your brain entertainment

ISSUE 64

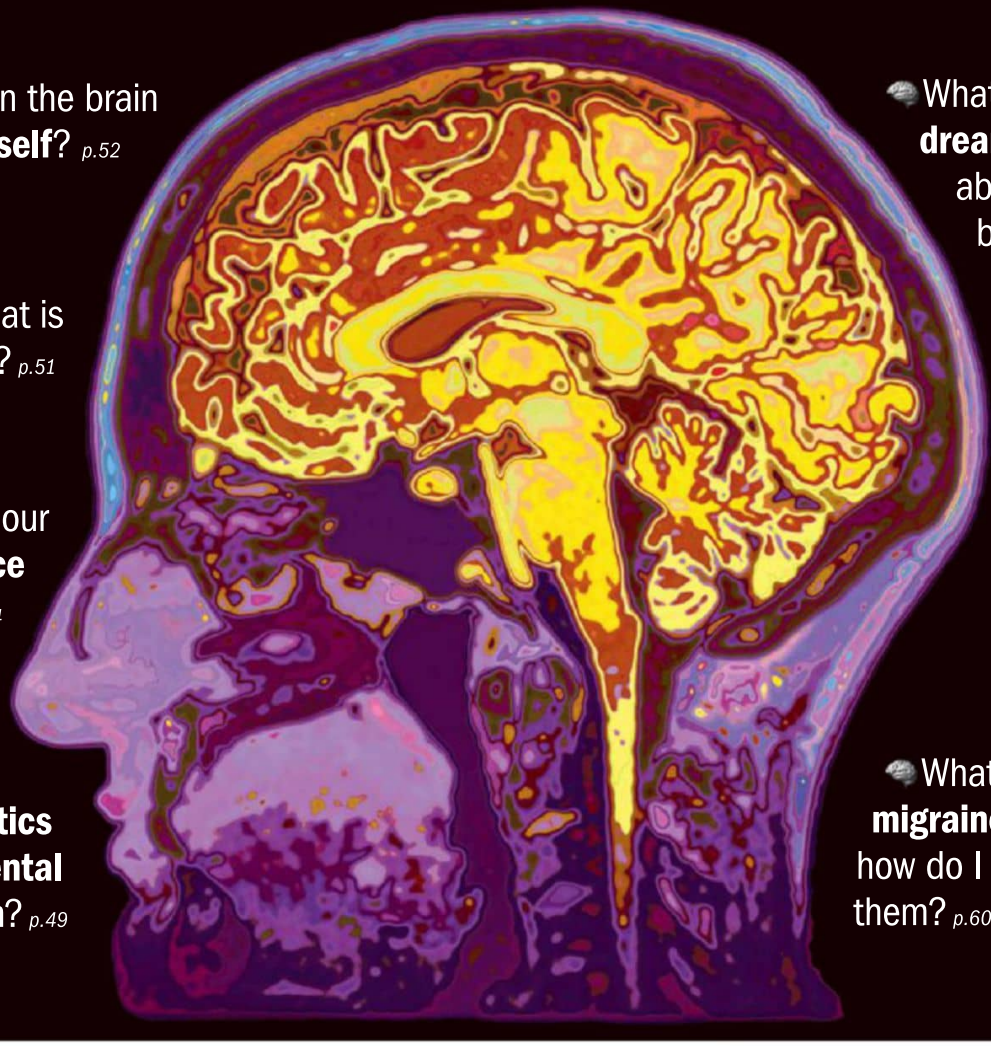
VERY interesting

the quest for knowledge

A USER'S GUIDE!

WHAT'S GOING ON IN YOUR...

BEAUTIFUL BRAIN



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ARE FOLLOWERS A BAD THING?

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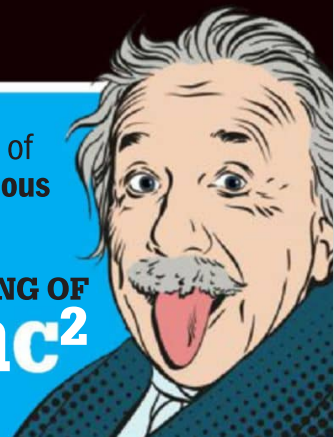

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Launch in 3, 2, 1...

NASA's mega rocket and spacecraft are nearly ready to launch. The rocket is the Space Launch System (SLS); NASA's most powerful launch vehicle, designed to take astronauts, cargo and robotic equipment to the moon and beyond. Atop the SLS is the Orion spacecraft. Orion was built with deep-space exploration in mind, and is carry four astronauts to distant planets and keep them safe during whatever adventure may. Now, just a series of tests and a "wet dress rehearsal" stands between the craft and the moon. The first launch will mark the start of many missions under NASA's Artemis programme, a mission taking us back to the moon, into "deep space exploration". NASA plans to set up a base camp at the moon's surface, as well as build "Gateway", a crewed space station.

Artemis will also act as a stepping stone for our next giant leap – the human exploration of Mars.

VERY interesting?

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A brainstorm brewing...

Our brains are remarkable machines, strange lumps of fat and water and chemicals and electricity that tell our bodies what to do and figure out which pathways to send signals down to make us breathe and talk and eat and write short introductions to new issues of popular magazines.

But while all of the mechanical stuff is fascinating – will we ever know why it's not possible to lick your own elbow? – it is arguably the more nebulous, esoteric elements of what's in our heads that continue to fascinate and confuse us. How and why we make decisions, mental health and what needs to be done to maintain it, what fuel makes us tick most effectively and why the world might appear a bit fuzzy from time to time: understanding all this and more might help us make sense of everything else. And in a world where media is only considered meta if it's online and involves artificial intelligence, consider that you'll be reading 'Your mysterious brain' (page 46) using your mysterious brain, and that what you learn will help you further develop and understand your mysterious brain.

Enjoy the issue!

If you'd like to subscribe, or to give a gift that keeps on giving, take advantage of our deals at www.coolmags.co.za. Keep your questions coming to VI@panorama.co.za.

