Moreover, despite some promising findings, the scientific jury is still very much out as to whether there is currently enough convincing evidence to back up the claim that video games make us smarter. In the meantime, perhaps we can leave behind those outdated concerns that tell us that video games are debilitating or maladaptive.

IS THERE A PSYCHOLOGICAL BENEFIT TO REACHING OUT TO OTHERS AT CHRISTMAS?

THERE ARE SURPRISING PERKS IF YOU EMBRACE THE SPIRIT OF THE HOLIDAYS

BY DR LISA FELDMAN BARRETT

We humans are social animals: we live in groups, form long-term bonds, and take care of each other.

Behind the scenes, we are also the caretakers of each other's nervous systems. Here's what I mean. Your brain works day and night to keep your body healthy by regulating its resources like water, oxygen, salt and glucose. This regulation is like a budget for your body. Actions that replenish your resources, such as eating and sleeping, are like deposits. Actions that spend resources, like getting out of bed in the morning, your heart beating while you read quietly, or your immune system protecting you from viruses, are like withdrawals from your budget. Some withdrawals are even healthful, such as exercising and learning new things — they're like investments that pay dividends later.

Anything that makes budgeting more efficient, like support from a loved one, is like a savings account. Anything that makes your budgeting less efficient, like being around someone who is unpredictable, who judges you, or is even harsh and insulting, is like paying a little tax. This is a simplified explanation, of course, but it captures the key idea that running a body is not a solo activity: body budgeting is influenced by other people.

Coordinated body-budgeting often has visible effects. Physiological changes in one person's body often prompt similar changes in another person's body, whether the two are romantically involved, just friends, parent and child, or strangers meeting for the first time. If you raise your voice, or even your eyebrow, you can affect what goes on inside other people's brains, and therefore you can affect their heart rate or the chemicals carried in their bloodstream. For better or worse. If a friend is in pain, you can lessen their suffering merely by holding their hand. You can also heighten their suffering by ignoring or rejecting them.

> "There are duelling holiday tropes: the warm and loving gathering, and the nightmarish kind"

Body budgeting can be particularly fraught during the holiday season. There are duelling holiday tropes: the warm and loving family gathering, and the nightmarish kind. If your holiday dinner is a cosy affair, you'll reap body budget benefits. But if the main event at the dinner table is an inebriated Uncle Edgar and overbearing Cousin Kiki in a no-holds-barred taunt-slinging match, then it's budgetary taxes all around.

So, here's the takeaway as we move into the festive season: the best thing for your nervous system is another human. The worst thing for your nervous system is also another human. Close relationships are good for us. We tend to live longer if we have them, and get sick and die earlier if we are socially isolated or persistently feel lonely – possibly years earlier, based on the data. Without outside assistance to manage your body budget, you bear an extra burden.

With this in mind, it may be helpful to visit even very challenging people during the holidays for the benefit of your future self, so you don't feel regret later. Regret is a painful emotion that can be a withdrawal from your body budget that may persist for years. And here's a tip: if you make yourself predictable to other people, in all likelihood they will be more predictable to you, which translates into body-budget savings.

Also, when encountering friends, families and colleagues with whom you disagree, try to cultivate a spirit of curiosity rather than being confident that you're right and they're wrong. Who knows, you both might learn something. Granted, this is a workout for your brain, much like exercise is a workout for your body. So treat it accordingly.

If family gatherings aren't for you, your body budget can connect with others in a variety of ways. Volunteer to help people in need. Be kind to a stranger. Run an errand for someone who could use a break. (When I'm feeling crappy, I bake bread or cakes for my neighbours.) The scientific evidence suggests that such moments of kindness may actually improve your own health and wellbeing, especially during times of stress.

WHEN WILL WE SEE A CONTRACEPTIVE PILL FOR MEN?

A GROUND-BREAKING STUDY IN MICE CREATED A MALE PILL THAT'S 99-PER-CENT EFFECTIVE

BY HOLLY MCHUGH

For decades, the responsibility of contraception has largely fallen on women. While birth control is certainly not a bad thing and allows us the sexual freedom we desire, it is not without its downsides. Mood swings, irregular bleeding, tender breasts and several other unwanted side effects are what many women endure in order to prevent pregnancy. Therefore, it is no surprise that ladies (and gents!) are keen for a male contraceptive alternative to level the playing field.

Currently, men have limited options when it comes to contraception, despite a willingness to share the responsibility. They can either use condoms or get a vasectomy, a surgical procedure for permanent male sterilisation. On the other hand, women have many choices that are more reliable than condoms and less permanent than sterilisation: birth control pills, intrauterine devices, patches, implants and injections.

In an attempt to develop a suitable method of contraception for men, scientists have spent years researching male contraceptive pills, but are yet to create an effective one that doesn't cause unwanted side effects. Most previously tested pills work by blocking the hormone testosterone to suppress sperm production. The problem with interfering with hormones like this is that it will undoubtedly cause side effects. For example, testosterone blockers cause symptoms like depression, weight gain, liver problems, acne and decreased libido. As a result, no contraceptive pills have made it to the shelves so far.

But now, it appears good things are on the horizon, after a team of eager researchers from the University of Minnesota reported they have developed a new male contraceptive pill. So far, it has proven effective in mouse studies and is set to enter human trials soon. According to their results presented at the American Chemical Society Spring 2022 meeting, the pill was 99-per-cent effective at preventing pregnancy after male mice received the drug orally for just four weeks – the same effectiveness as the current contraceptive pill for women. This is a promising result. Plus, in even better news, the pill appeared to have no side effects, thanks to the lack of hormones. This remained true even after delivering an overdose of the drug.

So how does it work? Unlike female birth control pills, this new pill contains zero hormones. Instead, it works by blocking a protein from binding to vitamin A, which is essential for sperm production and fertility. Essentially, it causes sterilisation. This may sound scary, but the researchers found that the sterilising effect of the pill could be totally reversed within four to six weeks of stopping the drug. After this point, male mice were successfully able to sire pups.

However, although this pill is a promising candidate, scientists caution people not to get ahead of themselves. So far, it is only effective in mice and may affect men differently – we are humans after all and work completely differently from rodents. But given the major positives seen in mouse studies and the absence of hormones, scientists are hopeful this contraceptive pill will remain effective and free of side effects.

If the upcoming human trials are a success, a male contraceptive pill may reach the shelves before we know it. This breakthrough will revolutionise male contraception and allow men the freedom to take control of their own reproductive health. Women will also no longer have to bear the burden of birth control alone – a win win for everyone. Watch this space!

GETTY IMAGES ILLUSTRATION: SAM BREWSTER

HOW CAN HRT HELP WOMEN?

THIS YEAR, THE GOVERNMENT HAS BEEN URGED TO MAKE HRT FREE FOR WOMEN IN ENGLAND

BY JHENI OSMAN

Hormone replacement therapy (HRT) relieves symptoms of the menopause by replacing hormones that are at a lower level leading up to and during the start of the process. Women usually start to experience the menopause between the ages of 45 and 55. During the menopause, the ovaries stop releasing eggs, and levels of the hormones oestrogen, progesterone and testosterone drop, which often causes symptoms such as hot flushes, night sweats, vaginal dryness, reduced libido, disturbed sleep, poor concentration, mood swings, anxiety and brain fog. During the perimenopause – the period leading up to menopause – a woman can suffer from these symptoms, but still have her period.

For many, the effects of perimenopause and menopause can be challenging, but for others they can be debilitating. HRT can help alleviate symptoms, but some patients are nervous about taking it, in part due to bad press following a couple of studies from more than two decades ago. In 2002, a study published in the *Journal Of The American Medical Association* claimed that taking HRT increased the risk of stroke, breast cancer and coronary heart disease. The next year, another study claimed HRT had caused 20,000 more cases of breast cancer over 10 years.

Since then, doubt has been cast on both studies' methods, while subsequent research has shown that lifestyle factors, such as diet and alcohol consumption, carry a greater risk for breast cancer.

"Obesity, alcohol intake of more than two units a day, or a late menopause all carry a greater risk for breast cancer than HRT itself," says Dr Edward Coats, consultant gynaecologist and reproductive medicine specialist. "We are still recovering from the 2002 study, which had a huge dataset, but was flawed. A generation of women have avoided HRT due to worries over increased risks. Menopause experts are looking at how to regain patient trust and communicate the risks and benefits."

"Diet and alcohol consumption carry a greater risk for breast cancer than HRT"

Indeed, for many women, the benefits of taking HRT outweigh any potential risk. Aside from easing menopause symptoms, HRT increases bone density, preventing hip and spine fractures. Even when the dose is low, these benefits remain for many years after stopping HRT. In women aged between 50 and 59, HRT reduces the risk of cardiovascular-related deaths, and does not increase the risk of heart disease or stroke. There is also good evidence that HRT reduces the incidence of bowel cancer.

However, there are a few conditions – endometrial cancer, breast cancer and venous thromboembolism (VTE) – where HRT may do more harm than good. It depends on the patient, so it is important to get specialist advice about the risk factors for these conditions. There are different types of HRT, and it can be administered in various ways, so women can work with their doctors to find what will be best for them.

"Deciding whether to use HRT is about understanding risk – and this is where it differs for different people," says Coats. "For the average person, there are more benefits than there are risks."

In October, the All Party Parliamentary Group on Menopause, which is made up of MPs, called on the government to support women going through the menopause. The group asked for all women to be invited for a menopause check-up when they turn 45, for updated menopause training to be provided for GPs and other healthcare professionals, and for the removal of prescription costs for HRT in England (in line with Scotland, Wales and Northern Ireland).

"A health check for women aged between 45 and 50 would be very useful," says Coats. "The problem is funding, as currently there are limited resources and rationing of healthcare. However, it is really important that women have access to information about the menopause and treatment options available to them."

ARE WE DONE WITH NFTS?

MILLIONS, MAYBE BILLIONS, OF DOLLARS WERE THROWN ON THE FUNERAL PYRE OF GIMMICKY DIGITAL ART THIS YEAR

BY DR MERAV OZAIR

Non-fungible tokens (NFTs) have been getting a lot of media attention this year. This is, no doubt, partly a consequence of celebrities auctioning their NFTs for hundreds of thousands, if not millions, of dollars. For example, Twitter founder Jack Dorsey's first tweet sold for $2.9m (£2.4m approx). This creates a sense of hype and celebrity status, giving the impression that everyone can create an NFT and then auction it off for millions of dollars.

Whenever there is money to be had, unscrupulous activity comes to the surface. Unfortunately, that's human nature. We have observed all sorts of scams – from phishing scams to bidding scams to fake NFTs (for example, OpenSea reported that over 80 per cent of NFTs minted using its minting tool were fake). NFT marketplaces have taken measures to prevent fraudulent behaviour on their platforms, and we will see increasing consumer protection as the tech matures.

We must, however, look beyond the hype and the scams, as the core power of NFTs is authentication. NFTs are here to stay, because the possibilities are boundless and go beyond collectibles and celebrities' tweets or photos. The future of NFTs lies in business and economic applications.

Whatever we do in our everyday life is transaction-based. To facilitate any transaction and the transfer of ownership, authentication is key. A transfer of ownership will not occur without authenticating the assets being transferred and the persons (or entities), who are engaging in the transaction. This is the true power of NFTs, providing authentication and facilitating the transfer of ownership.

NFTs can create new ownership opportunities and facilitate transactions that were not feasible in traditional systems. BlockBar is an example for such a scenario. The BlockBar platform sells NFTs of rare or exclusive alcohol, including a Glenfiddich 1973 whisky and a 1976 Dictador rum in a

ALAMY ILLUSTRATION: SAM BREWSTER

Lalique bottle. The NFTs authenticate the physical rare bottles, which are stored in a climate-controlled and bonded warehouse in Singapore. Each NFT represents an ownership of a physical bottle, and this ownership can be transferred or sold between people globally, without anyone having the bottle at their dinner table. Theoretically, this exchange of ownership could proceed for years, until someone decides to open the bottle. When this happens, the NFT will be destroyed so it cannot change ownership any longer.

This type of transaction has not been feasible in traditional systems. Authenticating a physical bottle is a costly process, involving attorneys, notaries or other intermediaries, and thus has never been done before. NFTs enable such a transaction in an efficient and low-cost manner, which opens opportunities for ownership and value-added investments.

A digital certificate of ownership such as an NFT can prove ownership of anything. It is not limited to virtual or digital content such as photos, videos, audios or tweets. An NFT can prove that someone owns a car, or has a marriage licence or university degree. These NFT certificates can be stored in the user's account on the blockchain, and shared when needed. Their utility and purpose are not as an asset or an investment to be traded, but rather as an authentication of a certificate, like in the traditional system.