Bruce Dennill
Editor

this issue

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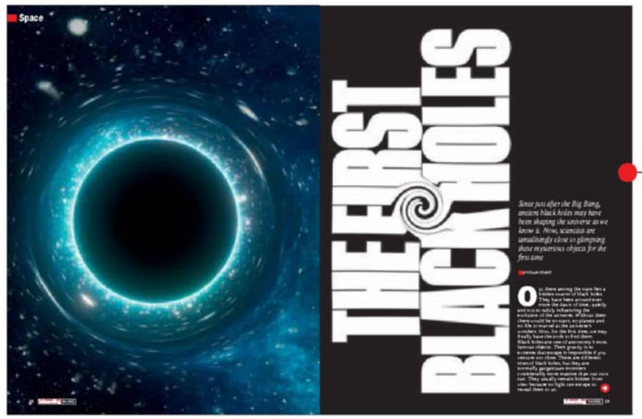

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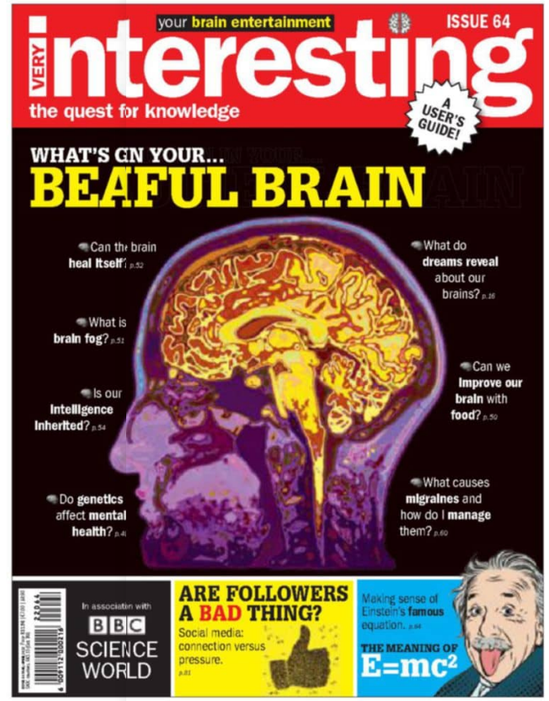

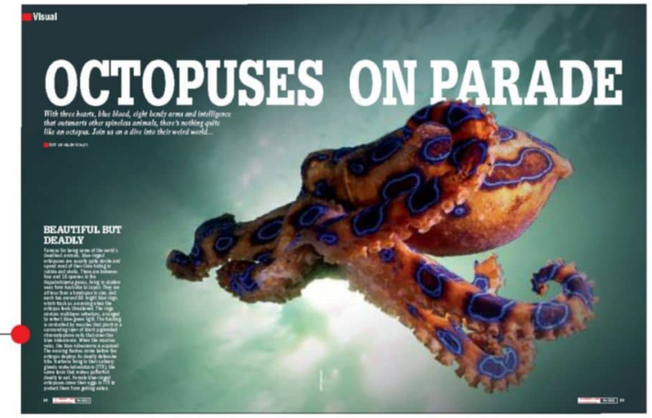

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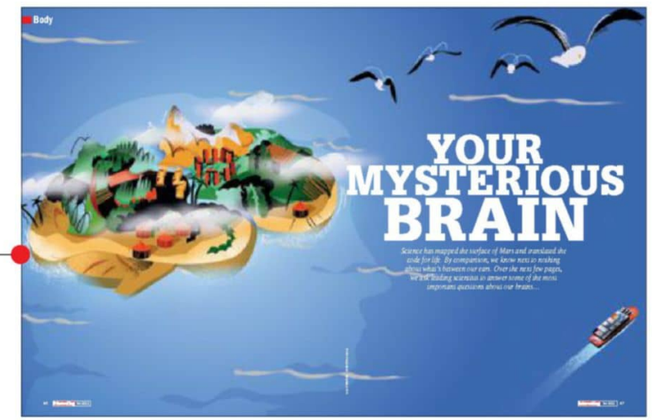
Beethoven's unfinished 10th Symphony *completed by an AI*

Computer scientists teach artificial intelligence how to compose like a master. p.72



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PLUS

All the questions you didn't know you wanted the answer to, including:

- Does sitting by a window help you work better?
- Could we harness energy from a black hole?
- Can any animals photosynthesise?
- Why do our veins look blue?
- Why is being polite all the time so exhausting?
- Does human body temperature impact global warming?
- How long did it take dinosaur eggs to hatch?
- What would happen if all volcanoes on Earth erupted at once?
- How is caffeine removed from decaffeinated coffee?
- Which is more hygienic: paper towels or hand dryers?
- Why doesn't Earth have rings?
- What would happen to my sperm if I had a vasectomy?
- How does geothermal energy produce electricity?
- Are you more likely to get chest infections if you've got no tonsils?

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Stripes make cheese look fatter.

Untoasted cheese

■ Why doesn't halloumi melt?
Ronald Mwangi, Pretoria

For a cheese to melt, it needs a protein structure that stretches in the frying pan or under the grill. Halloumi contains a tightly knit three-dimensional network of milk proteins that hold fast during cooking. The cheese is made by coagulating milk into lumpy curds, which are scooped out and pressed to remove the remaining liquid. The dry curds come together when they're heated at up to 90°C in purified whey, then the resulting cheese is sprinkled liberally with salt. The heating step is the secret to halloumi's heat resistance, causing protein networks to retract and strengthen. The heat and salt also kill acid-forming bacteria that could weaken the cheese's structure. Halloumi is therefore less acidic than melting cheeses.

Making a point

■ How does a smartphone 'read' my fingerprint?
Nelson William, Soweto

Phones use one of three different technologies to read your fingerprint: optical, capacitive or ultrasonic. An optical fingerprint reader is the oldest of the three. It uses a specialised miniature camera to take a picture of your finger, often backlit with little LEDs or the phone's screen. Unfortunately, these sensors are easy to fool – even a good photo can trick them, so it may be combined with a capacitive sensor, the second technology, to check there is really a finger there. A capacitive fingerprint sensor uses a grid of tiny capacitors that store electricity, which is discharged only at the points where your fingerprint ridges touch. An array of thousands of capacitors can then be used to map the pattern of your fingerprint. Sometimes, these sensors also support swipes or force sensing. The third and most advanced form of fingerprint sensing uses ultrasonics. Much like the ultrasonic scanners used for medical purposes, an ultrasonic sound pulse is transmitted to your finger and the reflected pulse is measured. Bats, whales and dolphins use ultrasonics to understand the shape of their surroundings; the sensors on a smartphone use it to understand the 3D shape of the ridges in your fingerprint. It can even work through the phone screen.

They grow up so fast ...

That's cold, man

■ How does freeze drying work?
John Shabangu, Durban

It's actually pretty similar to regular drying. Molecules in a liquid are more tightly bound than in a gas but, at the surface, there are always some that get bumped enough by their neighbours to jump clear – like a snooker ball getting bounced off the table by a powerful shot. Drying is just molecules getting progressively jostled out of the liquid until they're all gone. The same thing happens with the molecules in a solid too but, since they're bound even more tightly, it happens more slowly. A vacuum speeds the process up dramatically, because there are no air molecules to ricochet the 'jumpers' back down, and so, any that do break free, can make good their escape. Freeze drying is very useful for food preservation. The food is first frozen to prevent it from spoiling, and it is then dried slowly in a vacuum for several days, with carefully controlled heat, to gently remove the water without affecting the food structure.