NFTs have the potential to revolutionise the real estate industry by replacing land deeds, titles and all documentations verifying the ownership of the real-estate asset with NFTs. These NFT certificates are traceable and trackable, and transactions are fully transparent, which will significantly reduce cost and time of processing of any change to the asset or change and transfer of ownership.

Collectible avatars on Reddit are a good example, and their success is a testament of the power of NFTs. The initial goal was to empower artists to create and sell their work. Artists are paid for every collectible avatar sold on the Reddit platform and are entitled to receive royalties from secondary sales in other open marketplaces. The value of this avatar goes beyond a mere collectible.

The business and economic applications for NFTs are boundless, and their usage may continue to grow as they make transactions smoother, safer and more transparent, while protecting creators' rights and providing a certificate of authentication.

WHAT'S THE MOST COST-EFFECTIVE WAY TO COOK THE CHRISTMAS TURKEY?

YES! IT IS STILL POSSIBLE TO ENJOY A SUCCULENT BIRD WHEN YOU'RE WATCHING YOUR ENERGY BILLS

BY DR STUART FARRIMOND

In the seven or so years that I have been the food scientist for BBC's Inside The Factory*, the episode that had people stop me in the supermarket was the Christmas special where I gave my top science-based tips on cooking the perfect Christmas turkey. In these times of rising fuel prices and climate concern, however, it feels more important than ever to pick a way to cook your prized bird in a way that makes for a killer dish without murdering the planet or your bank account. For more tips on cooking a turkey in the oven, visit* ***bit.ly/cook_turkey_science***

OVEN ROAST

If you're cooking a roast this Christmas, you'll probably be doing it in the oven. From a physics point of view, oven roasting is a ridiculous way to cook anything. Your oven is essentially a hot, dry chamber that blows air around, just like a hairdryer, and is perfect for dehydrating rather than cooking. This is because heat transfers pitifully slowly from dry air into anything solid or liquid – just try hovering your hand in a 200°C oven and it will feel warm, whereas a mere splash of 80°C water would instantly scald.

It's going to take roughly three hours and 30 minutes of preheating and cooking time to roast a 6kg turkey (enough to feed 8-10 people). Modern electric ovens will fizzle through some 3.2kW worth of power during this time, sending up a 600g plume of carbon dioxide. Gas oven owners have a less efficient appliance that will blaze through 5.4kW worth of gas, belching out nearly a kilogram of carbon dioxide. A gas-cooked bird will have a lower energy bill, however, such is the price of electricity now.

For a tastier turkey and a faster result, try spatchcocking. This means cutting out the turkey's backbone using a serrated knife or pair of heavy-duty kitchen scissors then squashing the bird flat in a large roasting tin, skin side up, so its limbs are butterflied outwards. The surface area is doubled and the cooking time roughly halved. The most flavourful bits of the turkey are the browned outer edges formed by the Maillard reaction, and a spatchcocked bird has more of these tasty surfaces, making it extra delicious.

Cost: £ (54p for gas) /£ (£1.08 for electricity)
Emissions rating: ●● (0.98kg CO_2 for gas)/ ● (0.6kg CO_2 for electricity)
Tastiness rating: ★★ (whole) / ★★★ (spatchcocking)

BARBECUING

You may not live in Australia, but a Yuletide barbecue might not be as silly as it sounds, if the weather stays dry on Christmas Day. To barbecue a large bird, you will need to turn the barbecue into an oven. You'll therefore need a large barbecue, lots of charcoal, and a tight-fitting lid with air vents so that hot air and smoke can circulate. Wait until the charcoals are covered in a good layer of ash and giving out maximum heat before starting. Place a foil tray under the turkey to catch the drips for gravy-making, if you like. With air vents three-quarters open, cook until the meat reaches 65°C, when measured using a meat thermometer. This may take two hours or more.

Charcoal is a rather dirty fuel, which, along with firelighters, means a barbie will send an estimated six to seven kilos of carbon heavenwards, equivalent to a 32km (20-mile) car drive, although about 40 per cent of that will be offset providing the charcoal is made from a sustainable wood source (which would be carbon neutral). A gas barbecue emits a third of that carbon, according to research using UK data. That said, gas is a fossil fuel and it won't impart the lip-smacking smoky flavour, which is surely the main reason for braving the outdoors?

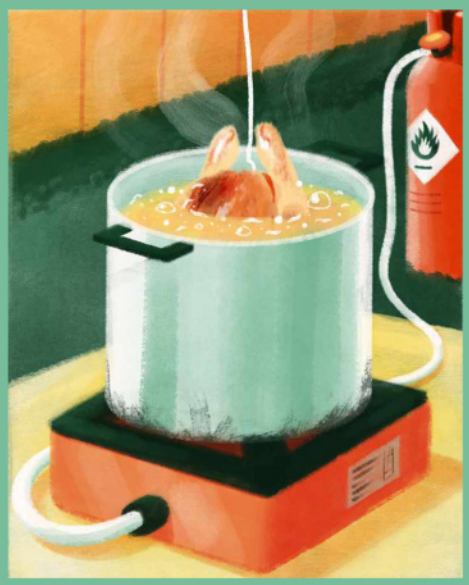
Cost: £££ (approx £3 for charcoal) / £££ (£3.50 for gas)
Emissions: ●●●●● (3.25kg CO_2 for charcoal) / ●●●● (2.2kg CO_2 for gas)
Tastiness: ★★★★ (for charcoal) / ★★★ (for gas)

DEEP FRYING

The unlikely winner in the league table of turkey tastiness is deep frying. Yes, you read that right: plunging an entire turkey into a pot of perilously hot oil. In the US, it's a common Thanksgiving party trick, where you can pick up a turkey fryer for less than 50 bucks. In Blighty, expect to pay double that. Or you could cobble one together with a propane tank, large ring burner, 30-litre metal stockpot and a coat hanger. Exercise extreme caution in this white-knuckle cooking venture: every year in the US the process kills five people, injures 60 and causes £10m worth of damage. After you have factored in 20 litres of oil to keep your bird submerged, it's also pricey. Oh, and if it's wet or snowy, you can forget it – hot oil and water have an explosive relationship.

For the brave (foolhardy?) who dare this technique, the spoils are delicious. Unlike the Sahara-like conditions of an oven, heat travels at lightning speed from oil to meat, meaning the whole bird is cooked in under an hour in oil at 175°C. Most of the moisture is also unable to escape, leaving a more succulent bird, and the Maillard reaction is sent into overdrive throughout the cooking period, creating that unmistakable fried-chicken crispy skin. The toll on the planet from a roaring propane tank is worse than a gas oven (although not as bad as charcoal).

Cost: £££££ (£35-40 for oil, although it can be reused)
Emissions: ●●● (1.4kg CO_2)
Tastiness: ★★★★★



SLOW COOKING

This 1970s gadget had a new lease of life in the 2010s when home cooks went in pursuit of more wholesome cooking. And now they're flying off the shelves once again as we all look to cut our energy bills. These delightfully simple contraptions heat their contents to a steady temperature for as long as the user desires. On a 'low' setting of 88°C, a slow cooker will gently bring meat and veg beyond their cooking temperatures: meat proteins cook at around 65°C, while plant cell walls break down and starches cook at a similar 58°C to 66°C. Cooking for six to eight hours also gives ample time for tough sinews (made from collagen) to break down into soft gelatine, transforming tough cuts of meat into tender fall-off-the bone succulent loveliness. Hands down this is the most energy-efficient way of doing your festive centrepiece, emitting a puny 230g of CO_2. That said, shoehorning your 6kg bird inside may be a squeeze, leaving little space for the veggies. The meat will be moist throughout, thanks to the steamy cooking climate, but the skin will be flabby and bland because the surface has had no chance to dry out and reach the 130°C+ needed for the Maillard reaction to fire up. Good for sandwiches this may be, but a slow-cooked turkey will not be crowdpleaser without a truly delicious gravy and some cracking roast potatoes.

Cost: £ (40p)
Emissions: ● (0.23kg CO_2)
Tastiness rating: ★★

ILLUSTRATION: SAM BREWSTER

IS IT GOOD FOR MY BRAIN TO AVOID THE NEWS FROM TIME TO TIME?

IT'S EASY TO GET SICK OF THE 24-HOUR NEWS CYCLE OF WAR, CLIMATE CRISES AND ECONOMIC TURMOIL

BY DR LISA FELDMAN BARRETT

Scientists can study how the human brain and body deal with information that people are likely to experience as distressing. We show test subjects a barrage of images or words designed to burden their nervous systems – exactly the sort of stuff we all encounter daily in the news (in fact, some of our most troublesome material comes from news reports). After a moment, we see changes in patterns of brain activity that are important for regulating bodily systems. Some changes occur in brain regions that have been dubbed the home of 'fight or flight' circuits, but really these regions are more generally important for coordinating and regulating your nervous system, immune system, and metabolism. As a result, we observe test subjects'

IS THE METAVERSE THE FUTURE?

OR HAVE ZUCKERBERG AND HIS TECH FRIENDS MISREAD THE ROOM...

BY PROF STEVE BENFORD

The metaverse is 30 this year! The idea first appeared in Neal Stephenson's 1992 cyberpunk novel *Snow Crash*. Stephenson imagined a future in which everyone took up residence in an online virtual world where they worked, played, lived, and, in this dystopian novel, also suffered from a mysterious physical and digital virus.

There have been attempts since then to create the metaverse for real, some good, some bad, and some truly laughable. Now, in 2022, some of the biggest global players have entered the game. Meta offers us a vision of the metaverse as a future social place, a virtual reality version of Facebook. Microsoft is taking the more serious approach, envisaging it as an office environment where we'll work online.

So what is the metaverse and will we all flock there? Common to all visions of the metaverse is that this place is presented as a coherent whole through interactive 3D graphics and sound. In other words, the metaverse is a globally connected virtual environment... albeit, a somewhat glitchy work-in-progress environment.

The metaverse is also universally talked about as a social experience, with its inhabitants communicating through their avatars. Despite the popularity of social media, much of today's internet remains an isolated place. We might be looking at the

"Just imagining an unpleasant event can bring on an electrochemical storm of changes"

pounding hearts, sweating palms, and gushing cortisol as their brains prepare their bodies to act. Even though they are safely tucked away in a comfy lab chair, just imagining an unpleasant event can bring on an electrochemical storm of changes.

As an example, my lab studied people's responses to news stories about the 2013 Boston Marathon bombing. When the stories contained a higher proportion of negative words, our test subjects reported greater distress. Afterwards, they were also more physically reactive to images of the bombing.

Even news that is unexpected or ambiguous, like a newly rising infection rate or the perils of governments ignoring carbon emissions, can turn the dial up on your distress. Such feelings arise when your brain works a little harder than, say, when you encounter news that you expect or that reinforces things you believe. This extra work adds a small burden to your metabolism in the moment, and it may feel unpleasant.

A little unpleasantness in the moment, perhaps, is the price we pay to be informed citizens. But over time, little burdens can accumulate, particularly with news outlets reporting more negative stories and using more negative words. Negative news is more likely to be shared on social media, which creates an incentive for news outlets to emphasise the negative, producing a positive feedback cycle of yuck. If you're not careful, you can find yourself treading water in a sea of badness. It can leave you exhausted, with a creeping sense of impending doom, even if your daily life is not so bad.

Even if you manage to keep the news from infecting your mood, there's another consideration: your experiences today seed your brain for what you experience tomorrow. When you're swamped with negative news, the onslaught can shape your overall world view, leading you to expect bad news and act accordingly. This process is gradual and subtle, not something you'd notice, but it adds up over time.

So, what should you do? Try taking it in small doses, and afterward, replenish what you spend. Take a walk with a friend. Get a good night's sleep. You can also give your nervous system a momentary break by consuming positive news, or even negative news that lets in some rays of light amidst the doom. In my lab's Boston Marathon study, for example, we found that stories of resilience, heroism, or kindness in the face of adversity can help a person cope. Our test subjects reported less distress when content about the bombings was more positive. They were less reactive to bomb-related images, and better able to distinguish shooters from non-shooters in photos.

Whatever you decide, don't consume negative news together with food. Stress within two hours of a meal leads your brain and body to metabolise what you eat in a way that adds the equivalent of 104 calories to the meal. If this happens daily, that's about an extra pound a month – which none of us needs in the holiday season.

same web page, but never see each other. In contrast, the metaverse will be crowded.

You might also take up permanent residence, acquiring real estate and making it your own by uploading user-generated content. Of course, this idea already underpins today's social media, and was core to *Second Life* through its economy based on the Linden Dollar.

Companies like Meta (Facebook), Microsoft and Sony have invested heavily in headset technologies with the goal of deeply immersing people in the virtual world of the metaverse. However, despite advances in resolution, weight and size, headsets remain clumsy, can require significant space, and cut us off from those around us in the 'real world'. They are still a niche technology.

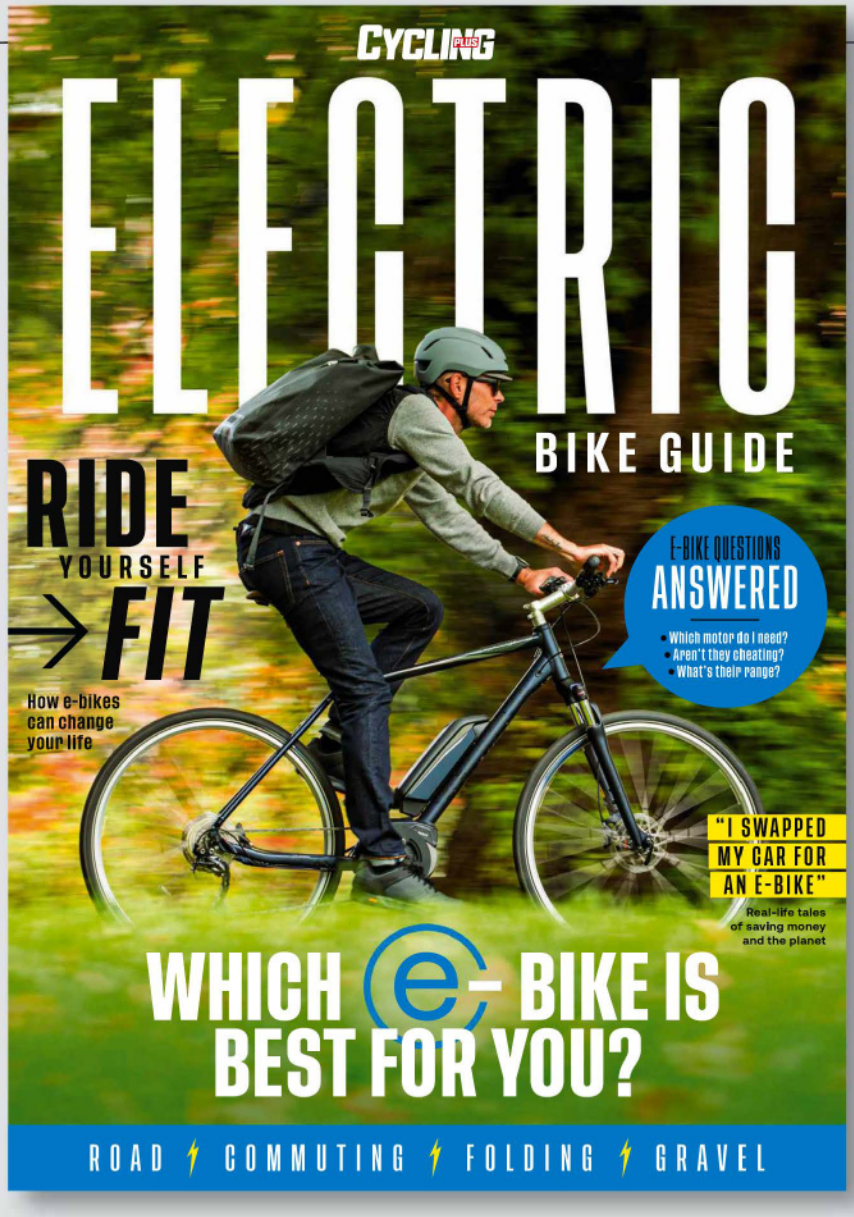
An extreme view of the metaverse is that it will become the universal 'front end' to the internet; we will enter the metaverse to do everything we might conceivably do online.

While the big tech names seem sure the metaverse is the future, this kind of technology requires full commitment, leaving the real world to live an almost second life in a digital world.

GETTY IMAGES X3

But let's say the metaverse came to fruition, and we all flocked to this virtual utopia, who would actually be in charge of our new techy global world? There appear to be several contenders for owners. But as a manifestation of the internet, surely no particular company will own it, but instead different metaverse implementations will talk to each other using agreed protocols. We might instead consider ownership in terms of who gets to purchase its virtual real estate and populate it with their own content. And who gets to regulate the metaverse? Who makes and enforces its laws? This is perhaps the most challenging and pressing sense of ownership today, given the current tensions between 'big tech' and governments over privacy, freedom of speech and online safety.

Turning full circle, we return once again to Stephenson's metaverse in which citizens' lives were policed by major corporations while governments were reduced to small administrative outposts. Perhaps the important question for the metaverse right now is not what kinds of technology it will use, nor even what we will use it for, but who will win the battle between corporations and governments for controlling it. SF



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Q&A

YOUR QUESTIONS ANSWERED

... HOW DO WE KNOW DINOSAURS ROARED?
... WHY DON'T BEES GET STICKY WHEN THEY MAKE HONEY?
... HOW DOES THE INTERNET ACTUALLY WORK?
... HOW DO I MAKE THE ULTIMATE SNOWMAN?
... HOW DO METEORITES FROM MARS END UP ON EARTH?
... WHY CAN I RAISE ONE EYEBROW BUT NOT THE OTHER?
... WHY DO WE FIND THINGS BEAUTIFUL?
... WHY IS MY BRAIN BUZZING AT 3AM BUT COMATOSE AT 3PM?
... WHY DO WE NEVER FORGET HOW TO RIDE A BIKE?
... IF WE COLONISE THE MOON, WILL THE COLONISTS EXPERIENCE NIGHT AND DAY?

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Science writer

ILLUSTRATION: DANIEL BRIGHT

HANNAH WADE, BIRMINGHAM

WHY DO LIFT RIDES WITH STRANGERS FEEL SO AWKWARD?

Much of it has to do with personal space. A study by the University of Wroclaw in Poland asked people around the world at what distance they found the physical presence of a stranger to be uncomfortable. People in England were in the middle in terms of the spread of preferences and, for them, discomfort kicked in at anything closer than a metre – barely avoidable in many elevators. Another factor is the lack of a social script. From business interviews to doctor's appointments, we navigate many situations in life by playing a role and following expected norms. But just what is the appropriate conduct when you're nose-to-nose with a stranger in a lift – stare at the ground and pretend they're not there, or strike up small talk? The good news is research shows that a brief chat might not be as awkward as you expect. ***CJ***

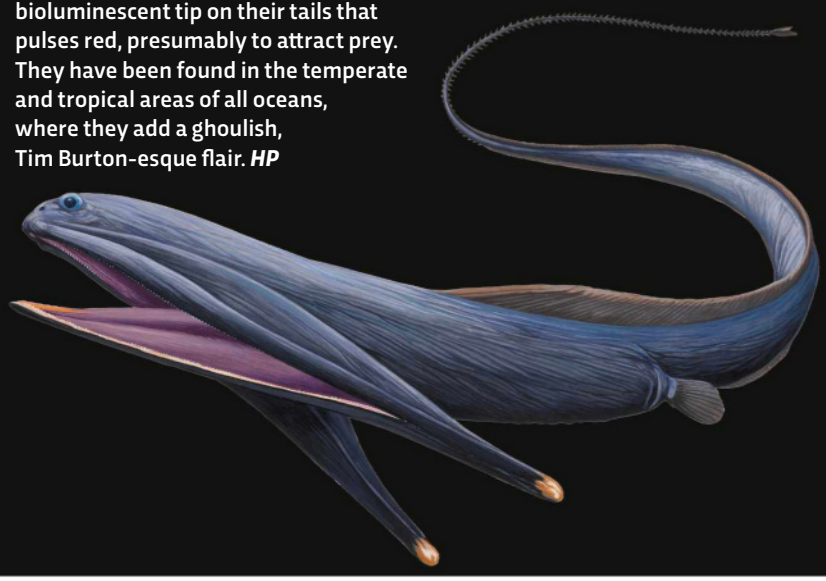
NATURE'S WEIRDEST CREATURES...

THE PELICAN EEL

In 2018, researchers controlling a remotely operated vehicle in Hawaiian waters stumbled across the best view to date of this deep-sea oddity. Spotted a mile down in the Papahānaumokuākea Marine National Monument, the critter looked like a sinister sperm, with its black, bulbous head and a lithe, whip-like tail. Without warning, its head then began to inflate and wobble, before morphing into a gaping pair of jaws, and then into a more streamlined form, before it disappeared into the darkness.

Until that moment, much of our knowledge of the pelican eel came from the mashed-up remains of individuals that had been roughly hauled up from the abyss. It's called the pelican eel because of its enormous mouth, which can expand to hold large volumes of water and prey, a bit like a pelican. Excess water is jettisoned via paired gill slits, while the food – small crustaceans and invertebrates – moves into the stomach, which expands to accommodate it.

The pelican eel has small eyes, tiny teeth and a loosely hinged jaw that's a quarter of the length of its body. Adults are around 75cm long, with a bioluminescent tip on their tails that pulses red, presumably to attract prey. They have been found in the temperate and tropical areas of all oceans, where they add a ghoulish, Tim Burton-esque flair. ***HP***



STEVEN RILEY, ABERDEEN

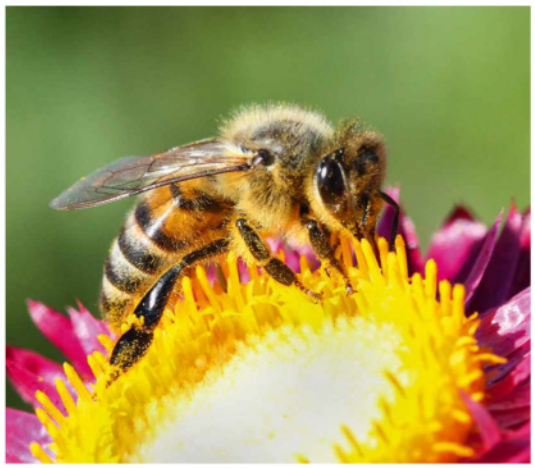
HOW DO WE KNOW DINOSAURS ROARED? WERE THERE ANY DINOSAURS THAT MIGHT HAVE CHIRPED LIKE A BIRD?

In films and television documentaries, dinosaurs often roar like lions. But in fact, there is no evidence to suggest that they made such noises. On the contrary, the existing evidence suggests they didn't, for a couple of reasons. First, a lion's roar is made possible by the big cat's vocal cords: folds of tissue in their throats. We also have vocal cords, as do many animals, but those of lions are fine-tuned to make loud and intense noises, and there's no direct fossil evidence that dinosaurs had these same structures. Second, dinosaurs were the ancestors of birds, so it's likely some made more bird-like noises. One 2016 study argued that some dinosaurs made closed-mouth vocalisations like the 'booms' ostriches make. Modern-day birds have a voice box, called a syrinx, that allows them to chirp. A syrinx was recently found fossilised in a bird that lived in the Cretaceous, raising the possibility that some non-bird dinosaurs had syrinxes too. ***SB***

SOFIE KEARNS (AGED 6), VIA EMAIL

WHY DON'T BEES GET STICKY WHEN THEY MAKE HONEY?

Honey, which is made by the eight species of honeybee, is a viscous mixture of sugars and water. It's stored inside honeycomb cells, which are sealed with wax until the energy-rich liquid is required to feed larvae or help adult bees survive the winter. If the comb becomes damaged and the honey leaks out, bees can indeed become sticky and even get stuck. Bee expert Prof Dave Goulson from the University of Sussex has seen it happen, but not often. "I think they're simply very careful when handling honey and meticulously groom off any sticky residues," he says. ***HP***



DEAR DOCTOR...

HEALTH QUESTIONS DEALT WITH BY *SCIENCE FOCUS* EXPERTS

CHRIS PAGE, KESWICK

MY IN-LAWS ARE HERE FOR THE HOLIDAYS. WHAT'S THE QUICKEST AND EASIEST WAY TO REDUCE MY STRESS LEVELS?

Any situation where you feel you can't cope or you're not in control is likely to make you feel stressed, so plan ahead to minimise these feelings. For instance, schedule 'escapes' for yourself during their stay – be that a walk with a friend or a trip to the shop for some groceries. Mentioning such plans politely at the outset of the visit will help prevent any awkwardness in the moment.

Similarly, plan private me-time breaks at home, such as a spot of gardening, or even just a long shower. These brief respites will prevent your feelings from overwhelming you.

Try to cultivate opportunities for shared positive moments with your in-laws, be that a trip to see some Christmas lights, taking the kids to the park, cooking together, playing a board game, or whatever else floats their boat (and that you might enjoy too).