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■ Stephen Visser
Still the only mag I buy every time I see a new issue.

■ Emily Petersen
Fun and learning – thank you!

■ Saul Dlamini
One for me and my kids – I love it!

■ Lizzie Beckett
So much stuff I didn't know I was interested in – ha!

■ Nosipho Bosman
New year, new subscription. Looking forward to 2022's stories.

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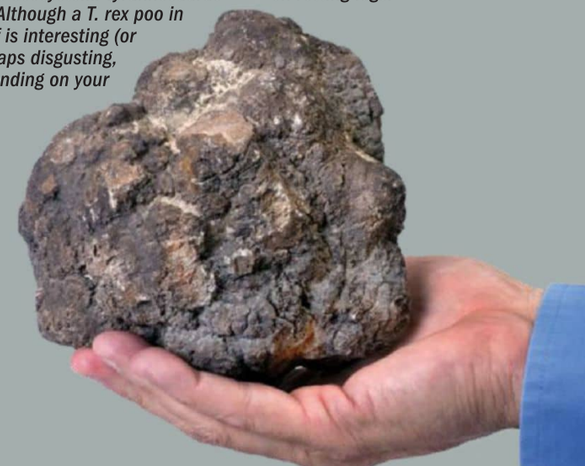
Scat, man

■ Does fossilised dinosaur poo exist?
Helen Isak, Cape Town

Dinosaurs, like all animals, would have needed to expel waste. Sometimes, pieces of dinosaur faeces turned into fossils, which we can find today. These are called coprolites. Some palaeontologists specialise in studying coprolites and use them to understand what food dinosaurs ate, and how they fit into larger food chains. The most famous dinosaur coprolite is an enormous specimen found in Late Cretaceous rocks in Canada. At over 30cm long and more than 2ℓ in volume, this huge piece of scat could only have been produced by the largest predator in the ecosystem: Tyrannosaurus rex. Although a T. rex poo in itself is interesting (or perhaps disgusting, depending on your sensibilities), this fossil is also important. It's full of chunks of bone, which tell us that T. rex could bite so hard that it crushed the bones of its prey – a highly unusual way of eating, with no obvious modern equivalent. Other dinosaur coprolites have been found with plants inside, and one even contains decomposing wood – a sign that the dinosaur was supplementing its nutrition with fungi and bugs that feed on rotting logs.



HISTORY

Skull from ancient human ancestor unearthed

The 250,000-year-old remains of a *Homo naledi* were found in the remote depths of the Rising Star cave system in Johannesburg

The partial skull of a young *Homo naledi*, an extinct species of hominin that lies within the *Homo* family tree but on a different branch to modern humans, has been discovered in South Africa. It's the first time that a child of this species has been found.

The remains were discovered around 12m beyond the Dinaledi Chamber in the Rising Star cave system – a complex 2km-long network of passageways and the original site of discovery of the first *H. naledi* remains in 2015. They are thought to belong to a child aged between four and six who died almost 250,000 years ago.

"*Homo naledi* remains one of the most enigmatic ancient human relatives ever discovered," said Prof Lee Berger, project leader and Director of the Centre for Exploration of the Deep Human Journey at Wits University, and an Explorer at Large for the National Geographic Society.

"It is clearly a primitive species, existing at a time when previously we thought only modern humans were in Africa. Its very presence at that time and in this place complexifies our understanding of who did what first concerning the invention of complex stone tool cultures and even ritual practices."

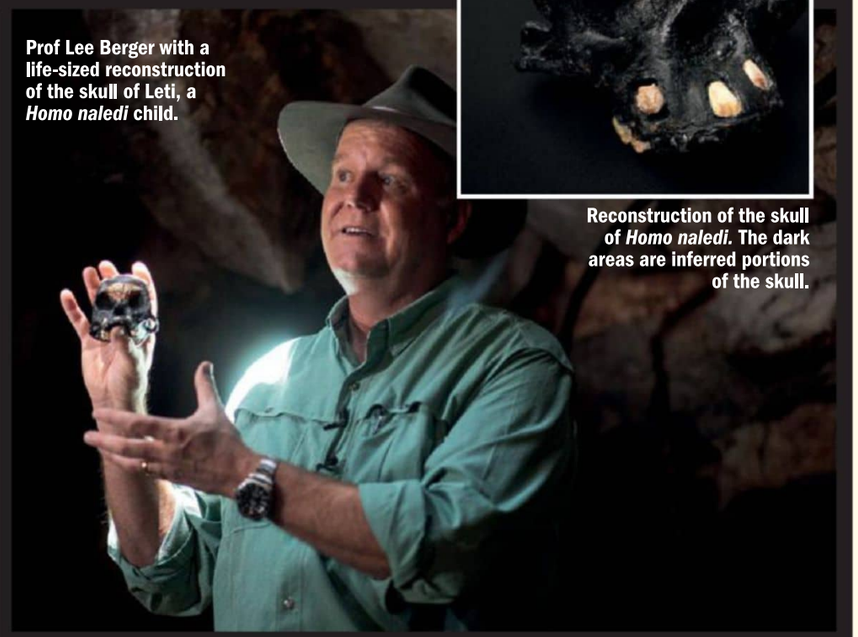
The researchers have named the skull Leti, which means 'the lost one' in Setswana, one of South Africa's 11 official languages. It was reconstructed from 28 skull fragments and six teeth, and joins almost 2,000 other individual fragments belonging to more than 20 *H. naledi* individuals unearthed in the Rising Star cave system since its discovery in 2013.

"This makes it the richest site for fossil hominins on the continent of Africa and makes *H. naledi* one of the best-known ancient hominin species ever discovered," said John Hawks, a biological anthropologist and lead author of a previous study on the fossil skeleton of a male *H. naledi*, nicknamed Neo, that was also found at the cave.

Leti's remains were discovered in a claustrophobically tight passage that measures just 15 x 80cm. Although the skull was found in many fragments, there are no obvious signs of injury, so the researchers are unable to speculate on how Leti died. There are also no signs of damage from carnivores or scavengers and no evidence of the skull being washed into the narrow passage by flowing water. This makes it likely that other members of its species were involved in transporting it to such a remote location.

"The discovery of a single skull of a child, in such a remote location within the cave system, adds mystery as to how these many remains came to be in these remote, dark spaces of the Rising Star cave system," said Berger. "It is just another riddle among many that surround this fascinating extinct human relative."

The researchers now plan to continue to explore the cave system, and hope that any new discoveries will enable them to shed further light on whether these chambers are in fact a burial ground of *H. naledi*.