If you strongly disagree with them on politics, religion, vaccinations, or some other topic, it might be tempting, in the heat of the moment, to confront their views. But do you really want to go down that road? Be pragmatic and honest with yourself: if these visits are rare, and/or you're unlikely to ever see eye-to-eye, perhaps it's better to avoid confrontation. Remind yourself of the good that can come from these visits – such as your kids having valuable time with their grandparents – rather than getting drawn into battles.

Finally, if tempers do get frayed, there are techniques to calm yourself down. 'Affective labelling' is a good one: go to a quiet space, such as the loo or your bedroom, and put a precise label on the emotion that you're feeling and why. Doing this will reduce the emotional intensity. Or try the 'fly on the wall technique': picture the scene from a fly's perspective and take a few slow, deep breaths. This will create 'psychological distance', which also has a calming effect. ***CJ***

GETTY IMAGES X4. ILLUSTRATIONS: DANIEL BRIGHT

VICTORIA GIBBS, NORFOLK

IS IT BETTER TO SKIP BREAKFAST AND HAVE A HUGE CHRISTMAS DINNER, OR SHOULD I SPREAD THE INDULGENCE ACROSS THE WHOLE DAY?

If you celebrate Christmas then you're almost certain to devour an enormous meal at some point on 25 December, your plate overflowing with proteins and carbohydrates. But should you add breakfast to the mix?

A recent 'big breakfast' study by scientists at Aberdeen and Surrey universities found that the time of day when you consume your calories does not affect metabolism. Funded by the UK's Medical Research Council, the trial involved 30 people on weight-loss diets, with some eating more in the morning, and others loading calories later in the day. The researchers found no difference in resting metabolic rate or weight loss for the two groups. However, those eating a big breakfast were significantly less hungry later in the day. Using breath tests for octanoic acid, a fatty acid absorbed in the intestine, the team showed that it took far longer for the volunteers' stomachs to empty after they'd had a larger breakfast.

The results tie in with another study showing that levels of a 'hunger hormone' called ghrelin are suppressed more after breakfast, than after an evening meal.

So, if you fill up on breakfast, not only will you be less likely to overindulge in your main meal, but you'll also have enough energy to fuel the hours spent over a hot stove cooking it. *ED*

BLAIR BENSON, VIA EMAIL

HOW DOES THE INTERNET ACTUALLY WORK?

The internet is a collaboration between computers all over the world (although some countries restrict access). When you type in a URL (uniform resource locator, or web address) such as **https://www.sciencefocus.com**, your computer first has to figure out which computer to talk to...

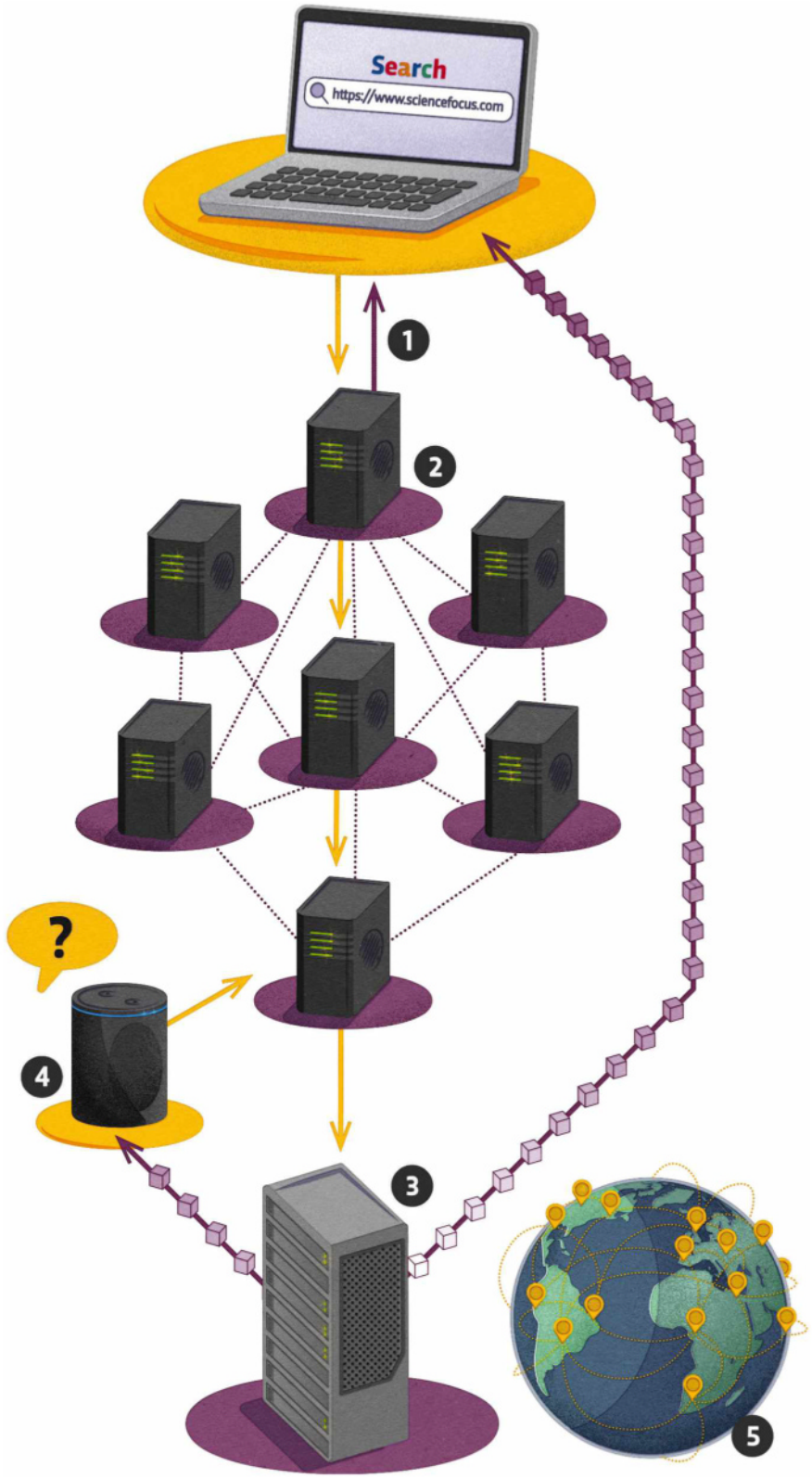
1 Every computer has a unique IP (internet protocol) address, consisting of sets of numbers separated by dots. To find the right IP address from the URL, your computer first talks to DNS (domain name system) servers, which pass the request up a hierarchy until each set of numbers has been resolved to get the IP address.

2 Your computer now starts to establish a connection to that address, a process that involves a chain of computers all passing data between your computer and the server that hosts the website you want. The chain is optimised to minimise the number of steps and potential errors, giving you the fastest, most reliable speed.

3 Once the connection is made, your computer can talk to the server, which will provide the data you want – a funny cat video, for example. They both speak the language of the internet: TCP/IP (transmission control protocol/internet protocol). Little packets of data are sent in this language that's been specially designed to check for errors and ensure all the data arrives correctly. Your computer also knows that the server follows the HTTPS (hypertext transfer protocol secure) protocol – the first part of the URL – so when it puts the packets together and sees an HTML (hypertext markup language) web page, it knows how to display the content.

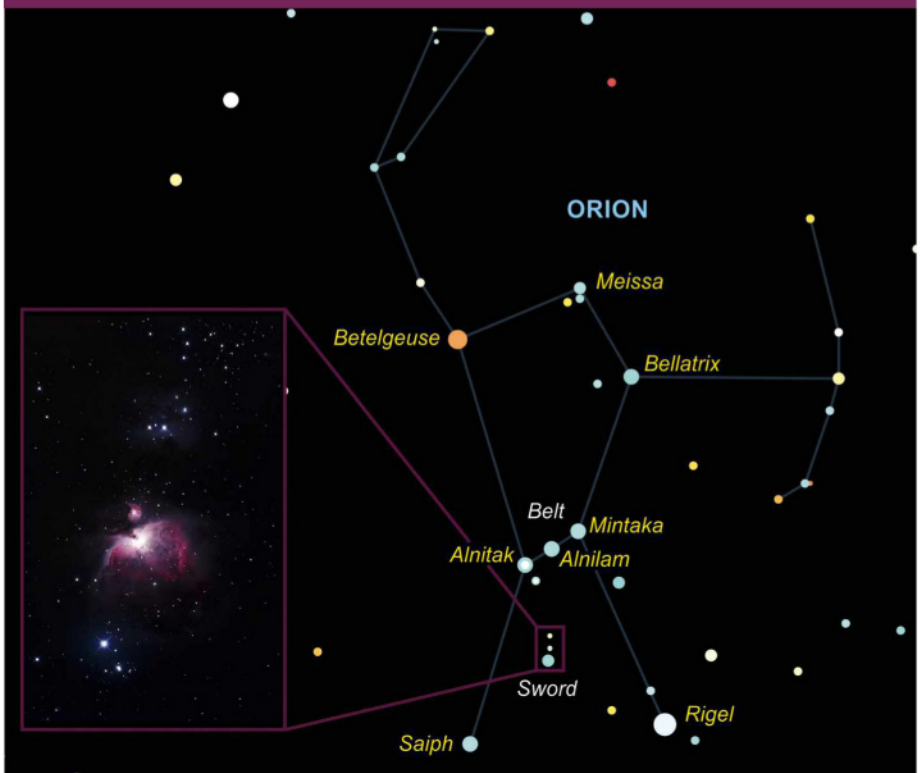
4 Today's web pages are often very complicated. Their HTML code may specify content stored on other computers, each with their own domain names, so as your computer displays the content, it has to keep asking the DNS servers 'where is this?' and quickly establishing new connections to other computers. Sometimes your computer asks more complicated questions, such as: 'what is being said in this audio recording taken from my user's Alexa device?' The servers then have to perform complex artificial intelligence processing and reply with the result.

5 All of this communication happens dynamically across the world, with servers providing data through whatever connections are available, making the internet amazingly robust. ***PB***



GETTY IMAGES ILLUSTRATIONS: DANIEL BRIGHT, PETE LAWRENCE

ASTRONOMY FOR BEGINNERS



HOW TO SEE ORION

WHEN: THROUGHOUT WINTER

The two most recognisable night-sky patterns visible from the northern hemisphere, have to be the Plough and Orion. As winter approaches, Orion the Hunter moves centre stage, a magnificent, large and easy-to-identify constellation.

Start at the centre of the pattern, which is marked by three stars of similar brightness, equally spaced in a straight line: Mintaka, Alnilam and Alnitak. This trio forms Orion's Belt. Hanging down from his belt is a faint north-south line of stars representing his sword. Look into the sword using binoculars or a telescope and you'll be rewarded with a view of the Orion Nebula, M42, a gaseous glow surrounding a newly formed group of stars known as the Trapezium Cluster. The top and bottom of the sword are marked by two open clusters, NGC 1980 and NGC 1981.

North of the belt are two stars marking Orion's shoulders: Betelgeuse and Bellatrix. Betelgeuse is a red supergiant estimated to be 1,000 times larger than our Sun. The literal translation of the name is contested, but can be taken to mean 'the giant's shoulder'. Bellatrix means 'female warrior'. North of the mid-point between Betelgeuse and Bellatrix lie three stars forming a small triangle representing Orion's head. The brightest of the three, Meissa, translates as 'the shining one'.

South of the belt lie the two stars that mark the lower portion of Orion; Rigel and Saiph. Rigel is a blue supergiant. Switch your view back and forth between it and Betelgeuse and the colour difference between them will be obvious. Saiph marks Orion's southeast corner and the name means 'sword'.

In addition to the constellation's main outline, as described, Orion appears to be holding a club, his arm extending north and east from Betelgeuse. On the western side, there is a faint curving line of stars that appear in the shape of a bow, although they actually represent an animal's hide. ***PL***

GLYN ELLIS, CARDIFF

HOW DO I MAKE THE ULTIMATE SNOWMAN?

Not all snow is created equal, as anyone who has tried to have a snowball fight or build a snowman only to have the snow fall apart in their hands will know. That's because the properties of snow vary greatly depending on temperature and moisture.

The best snow for building snowmen is moist or wet snow, which forms when the air temperature is just above freezing — between 0°C and 2°C — meaning that some of the snow melts, creating free water between the ice crystals that acts like glue. Ideally, the snow should be around 3 to 8 per cent moisture. Any more than 15 per cent moisture, and snow becomes slush and too wet to hold a shape.

Freshly fallen moist or wet snow forms as dendrites – the classic branched snowflake shape – and the branches provide more surface area for the water 'glue' to stick to, making this type of snow ideal for snowballs and snowmen. When temperatures drop well below freezing, there is little or no liquid water to act as glue, and the ice crystals instead tend to form as flat plates, which have a lower surface area, making them less sticky.

There are other things to consider when building a snowman. You'll want a level area of ground; ideally not a driveway because tarmac tends to absorb heat, which can melt your snowman prematurely. Similarly, building your snowman in a shady spot will help it last longer.

Start by packing a ball of snow in your hands. The warmth and pressure from your hands will slightly melt the snow, creating more watery glue to hold the crystals together, which will refreeze once you've finished building, making the snowman stronger. Roll each ball across the snow, aiming for a roughly 3:2:1 size ratio for the base, torso and head to maximise the snowman's stability. Slightly flatten the top of the ball before you stack the next one on top, and reinforce the base of the snowman by packing extra snow around the bottom. ***CA***

REBECCA JONES, VIA EMAIL

HOW DO METEORITES FROM MARS END UP ON EARTH?

There are several strands of evidence implying that some meteorites found on Earth actually originate from Mars. Scientists have used a technique called 'radiometric dating' to determine the ages of these chunks of rock. The method, which is analogous to radiocarbon dating of organic material, looks at the ratios of certain radioactive isotopes in the meteorites. Since isotopes decay at well-determined rates, a comparison of their ratios reveals the time since the meteorite was formed, or at least the time since it was last heated. Most meteorites turn out to be about 4.56 billion years old, because they come from asteroids that date from the creation of the Solar System, 4.56 billion years ago. Anything younger than this must be from a planet or moon, the only places in the Solar System that could have formed rocks younger than 4.65 billion years.

Scientists have found that the ratios of oxygen isotopes in meteorites are different for each 'parent body'. The reasons for this are still unclear, but it's probably related to the way the Solar System originally formed. Martian meteorites are found to have isotopic compositions that match the rocks of Mars. Furthermore, some Martian meteorites are found to have trapped gases whose isotopic composition exactly matches that measured for the atmosphere on Mars. Taken together, these strands of evidence make the meteorites' origin pretty certain: they arrived here from Mars.

But if these chunks of rock are from Mars, then how did they get to Earth? Scientists believe that, given a sufficiently powerful impact by a comet or asteroid, chunks of the Martian surface can be ejected into space. A small number of these could end up in orbits that put them on a collision course with Earth. Those chunks big enough to survive passage through Earth's atmosphere will reach the surface. To date, more than 200 such 'Martian meteorites' have been found. ***AG***

JENNIFER BRUCE, VIA EMAIL

WHY CAN I RAISE ONE EYEBROW AND NOT THE OTHER?

There isn't much of a consensus on this. Some people think it's due to greater muscle dexterity on one side of the face, others say one eyebrow is dominant in the way that one hand is dominant, while others argue that there's a genetic component to it. It might be a combination of all three of these factors, or perhaps none of them at all – there's no definitive answer, unfortunately. However, if it's a skill you'd like to improve, with a bit of practice, you can apparently learn to raise both eyebrows independently. ***NM***

BONNIE GREEN, VIA EMAIL

COULD ANYTHING REALLY MAKE RUDOLPH'S NOSE GLOW RED?

Scientists have already transferred bioluminescent genes from jellyfish and corals into many other organisms, including bacteria, fungi, fish and mammals. The setup can be designed so the genes are only active in certain tissue types, such as the epithelial cells that line the nose. Then, when ultraviolet light is used to illuminate the tissue, it glows. As technology continues to evolve this is, perhaps, something that Santa would consider. Like the wingtip lights on a plane, a flashing hooter could help to improve Rudolph's visibility in the night sky, keeping both Santa and his reindeer safe as they deliver their booty. ***HP***

WHY DO WE FIND THINGS BEAUTIFUL?

Much of what we find beautiful is highly subjective. However, experts who have interviewed large numbers of people and analysed some of the world's most revered works of music, art and architecture have identified common attributes among the things we find beautiful. These universal qualities include simplicity, pattern, rhythm, symmetry, certain juxtapositions of colour, specific combinations of musical notes and physical elements arranged in certain ratios and geometries.

Neuroscientists also know a bit about what happens in our brains when we perceive beauty. In one study, volunteers inside a brain-imaging fMRI scanner were asked to rate pieces of visual art and music as either 'beautiful', 'ugly' or 'indifferent'. When the participants experienced beautiful images or music, the researchers saw activity in a region of the brain called the medial orbitofrontal cortex, which plays a role in our feelings of reward and pleasure. Other studies have identified that part of the region known as the striatum – also involved in reward and judgment – responds to beautiful faces.

But why do we experience beauty at all? Does it have a purpose? The leading theory is that we're hardwired to appreciate forms and patterns that are pervasive in nature, such as fractals, the Golden Ratio and symmetry, because they helped our ancestors survive. A symmetrical face, for instance, suggests good health and strong genes in a potential mate. Our brains recognise plants that grow in fractal patterns as healthy and safe to eat, and make us wary of those that grow askew. Things that help us survive activate the reward centre in our brain, inducing feelings of pleasure and, in doing so, cause us to attach value to them. *CP*

SHUTTERSTOCK, GETTY IMAGES X2, NASA ILLUSTRATIONS: DANIEL BRIGHT

HENRY PARR, FROME

WHY IS MY BRAIN BUZZING AT 3AM BUT COMATOSE AT 3PM?

You're not alone if you spend much of the night ruminating about daily stressors, checking the time and worrying about how tired you'll be in the morning. Then spending the next day struggling to think straight and keep your eyes open. So, how can you break this cycle of anxiety and sleeplessness?

The first tip, and one of the most important, is to avoid lying awake in bed. If you haven't nodded off within 15-20 minutes of resting your head on the pillow, get up. Take yourself off to another room and do something relaxing like reading, meditating or listening to music. Then, when you begin to feel sleepy again, go back to bed. This can be hard when you're so tired that it's a struggle to get out from under the duvet, but it works. The idea is to build a strong association with your bed and sleep.

When you're in bed, calming any nuisance thoughts with relaxation methods can be helpful. They can feel a bit silly at first, but things like guided imagery, mindfulness and progressive muscle relaxation are all beneficial for a racing mind. You can find guides to these calming exercises online.

Finally, don't forget the basics of sleep hygiene. Keep work materials, computers and screens out of the bedroom, and avoid looking at screens (especially those displaying social media) for an hour or so before bed. You might also want to try avoiding caffeinated drinks after 2pm, and alcohol and heavy meals in the evenings, if you want to increase your chances of getting a better night's sleep. A warm bath in the evening can help too, as can exercise during the day, but try to avoid strenuous workouts in the three to four hours before bed if possible (sometimes the adrenaline this late in the day can be detrimental to your sleep).

If you find yourself feeling comatose the next day, resist the urge to nap, unless it's for safety reasons such as when you're driving. If you absolutely can't get by without one, try to limit it to 30 minutes and don't nap after 3pm. Avoid big lunches, which can make you feel sleepier in the afternoon, especially if the food has a high sugar content. We tend to crave less healthy foods when we haven't slept, but protein-rich meals might help to avoid that afternoon crash. If possible, a brisk walk and some fresh air might help to fend off the comatose feeling too. Above all, be kind to yourself, and lower your expectations for what you might be able to achieve the day after a restless night. ***NM***

LUCY HANNIGAN, SUNDERLAND

WHY DO WE NEVER FORGET HOW TO RIDE A BIKE?

Life experiences and facts are one type of memory. Riding a bike is another: it's a skill, or a learned pattern of movement that neurologists refer to as 'procedural memory', more commonly known as 'muscle memory'. There are, of course, lots of skills – like driving a car or tying your shoelaces – that are so embedded in our minds that we barely have to think about them. It's not clear why procedural memories are harder to forget than others, but it might have something to do with where they're stored in the brain; an area that seems relatively protected and resistant to rewiring. ***HB***

SARAH PHELPS, VIA EMAIL

HOW DO PARROTS SAY HUMAN WORDS WITHOUT LIPS?

My friend's African Grey parrot speaks so convincingly, she can order herself treats via the family's smart assistant. No lips, no vocal cords, just sheer opportunism. She does this by using her syrinx, a hollow, Y-shaped structure unique to birds, that sits between the base of the windpipe and the lungs. As the bird breathes, air passes through the syrinx, which vibrates and makes a noise. The form of this noise is acutely controlled by a series of muscles and soft bony rings on the outside of the syrinx. This enables parrots to sing, call and mimic words, such as 'Pretty Polly' and 'Alexa, buy more millet'. ***HP***

FRED VERNON, VIA EMAIL

IF WE COLONISE THE MOON, WILL THE COLONISTS EXPERIENCE NIGHT AND DAY?

Yes, anyone living on the Moon will experience night and day, but a lunar day and night would last almost an entire Earth month.

Earth's gravity causes the Moon to elongate slightly on the sides nearest and farthest from us. The gravitational forces acting differently on the near and far side of the Moon's 'bulge' creates a torque that acts to alter the Moon's rotational period so that it matches its orbit period. This is known as 'tidal locking'.

Because the Moon spins in the same time as it orbits Earth, it only ever presents the same face to us. But even though the Moon is 'tidally locked' to Earth, it's still rotating with respect to the Sun. Its rotation period is 29 days, 12 hours and 44 minutes (also the length of the 'lunar month' on Earth). So, a lunar colonist would experience about two weeks of daylight, followed by about two weeks of night.

Of course, from the nearside of the Moon, Earth appears to stay in exactly the same position in the sky while the stars rise and set — although Earth's exact position depends on where you are on the Moon. The phase of Earth will change, just like the Moon's does, over a lunar month, but Earth itself will be seen spinning once in a little over 24 hours.

Earth would be fully illuminated (a 'full Earth') in the middle of the lunar night, while at 'new Earth' it would be almost hidden in the glare of the Sun and showing its unlit, night-time hemisphere. Since Earth is about four times the size of the Moon, solar eclipses visible on the Moon last much longer than on Earth. Every time people on Earth see a total lunar eclipse, anyone living on the Moon would see a total solar eclipse. ***AG***

QUESTION OF THE MONTH

TOM SHEPHERD, BRISTOL

IF YOU PUT ALL THE GERMS (AND BACTERIA) IN THE WORLD ON TOP OF EACH OTHER, WOULD WE BE ABLE TO SEE THEM?

Between bacteria and archaea (another type of single-celled microbe), there are more than 10^{30} individual cells. Although most are about one micrometre long (0.001mm), it's such a colossal number that laid end-to-end, they would stretch for 10 billion light-years! This bacterial thread would still be difficult to see, because one micrometre is about 75 times thinner than a human hair. But if you wrapped the thread around the Milky Way, it would encircle it more than 20,000 times, creating a 2cm-wide ribbon that might catch enough light to be visible to the naked eye.

Statistics like this show just how bad we are at visualising large and small amounts. Ten billion light-years is an unfathomable length, but if we packed all the bacteria into a cube (and it didn't collapse under its own weight) it would only be around 10km on each side, which seems much more manageable. In reality, up to 80 per cent of all the bacteria in the world are found in biofilms on rocks, in the soil, on stagnant water and in virtually every other habitat, including your mouth and intestines. These biofilms are a few hundred bacteria thick and can contain bacteria, archaea and fungi of various species banding together in a kind of city. You can see biofilms whenever you clean your house. The red, black or brown slime on your shower head, under the rim of the toilet or on the draining rack on the kitchen sink are all bacterial biofilms, each consisting of tens of millions of bacteria. *LV*

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

GETTY IMAGES X4 ILLUSTRATION: DAN BRIGHT

CHRISTMAS QUIZ

HOW WELL HAVE YOU BEEN PAYING ATTENTION IN 2022?

1. At the start of the year, it was announced that China's Artificial Sun broke the world record for the longest sustained nuclear plasma reaction after running for 17 minutes, 36 seconds. But how hot did it get?

A. 50,000,000°C
B. 70,000,000°C
C. 30,000,000°C

2. The largest known bacteria, *Thiomargarita magnifica*, is found in the tropical mangroves of Guadeloupe in the Caribbean. How big is it?

A. 10mm
B. 2mm
C. 1mm

3. The most expensive NFT sold to date is 'The Merge'. Almost 30,000 collaborators pitched in to buy parts, but how much did this artwork sell for?

A. $25.4m
B. $127m
C. $91.8m

4. A mysterious cube was detected on the far side of the Moon by China's Yutu-2 rover. What was it?

A. Alien monolith
B. A rock
C. Spacecraft debris

5. Why did NASA's DART mission deliberately crash into an asteroid on 26 September?

A. It was part of a planetary defence strategy: to find out whether we can deflect an asteroid
B. It was part of a military operation: to test classified military equipment
C. It had already finished its mission: the spacecraft was at the end of its life

6. A new antibiotic, solanimycin, has been recently found in what food?

A. Carrots
B. Potatoes
C. Onions

7. Which year is Halley's Comet due to return to our skies?

A. 2023
B. 2061
C. 2045

8. To investigate whether it could rain diamonds on the ice giants Neptune and Uranus, scientists created nanodiamonds by firing powerful laser flashes at what material?