Prof Lee Berger with a life-sized reconstruction of the skull of Leti, a *Homo naledi* child.

Reconstruction of the skull of *Homo naledi*. The dark areas are inferred portions of the skull.

NATURE

Scientists discover why dogs tilt their heads

Research has shown that 'genius' dogs who can learn lots of instructions often tilt their head when they hear their owners speak

Some genius dogs can learn the names of more than 100 toys, new research has found. Those that can pass the toy test – understanding the names of two or more of their favourite playthings and retrieving them on request – are so-called 'gifted word learner dogs'. These gifted dogs have helped researchers to understand a behaviour that has never previously been studied: the head tilt. Much like humans have a preference for one side of their body, dogs exhibit a preferred paw or nostril. These asymmetric behaviours include tilting the head, but until now, it's been unclear when and why it happens.

New research, published in the *Animal Cognition* journal, suggests that dogs tilt their head when they process something meaningful, or when they expect to be told something important.

"There are some studies suggesting that tilting the head could be a health-related problem," said Dr Andrea Sommese, lead author of the new study and researcher at Eötvös Loránd University, Hungary. "But it didn't seem likely, because we saw dogs doing it randomly, and I'm pretty sure you've seen a dog tilting its head – it's very common behaviour!"

Sommese and the team at the Family Dog Project, a research centre studying the behaviour of dogs, set out to understand head tilting with a group of 'genius' dogs that they'd worked with on a previous study. This involved 40 dogs and their owners undergoing three months of training to see if the dogs could learn the names of their toys.

"We asked each of the owners to play with the dogs using two toys, and to tell the dogs the names of the toys as much as possible. After this intensive three months' training, we saw 33 of the dogs weren't able to learn the difference between the two toys – we called these the 'typical' dogs.

"But the other dogs, during this time, they didn't just learn the two toys, they learned 10, 20, 30. Our so-called 'best dog' knows the name of 160 toys or something." There was a steep difference, Sommese explained. Either a dog learnt a lot of different toys, or none. However, Sommese stressed that he's not saying dogs that can't learn toy names aren't clever in other ways.

"We think that learning words is like a talent. In humans, there are people who are better at music or math or art – it seems that there is the same kind of thing going on for dogs. Some dogs are particularly skilled in this, but it doesn't mean that they're smarter. They just have one unique talent, as much as other dogs are better at sniffing or better at hunting."

After the experiment, the researchers noticed that the gifted dogs would tilt their head nearly every time their owner asked them to fetch a particular toy.

"Because we knew for sure that they know the name of some of their toys, we thought that it was something meaningful and important for the dog that made it tilt its head. It seemed to be as if the dog was saying, 'Okay, now I'm focused, I'm concentrated on the task.'"

The team initially thought it had to do with a dog's hearing, the way we might turn our head to face a person speaking in order to hear them better. But they quickly noticed that the dogs showed a preference for which side their head tilted, regardless of the position of the owner.

"It's not that typical dogs don't tilt their heads," Sommese explained. "I observed this behaviour with my own dog. It's just that we don't know what's meaningful for them and why."

The group of genius dogs present a unique opportunity for study, Sommese said. Though researchers know dogs process language in a similar way to humans, we don't really understand what language means for them. "That's why we are so stoked to have these gifted word learner dogs, because we are getting closer and closer to finding some answers."

Dogs seem to tilt their heads when processing something important.

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Think your dog is a genius? Head to Genius Dog Challenge at geniusdogchallenge.com and share videos of your pup so that the team can confirm if you have a gifted word learner!

GETTY IMAGES

Shorts

- More than 2.5 million deaths are prevented by vaccines every year.
- Measles deaths were reduced by 78% worldwide between 2000 and 2008, thanks to the use of vaccines.

HEALTH

Combatting virus variants before they emerge

The technology could be used to create universal vaccines for COVID, malaria and more, its creators say

According to the World Health Organization, immunisation currently prevents four to five million deaths every year. However, an additional 1.5 million deaths could be avoided through the use of more effective vaccines.

Vaccines work by training the immune system to respond to infection by a specific pathogen, such as a virus, parasite or bacteria. At the heart of every vaccine is an antigen – a small, safe molecule based on part of the pathogen, which triggers the protective immune response. However, most vaccine antigens are based on a single pathogen component, such as the spike protein of the COVID SARS-CoV-2 virus, which limits their effectiveness and ability to cope with new variants.

Now, Oxford-based biotech startup Baseimmune has developed an algorithm-based system capable of creating antigens containing all the parts of the pathogen. The technology could help researchers to develop the next generation of universal vaccines that protect against future variants that could evolve in several major diseases.

"The major problem with current vaccines is that they aren't designed to account for the evolutionary arms race that occurs between pathogens and the human immune system, and can't protect against future variants or new mutations," said co-founder and software engineer Phillip Kemlo. "Our prediction algorithm addresses all of these challenges, accelerating the creation of vaccines that are as good as they possibly can be, and will stand up to whatever variants may come in the future."

Baseimmune's vaccine design algorithm draws on genomic, epidemiological, immunological, clinical and evolutionary data to create blueprints for antigens capable of responding to a particular pathogen in its current form, as well as likely variants that may arise in the future. Back in January 2020, the Baseimmune team fed the small amount of existing data about SARS-CoV-2 into their algorithm, which correctly predicted major variants such as Alpha and Delta that would not emerge for another year.

They were recently awarded R70 million in funding in an investment round led by Hoxton Ventures and including early investors Creator Fund. They plan to use the money to help create future-proof universal vaccines for several major diseases, including COVID and malaria.

"I grew up in Brazil and saw first-hand the impact of infectious disease, as my aunt lived her whole life with the devastating effects of polio, a vaccine-preventable disease," said co-founder Ariane Gomes. "The COVID pandemic has reminded us that infectious diseases aren't going anywhere, so we urgently need to develop the next generation of vaccines to help protect us all."

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Q&A
Questions & Answers

Got questions you've been carrying around for years? *Very Interesting* answers them! Mail your questions to VI@panorama.co.za

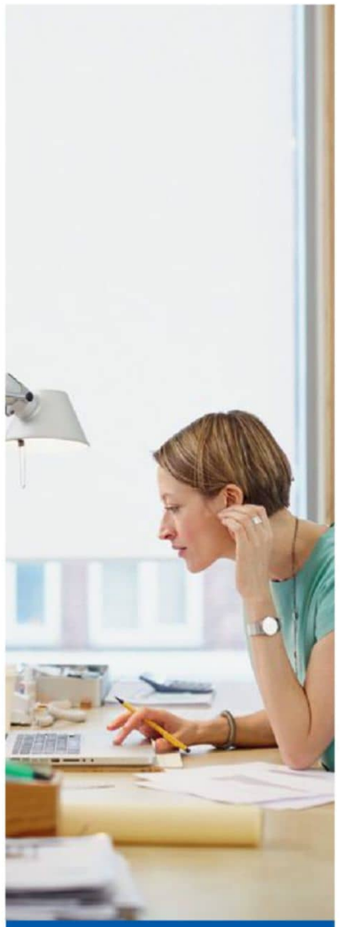
Which animals could most humans beat in a fight?