A. Steel
B. Glass
C. Plastic

9. Researchers from UCL and the University of Cambridge found that Neolithic humans were infected with intestinal parasites. They recovered eggs of capillariid worms from what?

A. The gut of a mummified 'bog body'
B. 4,500-year-old human poo
C. Organic remains inside a clay pot

10. A new fabric, developed by researchers at the Massachusetts Institute of Technology and the Rhode Island School of Design, can react to your heartbeat. What part of the human body was the fabric modelled on?

A. The ear
B. The skin
C. The eye

11. If you're trapped under rubble, which animal might come to your rescue?

A. Search and rescue bats
B. Search and rescue rats
C. Search and rescue cats

12. An international team of neuroscientists have successfully taught mini brains to play which classic computer game?

A. *Pac-Man*
B. *Space Invaders*
C. *Pong*

13. Which animals are currently favoured to become the first interstellar space travellers?

A. Tardigrades
B. Spiders
C. Cockroaches

14. On 19 July 2022, parts of the UK reached record high temperatures. The Met Office recorded and verified the new record from Coningsby in Lincolnshire. How hot did it get?

A. 40.3°C
B. 42.4°C
C. 38.7°C

15. A study from the British Dietetic Association found that modern diets are lacking in what carbohydrate?

A. Starch
B. Sugar
C. Fibre

16. By examining fossilised teeth from the Bulgarian National Museum of Natural History, palaeontologists found that a giant species of which animal roamed Europe six million years ago?

A. Emu
B. Jaguar
C. Panda

17. Where are Britain's temperate rainforests located?

A. The eastern coast – Yorkshire, Norfolk and the Isle of Sheppey
B. The western coast – Scotland, the Lake District, Wales and the southwest
C. The southern coast – High Weald, the Kent Downs and the Isle of Wight

18. What is the longest cranial nerve in the human body, running from the brain to large intestine?

A. The vagus nerve
B. The oculomotor nerve
C. The trigeminal nerve

19. Scientists from Ben-Gurion University in Israel taught goldfish to do what?

A. Sing
B. Ride a bike
C. Drive a car

20. Very few human remains have been found at the site of the Battle of Waterloo. Researchers from the University of Glasgow investigated historical accounts, and concluded what?

A. The remains were ground into fertiliser
B. The remains were eaten
C. They were looking in the wrong place

ILLUSTRATIONS: JAMES OLSTEIN

21. On 12 May 2022, the Event Horizon Telescope Collaboration revealed the first-ever image of the black hole at the centre of the Milky Way. What is it called?

A. Capricorn A* (Cpr A*)
B. Sagittarius A* (Sgr A*)
C. Aquarius A* (Aqr A*)

22. B vitamins found in which popular spread may help reduce feelings of anxiety and depression?

A. Nutella
B. Marmalade
C. Marmite

23. In July 2022, what type of mammal was spotted in London for the first time in 100 years?

A. Lynx
B. Pine marten
C. Lemming

24. On 11 October 2022, an AI made history and became the first ever robot to provide evidence in the House of Lords – and then fell asleep. What was its name?

A. Ai-Na
B. Ai-Da
C. Ai-Va

25. What is a wobbegong?

A. A percussion instrument
B. A type of tree
C. A type of shark

26. Which mascot is accompanying astronauts on board Artemis 1?

A. Shaun the Sheep
B. SpongeBob SquarePants
C. Buzz Lightyear

27. In 1915, Ernest Shackleton's ship was lost to the depths of the Weddell Sea on a mission across Antarctica. In March 2022, robots finally uncovered its final resting place. What is its name?

A. *The HMS Endeavour*
B. *Endurance*
C. *The Octavius*

28. At the current best estimate, how much wood would a woodchuck chuck, if a wood chuck could chuck wood?

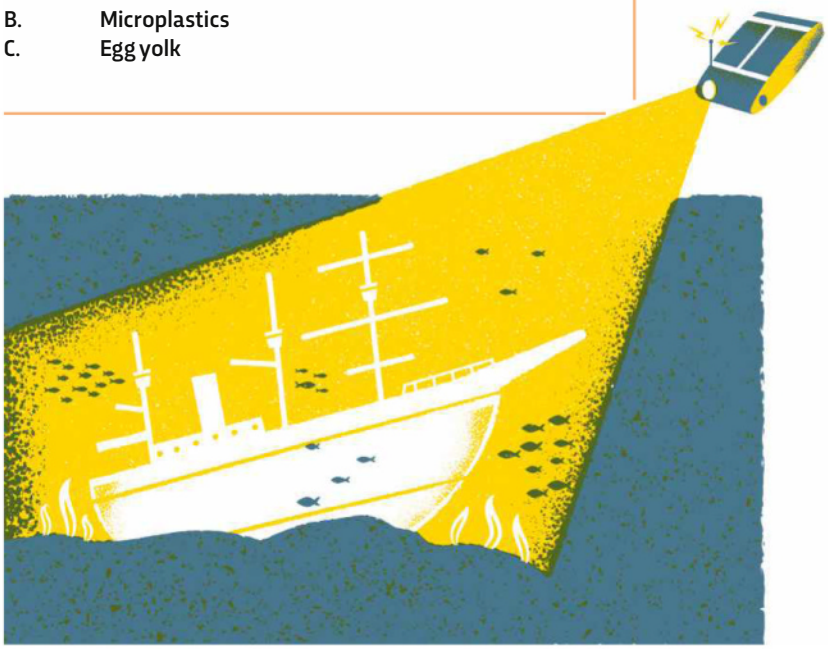
A. 700 pounds of wood
B. 100 pounds of wood
C. 500 pounds of wood

29. Which of these has the potential to treat autoimmune diseases, when transplanted from a donor to a recipient?

A. Spit
B. Poo
C. Wee

30. In February 2022, a newly hatched baby ghost shark was found off the coast of New Zealand. What was in its belly?

A. Fish
B. Microplastics
C. Egg yolk



31. **The US National Institutes of Health says that drinking what type of beverage can reduce the risk of death?**

A. Black tea
B. Bubble tea
C. Peppermint tea

32. **UK-based JET facility in Oxford generated the largest-ever amount of energy in a sustained fusion reaction. The project generated 59 megajoules of heat energy over what time period?**

A. 2 seconds
B. 5 seconds
C. 48 seconds

33. **In August, NASA reported that the MOXIE experiment onboard the Mars rover Perseverance has generated around 50 grams of oxygen. How much breathable air for one person does this equate to?**

A. 10 minutes
B. 100 minutes
C. 50 minutes

34. **By weight, approximately how many epidermal cells does one human shed in a year?**

A. 1kg
B. 500g
C. 4kg

35. **NASA's DART spacecraft crashed into the asteroid Dimorphos. Dimorphos has a larger companion asteroid – what is it called?**

A. Didymos
B. Darius
C. Demeter

36. **On 15 January 2022, the underwater volcano Hunga Tonga-Hunga Ha'apai in the southern Pacific Ocean erupted. Acoustic ripples from the explosion travelled at the speed of sound to Miami, around 11,466km (7,125 miles) away. How long did it take these pressure waves to reach Miami?**

A. 10.5 hours
B. 15 hours
C. 13.25 hours

37. **NASA's first asteroid sample spacecraft, OSIRIS-REx, is on track to return samples to Earth in September 2023. Which asteroid did it collect samples from in 2020?**

A. Fortuna
B. Bennu
C. Ryugu

38. **In July 2022, which animal was introduced into the Kent countryside as part of a rewilding effort?**

A. Wildebeest
B. Reindeer
C. Bison

39. ***Quetzalcoatlus*** **was a type of pterosaur that lived around 70 million years ago, and is the largest known flying animal to have ever existed. How big was it?**

A. The size of a double-decker bus
B. The size of a minibus
C. The size of a 1950s (pink) Cadillac Eldorado

40. **In August 2022, the JWST detected the first clear evidence for what type of gas, in the atmosphere of WASP 39-b, a hot Jupiter exoplanet located around 7,000 light-years away?**

A. Oxygen
B. Nitrogen
C. Carbon dioxide

ANSWERS

1 B 2 A 3 C 4 B 5 A 6 B 7 B 8 C 9 B 10 A
11 B 12 C 13 A 14 A 15 C 16 C 17 B 18 A 19 C 20 A
21 B 22 C 23 B 24 B 25 C 26 A 27 B 28 A 29 B 30 C
31 A 32 B 33 B 34 C 35 A 36 A 37 B 38 C 39 A 40 C

ILLUSTRATIONS: JAMES OLSTEIN

DIY SCIENCE AT CHRISTMAS

GOT TIME TO KILL AND KIDS TO KEEP QUIET OVER THE HOLIDAYS? HERE'S SOME FESTIVE ACTIVITIES WITH A LITTLE LEARNING BAKED IN

BECKI CLARK X2

Make a Jupiter-themed wreath for your door

All you need to make a Christmas wreath is some foraged materials and a little knowhow. But with a few careful choices you can give your wreath an astronomy theme by introducing some planetary colours to your festive decorations.

As planets are (generally) round, they're the ideal subject matter for a wreath. Jupiter's colours work well for a Christmas wreath, which means you'll need to gather cream and brown materials, such as bracken, ferns, dried flowers and grasses. And of course, you'll need something red to signify the Great Red Spot – a large anticyclonic storm that's been swirling in Jupiter's atmosphere for centuries. You could use a hydrangea head, poinsettia or achillea, which you may still be able to find in your garden.

If you want to give your wreath an Earth theme, look for green, blue and white foliage. Alternatively, you could use red and orange foliage if you decide to base your wreath on Mars.

Deciding on a colour palette is a good starting point, but highlighting distinguishing features, such as the Great Red Spot on Jupiter or the rings of Saturn, is a great way to make your wreath stand out from the crowd. (You can see Jupiter, as photographed by the James Webb Space Telescope, on p57.)

You can find plenty of construction materials outside: berried ivy, eucalyptus, ferns and hawthorn work brilliantly for wreaths, and you might also still have things in your garden that you can add. Think about the look of your wreath before foraging and there'll be no need to waste anything.

If you're planning on using dried flowers and grasses, you'll need to allow a few weeks to let them dry, however most will dry into the wreath – so you can work with fresh materials knowing they'll dry out over time.

What you'll need

- Rattan base
- Wire
- Scissors
- Selection of cream, brown and red foliage
- Dried oranges
- Dried hydrangea heads
- White statice flower (or similar)
- Something red to represent the Great Red Spot
- Ribbon

What to do

1. Weave the ends of the brown foliage into the rattan base, securing it with wire if necessary. Position your foliage so that it all faces the same direction and fans out slightly, to create balance and movement.

2. Thicken up the left-hand side by adding grasses and bracken. Try to vary the colours, to represent Jupiter's stripes. Like before, weave the ends of the foliage into the base and secure with wire if needed.

3. Staying on the left-hand side, attach the dried oranges. Fill in any gaps between the oranges with brown and cream foliage, so they look like they're nestled into the wreath, rather than sitting on top of it.

4. To represent the auroras discovered by NASA's Voyager 1 space probe in 1979, cluster some white statice flowers (any white flower or berries will do) at the top and bottom. Cutting the flower stems short enables you to poke them into the base, and have them sit facing outwards.

5. Finally, use the other materials to feather around the left-hand side, and into the right, to finish off the main bulk of the wreath. The last thing to do is to add the finishing touch: the Great Red Spot in the bottom-right. Tie on a ribbon and it's ready to hang and celebrate the season.

by BECKI CLARK (@becki_clark_)
Becki is a creative designer and author. ***beckiclark.com***

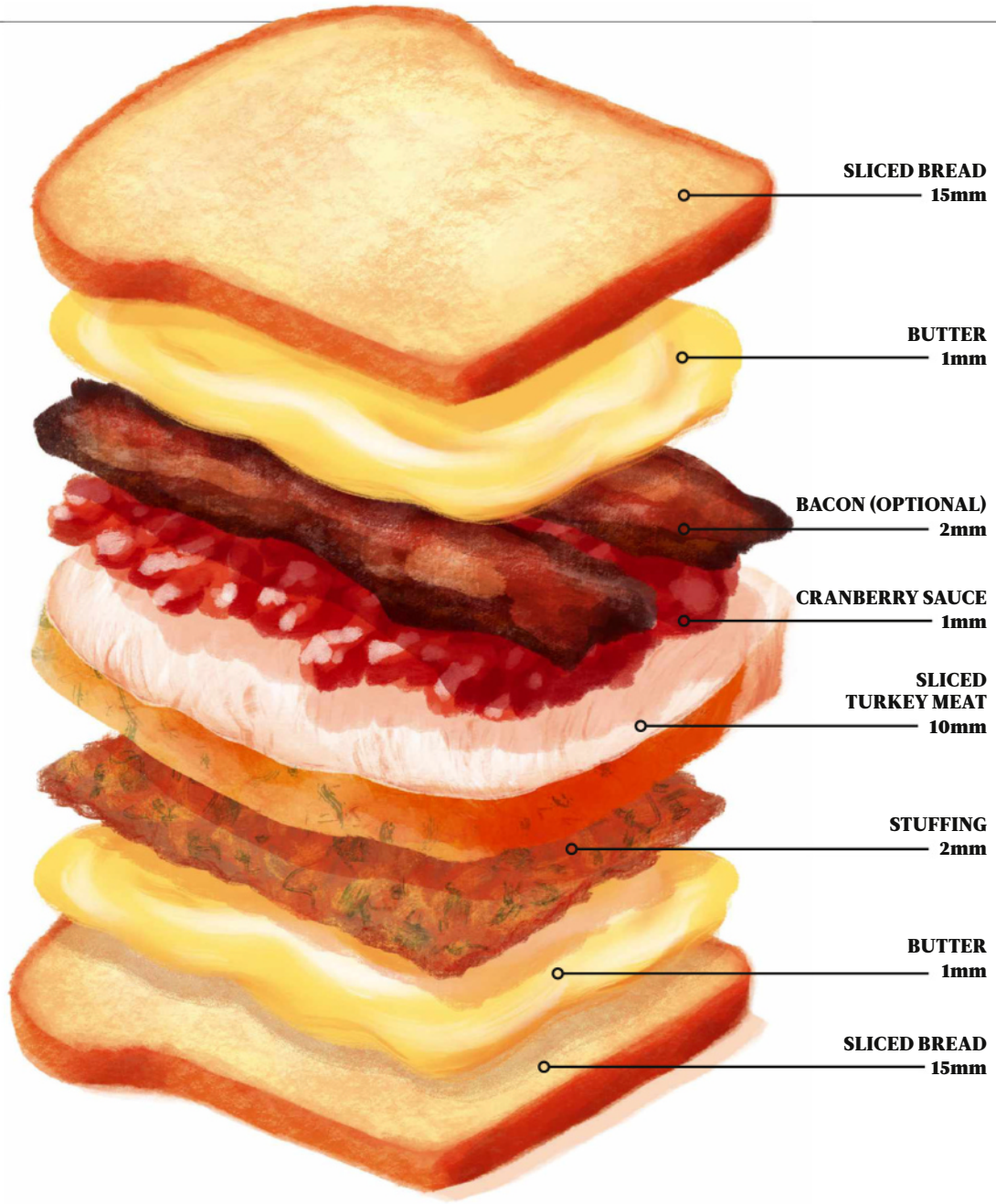
"As planets are (generally) round, they're the ideal subject matter for a wreath"

How to make the ultimate Christmas leftovers sandwich

After a typically indulgent Christmas dinner, you're usually left with a mountain of meat, stuffing, roast potatoes and the half-dozen pigs-in-blankets that not even Uncle Carl could squeeze in. Casting all this in the bin would be a profound waste and an environmental travesty: 1kg of food waste in landfill produces the equivalent of 2.5kg of carbon dioxide emissions. There's only one thing for it: all those leftovers need to be eaten! Enter the Christmas leftovers sandwich...

You can forget the simple 'leftovers crammed between slices of white bread' recipe of yesterday, though. Nowadays, the 'Christmas sandwich' is the stuff of hipster coffee bars, delicatessens, supermarkets and corner shops alike. You can all too easily find yourself agonising over an endless choice of artisanal sandwiches, paninis and wraps loaded with prime turkey, organic sage and onion stuffing, and sickly-sweet cranberry sauce. There's even an annual Christmas sandwich festival in London, where top chefs showcase their best offerings. But in these belt-tightening times, it's reassuring to know that with a bit of food science, you too can turn what was once pauper's fare into a feast to rival the high street's finest offerings.

The first critical decision when you're constructing the ultimate Christmas leftovers sandwich is bread. And the trick is to keep it simple. You can shun the crusty bloomers and posh brioche – the filling is the star of the show here. My previous research has found that bread should be high quality but primarily serve as a soft, neutral vehicle for what's inside. The total thickness of the bread should be about the same as that of the filling.



To each slice add a generous 1-2mm smearing of butter, which excites fat receptors in the mouth and enhances flavour, but also provides a waterproof layer to protect the bread from any liquid seepage and unpleasant sogginess from the filling. Butter (which is more flavourful than margarine) allows flavour compounds to better disperse throughout and release their aromas, thus boosting the sandwich's overall enjoyment factor.

Always avoid the temptation to shoehorn as much as possible between those two slices. For maximum enjoyment, my research has shown that the total height of the sandwich should comfortably fit in the mouth, which works out at between 4.5cm and 5cm for most people's chops.

Turkey is the centrepiece of the classic Christmas sandwich, which presents a challenge because it's perhaps the blandest meat going. Few people realise that turkeys are actually game birds, which have succulent and tasty meat – a far cry from today's oversized broiler birds that are bred for lean bulk rather than fat and flavour. A broiler turkey's unexercised muscle and absence of fat reserves creates the perception of dryness and blandness.

As well as a goodly portion of fat (from the butter, if not the bird), a great sandwich relies on a balance of the basic tastes: sweetness, saltiness, sourness and umami. A steady hand is needed when applying the cranberry sauce – too much and it's game over. When overall sweetness of each mouthful exceeds

HOLLY SPANNER ILLUSTRATION: SAM BREWSTER

the equivalent of a 9 per cent sugar solution, food becomes sickly and unappealing. Stuffing is a must as it adds a little sweetness but also, and more importantly, gives much needed depth – its sage and onion aromas waft up the back of the throat and into the nasal cavity, where it's experienced as a burst of herby flavour. Generally speaking, the more mouth sensations that are experienced with every bite, the more enjoyable the food is.

A good grind of pepper will give some pungent heat to titillate the mouth – the irritating chemical in black pepper, called piperine, stimulates hot-pain nerve fibres in the same way chilli does to create the illusion of heat. If you're feeling adventurous, add some leftover bacon for crunch and texture, an extra hit of saltiness and a powerful kick of umami – the savoury 'meaty' taste that makes soy sauce, Parmesan and cured meats so irresistible. If you don't use bacon and use unsalted butter, then season the meat with a sprinkle of salt. This amplifies all the flavours and boosts sweetness perception.

Forget all the trendy extras like Brie, chorizo, cabbage slaw and mayo. Research shows that a sandwich's deliciousness and structural integrity plummets when you have over four fillings (3.6 being the optimum, if that were possible!). Serve with a side of salad for some freshness and much-needed healthfulness. Following the rules above, select your favourite ingredients and whatever you do, don't subject your family to the bland turkey horror that marred my youth.

Final note: I recommend buying a heritage breed bird that has been bred to high welfare standards, if you want to discover real turkey flavour.

by DR STUART FARRIMOND

Stuart is the author of The Science Of Cooking *(£20, DK).*

Make a DIY bauble for your tree, inspired by the James Webb Space Telescope

The James Webb Space Telescope (JWST) was launched on Christmas Day 2021, so why not celebrate its one year in space with your own handmade version? You don't need much in the way of materials, and it's a fun project that won't take much time. You can make a single ornament threaded with ribbon, or string several into a chain to make a JWST garland. If you're looking for a way to spice up your bauble, how about replacing the gold card with one of the incredible photographs from the JWST itself? Turn to p44 for inspiration.

What you'll need

- Templates
- Scissors or a craft knife
- Gold card
- Black card
- Metal ruler
- PVA glue
- Hole punch
- Grommets
- Ribbon

What to do

1. First, download and print the templates from **bit.ly/JWST-bauble**. There are three pieces that make up this JWST ornament: the front grid (A), the primary mirror (B), and the back (C).

2. Cut out the templates for B and C using scissors or a craft knife. Use the templates to cut B from gold card, and C from black card, for the back of the bauble.

3. Using a craft knife and a metal ruler, use the template to carefully cut A from black card. If you don't have a craft knife, you can use a pair of small scissors with a fine blade, like nail scissors.

4. Using PVA glue, stick A onto B. Wet glue, like PVA, is ideal for gluing onto card with a texture (if you're using glitter card, for example), otherwise a glue stick is fine for smooth card.

5. Glue C to the back of B to give your bauble a backing and a little extra stability. Then leave it leave to dry.

6. Once the glue is dry, punch a hole in the top using a hole punch. Reinforce the hole using a grommet for added durability, if you wish.

7. Finally, thread some ribbon (or similar) through the hole, and tie a knot in it to secure it on your bauble.

by HOLLY SPANNER

Holly is staff writer for BBC Science Focus.

Puzzled over presents

Zak has forgotten to attach name tags to his Christmas gifts. He remembers that the silver present wasn't for his mum, and dad's present is either gold or red. The blue present belonged to either his sister or his brother. If his mum's present is red, his sister's is gold, but if his mum's is gold, his sister's is blue. Who should **receive each gift?**

Insulation calculation

Sven Svensen is nearing the final phase of his preparation for his trek across the Arctic. An important part of his preparation is to put on weight to help protect him from the cold. Starting today, and for the following 200 days, he must gradually increase the number of calories he eats by 100 every day, starting from his usual 2,540-calorie daily intake. It doesn't really matter what he eats to gain the weight, so he'd prefer to do it by eating Wazoo nutrition bars, which contain 140 calories each. On how many of the days where he follows this plan will he be able to consume nothing but Wazoo bars?

For the answers to these puzzles, and for more Christmas brainteasers, visit **bit.ly/xmas_puzzles_2022**

WARNING: REMEMBER TO ALWAYS DRINK RESPONSIBLY

FESTIVE COCKTAILS WITH A SPLASH OF SCIENCE

Alcohol (aka ethanol) is a deeply unpleasant, toxic substance that irritates the mouth and sends a harsh burning sensation rushing up the nose. It's a poison that needs mellowing. Hence, we have cocktails.

An analysis by chef and bartender extraordinaire Dave Arnold, revealed that the average alcohol concentration of the world's favourite cocktails was 15-20% ABV, sugar concentration was 5-9g/100ml (equivalent to about four sugars in a cup of tea), and acidity was somewhere between a Honeycrisp and Granny Smith apple (equivalent to 0.7-0.9 per cent solution of citric acid). If you want to throw something together following these tried and tested ratios, mix two parts high-strength alcohol (gin, vodka, whisky, rum) to one-part sugar (or maple syrup) and one part sour (lime or lemon juice). A daiquiri, for example, can be made with two shots of rum, a shot of freshly squeezed lime juice and a shot of sugar syrup (one part sugar to one part water by weight), shaken with ice and poured.

Ice is key, as it dilutes and chills the drink. As ice cubes melt, they absorb heat from the surroundings – clatter your iced cocktail in a shaker for over 12 seconds and the liquid that emerges is -4°C!

For flavours, we can turn to flavour-pairing theory. This is based on the principle that flavours that harmonise well (red wine/red meat, tomato/basil, pork/apple) do so because they share many flavour compounds. By analysing flavour compounds in different ingredients, we can predict pleasing combinations. Applying these principles with some Christmassy twists, here are my three festive cocktail suggestions to dazzle you and your guests...

GETTY IMAGES X2, ALEX AND SONJA OVERHISER/A COUPLE COOKS

SANTA'S SNOWBALL

The most famous of Christmas cocktails, the snowball is mixture of advocaat, lemonade and lime, although it has the alcohol content of an alcopop (7% ABV), making it more of an alcoholic lemonade than a cocktail. Advocaat is an egg and brandy liqueur, invented by the Dutch. It makes for a rather sickly drink, so to knock off some of the acidity and up the alcohol content, I've added some Cognac. Pour the advocaat and Cognac over ice in a glass of your choosing, add the lemonade and stir. Add lime juice, giving a final stir.

Lemonade: 2 measures (50ml)

Advocaat: 2 measures (50ml)

Cognac: 1 measure (25ml)

Fresh lime juice: one tablespoon (15ml)

Alcohol content: 13.2% ABV

Sugar: 6.4g/100ml

Acidity: 0.86 per cent

CHOCOLATE CRACKER

If you make this cocktail, opt for chocolate-flavoured vodka (38% ABV), rather than a chocolate vodka liqueur (28% ABV), which will be sweetened. The acidity comes from lemon or lime juice, while salt increases flavour perception, as well as the sensitivity of sweetness receptors. Mix all the ingredients in a glass with four ice cubes and stir well. Strain into a glass containing a cube of ice. Garnish with coffee beans, crystallised ginger or a cinnamon stick, all of which are strong flavour pairings to chocolate.