Gavin Smit, Fourways

According to a recent YouGov poll that asked which animals people thought they could beat in unarmed combat, 38% thought they could rough up a medium-sized dog, 18% thought they could vanquish an eagle, and 7% fancied their chances against the world's longest venomous snake, the king cobra. Rats and house cats were the easiest presumed pushovers, with two-thirds of participants claiming they could see one off, while grizzly bears, elephants and lions were rightfully respected – only 2% of pollsters claimed they would be able to take one down.

Perhaps unsurprisingly, men were more likely than women to think they could win a fight with an animal. For example, 15% of men felt they could take on a chimpanzee, compared with just 4% of women.

Inexplicably, different nations have different views on the subject, with 61% of people in the US claiming the ability to subdue an angry goose, compared with 45% of Brits. Thankfully, no animals were harmed in the making of this poll. It's all opinion, bluster and hubris.



Does sitting by a window help you work better?

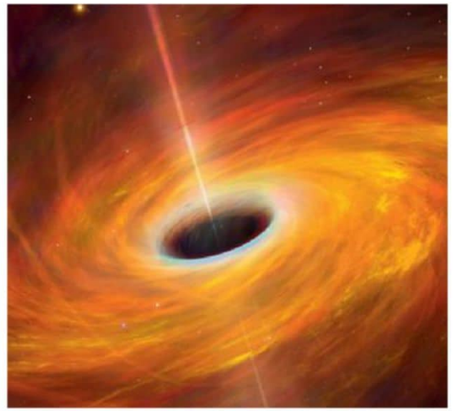
Claire Fielding, Johannesburg

Yes. A 2018 study at Cornell University found that natural light from a window reduced eye strain, headaches and drowsiness. And a 2021 study at the Bartlett School of Architecture, University College London, found that workers in open-plan offices were most productive when sat at window desks. However, this depends on the office layout. Workers facing windows with a large number of desks behind them reported lower productivity. Possibly due to the nagging fear of co-workers talking about them!

GETTY X2 ILLUSTRATIONS: PETE LAWRENCE, DANIEL BRIGHT

Could we harness energy from a black hole?

Sibusiso Dlamini, Tshwane



Scientists have long considered whether energy can be extracted from black holes. One possibility, called the 'Penrose process', makes use of the 'ergosphere' – the volume just above a rotating black hole's event horizon where space-time itself is dragged along with the stupendous rotation. The physics of the ergosphere shows that, if a mass approaching the event horizon is broken in two, so that one piece falls into the black hole, then the other piece could exit the ergosphere with more energy than it started with. The black hole essentially donates some of its angular momentum to this mass, thereby increasing its energy.

A recent suggestion is that energy could be harnessed from this process by breaking and recombining magnetic field lines in the ergosphere. This would cause infalling matter to be naturally split into two plasma flows, one of which would receive an energy boost from the black hole. The Penrose process could also impart energy to one of the particle-antiparticle pairs, sometimes called 'virtual particles', that produce 'Hawking radiation'. These matter and antimatter pairs are constantly being created and destroyed due to minuscule quantum fluctuations in the fabric of space-time.

Another possibility, called the 'Blandford-Znajek process', uses an external magnetic field to extract the rotational energy of a rotating black hole. Here, the black hole is acting like a massive conductor spinning in the magnetic field of its accretion disk. The magnetic field lines are dragged around the black hole, causing them to eject jets of plasma in opposite directions. This is believed to be the process that creates the energetic plasma jets seen in 'quasars'.

Although the engineering required for any of these possibilities is far beyond our current capabilities, the physics suggests that energy generation from black holes could reach 150% efficiency, far greater than any energy-generation method currently used on Earth.

EXISTENTIAL CRISIS OF THE MONTH

Are hackers monitoring my every move through my phone?

Terry Naidu, Johannesburg

Nearly a decade ago, an Israeli technology firm called the NSO Group, run by former members of the Israeli Intelligence Corps, created mobile phone spyware software called Pegasus. Classed as a weapon, the Israeli Ministry of Defense licenses the export of Pegasus to foreign governments. Recently, it was discovered that this spyware has been used by many countries to infect the phones of activists, journalists and political leaders.

The spyware software is extremely clever, using multiple vulnerabilities in different apps on your phone. It may be installed by clicking on a link, but most insidiously it could even infect modern iOS iPhones through a simple iMessage with no clicks needed. Once infected, it provides access to your passwords, location, text messages, call and app data, and even the microphone and camera.

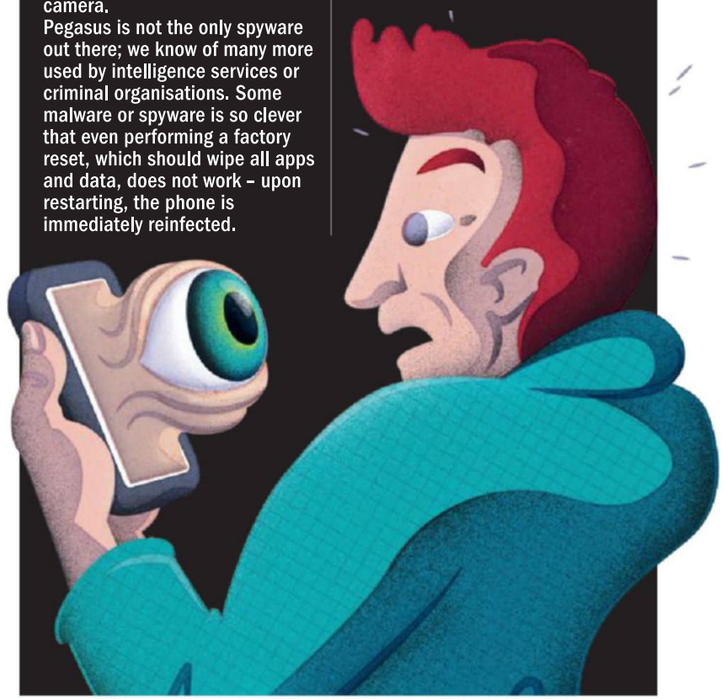
Pegasus is not the only spyware out there; we know of many more used by intelligence services or criminal organisations. Some malware or spyware is so clever that even performing a factory reset, which should wipe all apps and data, does not work – upon restarting, the phone is immediately reinfected.

Q&A FLASH

- In 2018, one in 36 mobile phones had high-risk apps (which allow actors easier access).
- Phone users have an average of 38 personal passwords.

You might get clues that your iPhone has been infected if your battery drains quickly when not in use, the screen turns on by itself without notifications, location services reports that your camera has used your location recently for no apparent reason, or you find a strange deleted photo that you never took.

In reality, we live in a connected world. If a powerful organisation really wants to hack your devices, they probably can.



Q&A
Questions & Answers

Got questions you've been carrying around for years? *Very Interesting* answers them! Mail your questions to VI@panorama.co.za

Can any animals photosynthesise?

Abdullah Abraham, Cape Town

Photosynthesis is an efficient way of making nutrients. Instead of wasting time finding, eating and digesting food, plants use solar power to transform carbon dioxide and water into oxygen and sugars. The plant generates fuel for itself, and air for us to breathe. The magic happens inside specialised organelles, called chloroplasts, which contain the green photosynthetic pigment chlorophyll.

Some animals have managed to harness the power of photosynthesis. For example, when sacoglossan sea slugs chow down on photosynthetic green algae, chloroplasts from the algae become incorporated into the animals' gut cells, where they continue to pump out nutrients long after the rest of the algae have been digested and expelled. It's a feat called 'kleptoplasty'.
Other animals, including some clams and flatworms, also use the photosynthetic powers of algae, but adopt a symbiotic approach where the algae remain unharmed. Corals are the classic example. Most reef-building corals contain colonies of algae, called zooxanthellae, which live in their tissues and bequeath the coral their hue. During the day, the algae provide the coral with most of their energy needs and, in return, the algae get a safe place to live with a stunning sea view.
The only vertebrate animal known to harness solar power is the spotted salamander. Here, water-dwelling algae colonise salamander eggs shortly after they are laid, then become incorporated into embryonic cells where they help to feed the developing animal from within. Experiments reveal that embryos with more algae survive better and develop more quickly than embryos with fewer algae.
All of which begs the question, could we humans ever photosynthesise? Even if we could crowbar working chloroplasts into our cells (which we can't) and precisely alter our genomes to control them (which we can't), we still don't have a big enough surface area to volume ratio to generate the energy we'd require to live. Put simply, humans just aren't leaf-shaped!

Why is human skin so rubbish?

Jenny Collins, Sandton

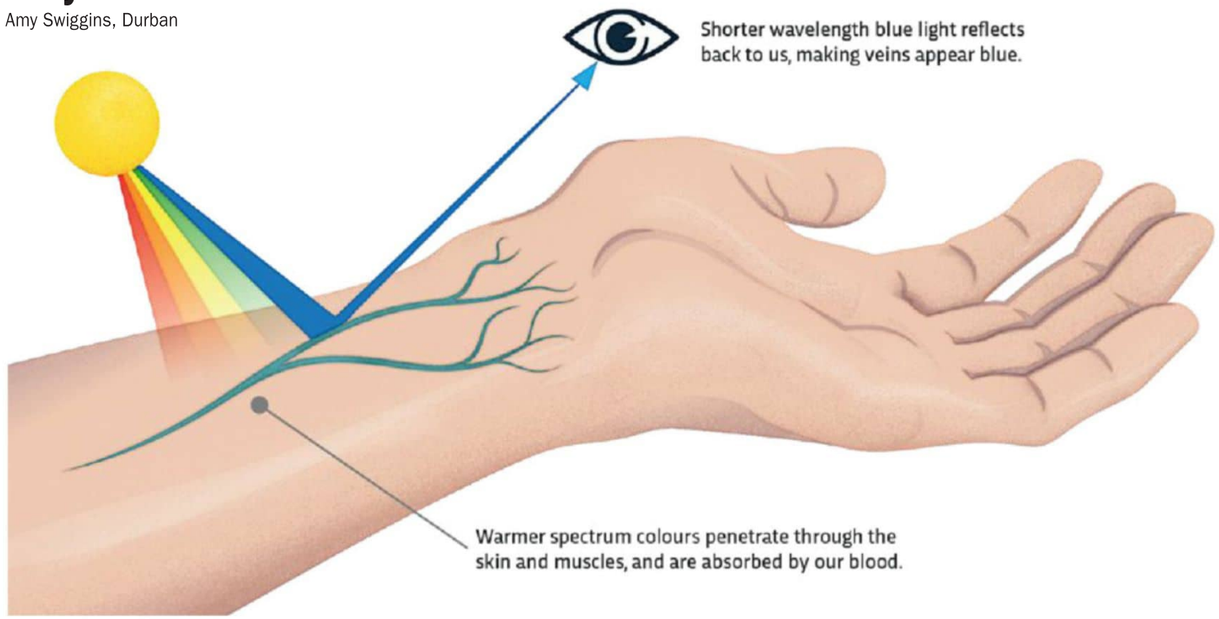
If you've ever tripped and grazed your skin, broken out in a rash, or suffered from acne or eczema, you might have found yourself wondering why human skin is so frail and fragile. Bruises, dry skin, calluses, hives, sunburn and scar tissue are among the many skin ailments that can, at best, irritate us, and at worst, seriously harm our health. But these gripes are minor when we consider all the things skin does for us.
The skin is the largest and fastest-growing organ in the body. It provides a waterproof yet breathable barrier that protects us from the elements, parasites and pathogens. It is strong, yet extremely flexible. It helps regulate body temperature, reduces water loss and manufactures vitamin D. And, although it sometimes produces scar tissue, skin is amazingly good at self-healing after damage.
Humans are the only 'naked' ape and our unique skin adaptations have been crucial to our evolution. For example, without hair to protect us, human skin evolved melanin to block harmful UV radiation. Specialised sweat glands helped our ancestors thermoregulate while walking long distances in hot conditions, and the high density of nerve cells in our hands may have proved crucial for our ancestors to shape and use tools. Skin is so versatile and adaptable that scientists are developing lab-grown skin grafts to deliver drugs – such as insulin to treat diabetes – directly into the body. Researchers hope these gene therapy skin grafts could one day treat a range of diseases.

Humans can sweat from pores like this one, allowing us to stay cool in the heat.

ALAMY; SCIENCE PHOTO LIBRARY; GETTY IMAGES ILLUSTRATION: DANIEL BRIGHT

Why do our veins look blue?