Chocolate-flavoured vodka: 2 generous measures (60ml)

Fresh lemon or lime juice: one tablespoon (15ml)

Simple sugar syrup: one tablespoon (15ml)

Chocolate bitters: two dashes

Pinch of salt

Alcohol content: 19.2% ABV

Sugar: 7.4g/100ml

Acidity: 0.70 per cent

FESTIVE 'MARTINI'

The classic martini is a mix of gin (or vodka) and vermouth, typically served with an olive. The name has come to mean anything served in a martini glass, and this creation is no different. Using vodka or gin as a base, it combines the fruitiness of cranberry juice with the tang of lime, and the orange notes of Cointreau. Shake with ice and pour into martini glasses rimmed with sugar, then serve with a curl of orange peel.

Gin or vodka: 2 measures (50ml)

Unsweetened cranberry juice: 1 measure (25ml)

Cointreau (triple sec): 1 measure (25ml)

Fresh lime juice: 2 teaspoons (10ml)

Alcohol content: 16.2% ABV

Sugar: 8.6g/100ml

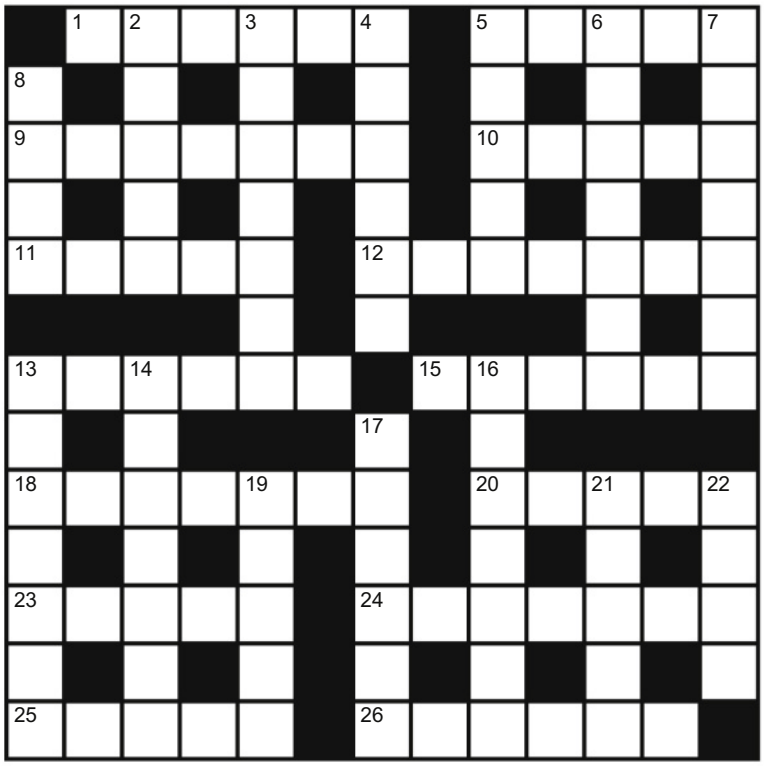
Acidity: 0.81 per cent

by **DR STUART FARRIMOND**

Stuart is the author of The Science Of Cooking *(£20, DK).*

CROSSWORD

PENCILS AT THE READY!



ACROSS

1 Principal design for plates (6)
5 Confronted a bunch of notes (5)
9 Pushy person gets hard result in a different way (7)
10 Gambling on removing top layer of sugar (5)
11 Some rituals have commendation (5)
12 Shot off to take in position of responsibility (3,4)
13 Garment for British parasite (6)
15 Show concerning meat (6)
18 Design on a gong taking shape (7)
20 Get to part of the river (5)
23 Not a soul has energy after midday (2-3)
24 I shall repeatedly include primarily wicked hostility (3-4)
25 Chair back makes a wet sound (5)
26 Machine being leaderless around Newcastle area (6)

DOWN

2 Wild stare that comes as a shock (5)
3 His heart is in crockery and exercises (7)
4 Your old listener's beginning to be vulgar (6)
5 Fellow isn't commonly vague (5)
6 Oriental feature – see correction (7)
7 Enjoy wagging tail, using fingers (7)
8 Friend is about to smell (4)
13 Crazy for fruit (7)
14 Admit objective is a self-inflicted setback (3,4)
16 Carry pear off beforehand as a precaution (7)
17 Fuel able to be seen in report (6)
19 Visitor formulated correct conclusion, we hear (5)
21 Like Scottish chap to be continental (5)
22 Target on course sounds complete (4)

ANSWERS

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

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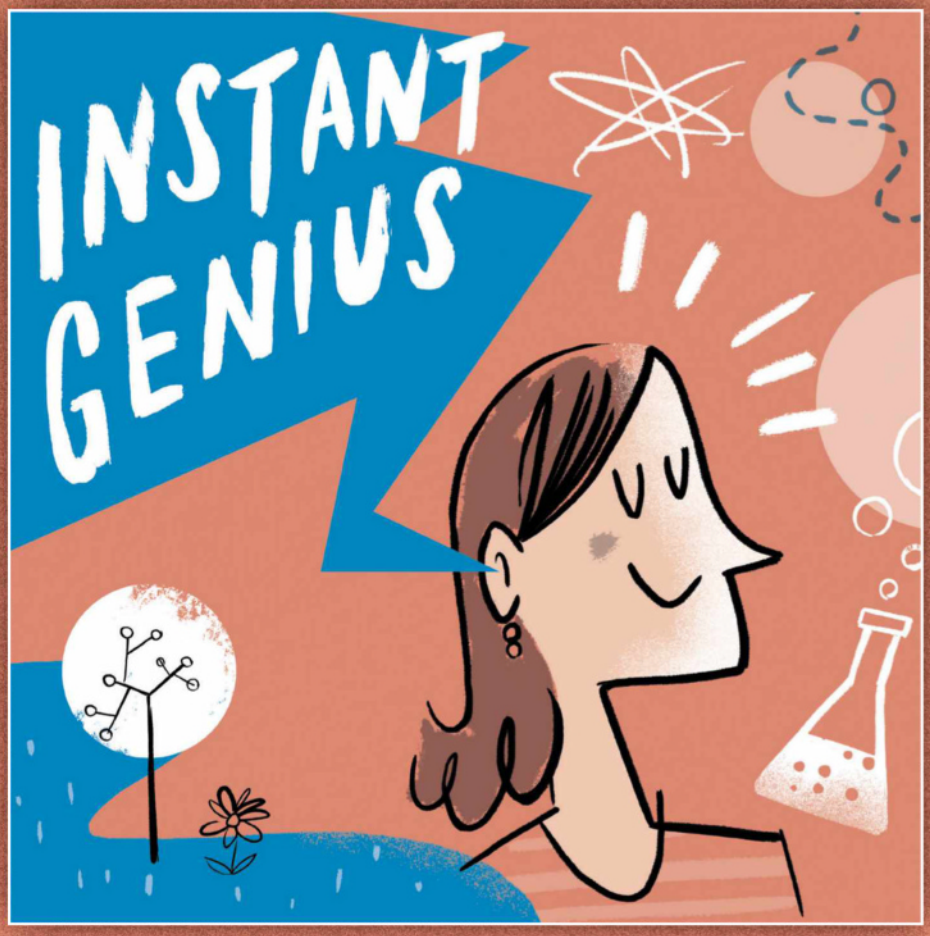


FEATURING

SEASHELLS
with ***Dr Helen Scales***

BEE COGNITION
with ***Prof Lars Chittka***

LIFE ON MARS
with ***Lewis Dartnell***

ARTEMIS
with ***Libby Jackson***

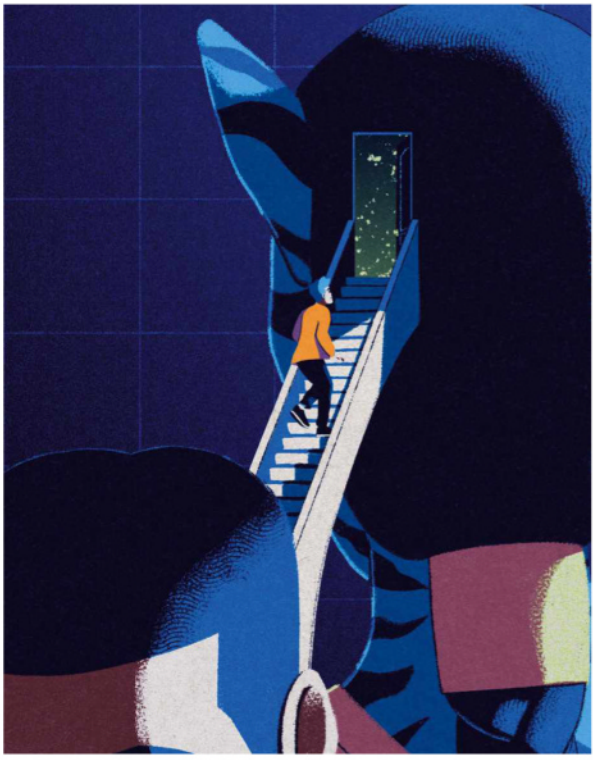
POPCORN SCIENCE

Could you port your mind into another body?

The *Avatar* sequel is out this month, in which lead character Jake Sully has left his human body behind...

by **STEPHEN KELLY**

Avatar: The Way Of Water, the sequel to the highest grossing film of all time, raises a lot of questions. Primarily, can anyone remember what happened in the first *Avatar*? And why is James Cameron seemingly devoting the rest of his life to making these movies? But for the purpose of this article, the most important question concerns the film's central idea: how feasible is it to transfer your consciousness into another body? Guillaume Thierry, a professor of cognitive neuroscience at Bangor University, is not convinced.



"There's a popular idea that the brain is just like a computer, but it's not," he says. "It's not made up of data that can be transferred from one brain to another. It's alive, and we don't know why or how. If I wanted to transfer my memories into a machine, I would need to know what my memories are made of. But nobody knows."

To explain the brain's complexity, Thierry cites a study from the Allen Institute For Brain Science in Seattle, which managed to map all the neurons in 1mm^3 of a mouse's brain. "It was a minuscule amount of tissue," he says. "But within it there were over 100,000 neurons and more than a billion connections between them. If you increase that to the size of the human brain, it's staggering. It's well beyond what people think."

In order to store that 1mm^3 of a mouse's brain, two million gigabytes were required. This leads to one of Thierry's biggest concerns: no hard drive could possibly hold the human brain. "It's well beyond the capacity of even the biggest single-memory computer," he says. "Not only that, but no artificial brain can simulate the speed of a real brain. One is purely sequential. The other one is fully parallel. The difference in speed is mesmerising. Whatever is happening in the brain is happening in real time. All the neurons can communicate through oscillation patterns in real time. A computer can't do that forever."

An idea that Thierry finds more feasible is the first *Avatar* film's concept of using your brain to receive the sensory input of another body. "You could have a system that reads, somehow, all the input from the senses in the second body and sends them, in real time, to your brain," he says. "Then everything that your brain wants to do can be sent back to the second body to make it react. The brain is basically an input/output interface. It gets some sensory input, and it produces a motor output and action."

But, says Thierry, the point it becomes "completely delirious" is when the main character, Jake Sully, has his mind transferred permanently to his Na'vi avatar. "You can probably read the input and output to some level, but the big problem is the rest of the brain function. You can't transfer that. It's just not possible. We have no access to it."

It's obvious why people would want to transfer their mind into something else, says Thierry. "Why wouldn't you want to be a blue warrior on a fantastic planet with lots of beautiful women on dragons?" But it's a desire based on a false belief: that the mind is separate from the body.

"The great majority of scientists believe that the mind is embodied," he says. "It emerges from the interaction between neurons and molecules. The minute these neurons change in their structure, or the molecules change in their nature, your mind's gone. And if you want to test that, drink four glasses of wine and look at yourself in the mirror. You'll see that your perception of yourself has changed. Why? Because the chemical state of your mind defines who you are – a holistic entity, a brain-mind system." **SF**

VERDICT

Nope, there's no chance of you plugging your mind into another body. No Na'vi avatars for you.

by **STEPHEN KELLY** *(@StephenPKelly)*
Stephen is a culture and science writer, specialising in television and film.

ILLUSTRATIONS: ADAM GALE MAIN ILLUSTRATION: DANIEL CRESPO

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