Amy Swiggins, Durban



Your blood gets its colouration from red blood cells, which contain haemoglobin – iron-rich molecules that are bright red when carrying oxygen and a darker, duller red when deoxygenated. So why, when you look at the veins in your arm, do they appear to be blue? The answer lies in the fact that different colours of light have different wavelengths, so they are absorbed and reflected differently when they hit our skin.
Red light has a very long wavelength, so it can travel through the skin relatively easily and is absorbed by the haemoglobin in the blood. Blue light, on the other hand, has a much shorter wavelength, and so it is mostly reflected by the skin. If you shine white light – a mixture of all the different wavelengths – onto your arm, where veins are present, the red light will be absorbed and the blue light will be reflected. This means that the light returning to your eyes will contain more blue than red wavelengths, making the veins look blue compared to the surrounding skin.
Medics sometimes make use of this phenomenon by shining a red or infrared light on the skin to help them locate a vein to administer an injection. Similarly, nightclubs sometimes use blue lights in the toilets to discourage intravenous drug use, by making it hard to see veins through the skin.

How many birds are struck by wind turbine blades?

Natasha Els, Lonehill

As wind energy has grown in popularity, reports of birds killed in collisions with moving turbine blades have become more common. Few studies have investigated the phenomenon, but estimates from UK research suggest that between 10,000 and 100,000 birds are killed by turbine blade strikes annually. That's a lot, but it's worth noting that approximately 55 million birds are killed in the country each year by domestic cats. Nevertheless, research suggests there may be ways to make wind turbines safer for wildlife. For example, a small-scale study in Norway found that painting one blade black reduced bird deaths by 70%.

Q&A FLASH

- **The largest wind turbine in the world – over 20 storeys tall – is in Hawaii.**
- **Wind power is the only large-scale power source that doesn't use any water.**

ILLUSTRATION: SAM FALCONER

ONLY IN YOUR WILDEST DREAMS

Even today, scientists don't know why we dream. But now, psychologists have found a way to communicate with lucid dreamers – people who can take control of their dreams – in the hope that they might help us explore what goes on with our brains at night

WORDS: DR CHRISTIAN JARRETT

Millionaires are jetting themselves into space and quantum computing lies around the corner. Yet, one of the most familiar and everyday aspects of human nature remains frustratingly tricky for scientists to study – dreaming.

Theories abound, but the truth is we don't know much about why or how we dream. A major hurdle for scientists has been the fact that when people are dreaming, they're largely closed off from the world – at least that's been the assumption for a long while. So, researchers have resorted to asking people, upon awakening, what their mind was doing while they were sleeping, but that's a sketchy and unreliable approach.

"Memories of dreams can be missing some parts of dreams and can be distorted and incorrect, so if that's all we have to go on, then building a solid science of dreaming will be difficult," says Dr Ken Paller, a psychologist and dream researcher at Northwestern University.

What would change the whole dream research landscape would be if there were some way to communicate and interact with someone while they were dreaming. It sounds far-fetched, like something out of the Christopher Nolan movie *Inception*, but in a significant breakthrough, that's exactly what an international team of researchers, led by Paller and Karen Konkoly, also at Northwestern University, managed to achieve. The work, which was published in the journal *Current Biology* in 2021, "opens up the opportunities for scientific explorations of dreaming considerably," says Paller. "We now have more ways to learn about dreaming."

Theirs is one of several new projects that have begun to exploit the research opportunities afforded by 'lucid dreaming' – a relatively rare state in which the dreamer, during rapid eye movement (REM) sleep, becomes consciously aware that they are dreaming. This is a new frontier of research, but lucid dreams have been known about for millennia. Aristotle described the state like this: "...often when one is asleep, there is something in consciousness which declares that what then presents itself is but a dream."

Not only does this wave of new work involving lucid dreams open up exciting opportunities to research the nature and function of dreaming, but it also raises intriguing practical possibilities for clinical interventions and self-development, including boosting learning and creativity.

Choose your dream

If you've ever been in a dream and known you were dreaming, then you've experienced the lucid dreaming state. It's estimated that about half of us fall into this category, with around 20% of us experiencing the phenomenon on a monthly basis and 1% having several such experiences each week. Sometimes, people in a lucid state can even begin to deliberately choose what happens in their dream, as if they were a director of their own movie.

This degree of conscious control is important for scientists, because it raises the possibility that the dreamer might be able to choose to communicate with the outside world.

In terms of what's happening in the brain during lucid dreaming, research is at a relatively early stage. There have been several studies that measured people's brainwaves via an EEG during lucid dreaming, but it has only been captured in a modern, high-resolution brain scanner a handful of times. "In short, we still don't know what the localised brain activity changes are associated with lucid dreaming," says Dr Benjamin Baird at the Wisconsin Institute for Sleep and Consciousness, University of Wisconsin-Madison, who has studied the neural correlates of lucid dreaming. "There is some preliminary neuroimaging data which suggests a role of the frontoparietal network [a network of connected regions spanning the front and rear of the brain that's involved in attention and problem-solving]," he adds, though he notes more research is needed to confirm this.

One thing Baird says does seem clear is that lucid dreaming seems to occur during periods of more intense brain activation during REM sleep. "REM sleep has peaks and valleys of activity when the brain is more or less activated as it goes along," he explains. "We become lucid at the mountain peaks of brain activation, when we are in the mental set of trying to recognise that we are dreaming – or sometimes by chance if something triggers us to consider whether we are dreaming."

Comedian Dave Green creates artworks while lucid dreaming, then draws them upon waking.

"You are navigating an environment created by your mind, yet it looks and feels like waking life."

Enter dreamworld

If you've never had a lucid dream, you might be wondering what it feels like. One person who is highly familiar with them is Dave Green, the English comedian-turned-lucid-dream artist, who first started having lucid dreams as a child. "Having a lucid dream is like being embodied in your imagination," he says. "You are navigating an environment that is entirely created by your mind, yet it looks and feels like waking life."

Unable to perform stand-up comedy during the pandemic, he rediscovered lucid dreaming and started using the experience to conjure artworks that he then creates upon waking. "Besides creating artworks, my favourite thing to do in a lucid dream is to fly. It is never anything less than ecstatic," he says. (If you are keen to experience this for yourself, the good news is that lucid dreaming is, to an extent, a trainable skill – see the opposite page for some basic techniques.)

For their breakthrough lucid dreaming study, Konkoly and Paller, along with their colleagues at other laboratories in France, Germany and the Netherlands, exploited the residual conscious awareness enjoyed by lucid dreamers. To do this, they recruited several experienced lucid dreamers, as well as some lucid dreaming newbies, who they trained to experience lucid dreams.

Next, they used a procedure developed by fellow dream scientist Dr Michelle Carr and her colleagues, in which beeps and flashing lights are repeatedly paired during wakefulness with an instruction to become lucid – that is to become mindful of one's thoughts and sensations, and to consider whether they reflect being awake or in a dream.

Konkoly and Paller's team then used these same sounds or lights while their participants were sleeping (as confirmed objectively by a measure of their brainwaves) to prompt them to become lucid while dreaming. Crucially, if the study participants entered a lucid dream state, they were trained to indicate this by making sweeping horizontal movements with their eyes. At this point, the researchers had used dreamers' eye movements to establish communication from within their dreams to the outside world. That's been done many times before, notably by the American psychophysiologist Dr Stephen LaBerge in the early 1980s as a way to objectively verify the lucid dreaming phenomenon – that is, that lucid dreamers really are aware and able to respond. But Konkoly and Paller and their international collaborators then went further, to create a situation of truly "interactive dreaming", as they

DAVE GREEN ILLUSTRATIONS: SAM FALCONER

HOW TO HAVE MORE LUCID DREAMS

There are three main techniques that dream researchers recommend for increasing your odds of experiencing a lucid dream, which can either be used on their own or in combination.

The first technique is 'reality testing', which involves making a regular habit during wakefulness of testing whether you are asleep or awake. For instance, several times a day you might check whether you can press the fingers of one hand through the palm of your opposite hand (a feat that is usually possible in dreamland, but obviously not while awake). This might sound odd, but the idea is that if you get into the habit of doing this while you're awake, you'll be more likely to try doing it while you're dreaming, and if you ever do, you'll realise that you're dreaming and you'll become lucid.

Another technique is called 'Wake Back To Bed' (WBTB) and involves setting an alarm for approximately two to three hours before you usually wake up. Upon waking, you then allow yourself to drift right off back to sleep, but with the renewed intention to lucid dream. The rationale here is that lucid dreaming occurs during REM sleep (the stage of sleep when narrative dreaming is most common), and so you're waking yourself up at just the right time of night when you're likely to be in the midst of REM sleep, and then diving right back into it with the active plan to lucid dream.

The final technique is called Mnemonic Induction of Lucid Dreams (or MILD for short), which involves repeating a mantra to yourself several times before you go to sleep, along the lines of, "The next time I'm dreaming, I will remember I'm dreaming." You can either try it when you first go to sleep at night, or you can combine it with WBTB in the early hours of the morning. Dave Green, the comedian-turned-lucid-dreaming artist, recommends the MILD technique: "I just repeat over and over again: 'Tonight I will have a lucid dream and create a drawing'," he says.

called it. After participants indicated they were in a lucid dream, the scientists gave them basic maths questions, such as 'eight minus six', which the participants answered successfully using eye movements, according to a code agreed earlier (for instance, in this case, the answer 'two' was communicated by a left-right, left-right eye movement).

By now the researchers had broken exciting new ground, successfully achieving two-way communication with participants while they were dreaming. They had succeeded at their goal, which, as they put it in their paper, was "akin to finding a way to talk with an astronaut who is on another world, but in this case the world is entirely fabricated on the basis of memories stored in the brain."

"[The research is] akin to finding a way to talk with an astronaut who is on another world."

Sleep talking

The study by Konkoly, Paller and their colleagues was focused on establishing a two-way communication between a dreamer and the outside world. It was a proof-of-concept study that promises to pave the way for many new and exciting projects, both to uncover more about the nature of the dreaming brain and for practical interventions to enhance learning and creativity, for instance.

However, even without the capability of two-way communication, other researchers have already tested the potential of lucid dreaming in various ways. For example, there is such a thing as lucid dreaming therapy, which involves teaching lucid dreaming techniques to sufferers of nightmares, so that they can choose to wake up from a nightmare or even change the narrative so that its content is less distressing.

Other researchers have explored the possibility that lucid dreaming could be used to practise motor skills. Dr Daniel Erlacher at the University of Heidelberg, and Dr Michael Schredl at the Central Institute of Mental Health in Mannheim, assigned a group of lucid dreamers to repeatedly toss a coin into a cup in their dreams. Compared with their baseline real-life performance, the participants' accuracy the next day was improved by a greater amount than a control group who didn't do any further coin-tossing practice in real life or dreamland.

It might also be possible to exploit lucid dreams to aid creative problem-solving. For instance, Dr Tadas Stumbrys and Dr Michael Daniels at Liverpool John Moores University found that lucid dreamers were able to call on the help of dream characters to help them come up with more creative metaphors. Crucially, the two-way interaction between dreamer and outside world established by Konkoly and Paller and others could build upon and expand these various ways to exploit the lucid dreaming state. For instance, their model of interactive dreaming suggests that sensory cues could be associated with desired dream content in advance and then played during the lucid dream state, making it more likely that the lucid dream will involve features that could help aid creativity or contribute to learning.

ILLUSTRATIONS: SAM FALCONER

Adverts while you sleep

That said, the path ahead is not likely to be all plain sailing. "[The technique for communicating with lucid dreamers] does not work every time we try," says Paller. "We are in the process of improving our methods, so I don't know how reliable they could be eventually."

Indeed, Paller cautions against getting too carried away: "I have an open mind about the potential for this method to be useful in the future," he says.

Another elephant in the room (probably a flying pink one, if you're dreaming) is the ethical issues raised by this entire line of work. If researchers can reach into our dreams and affect what we dream about, then that presents the possibility that other people can too, such as advertisers who might reach us in our sleep via smart speakers or other devices. Indeed, that's already begun: early in 2021, American beer company Coors experimented with deliberately inducing dreams of their product among volunteers.

These developments recently prompted a large group of dream scientists, led by Dr Robert Stickgold at Harvard Medical School and Dr Antonio Zadra at Université de Montréal, to write an op-ed warning of the ethical dangers of advertisers exploiting the advances in their field.

"Brain science helped design several addictive technologies, from cellphones to social media, that now shape much of our waking lives; we do not want to see the same happen to our sleep," they wrote.

Paller and Konkoly were actually among the co-signatories of the letter, and they too are mindful of the important ethical implications of their work. "Messages delivered during sleep to an unwilling individual could be regarded as a form of inappropriate advertising and made illegal," says Paller.

As Zadra elaborates, "While the technologies themselves are neutral and hold promise in fostering creativity and treating psychological disorders, their use to alter and motivate purchasing behaviour through dream hacking is worrisome."

Just as science has taken us to uncharted territories in space and on Earth, raising new ethical questions along the way, the same is now true for a new frontier as researchers accelerate their exploration of our sleeping minds. ■

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Dr Christian Jarrett (@Psych_Writer) is a neuroscientist and Deputy Editor of online magazine *Psyche*. His latest book is *Be Who You Want: Unlocking The Science Of Personality Change*.

ENVIRONMENT

Animal and plant life has colonised the Great Pacific Garbage Patch

The finding marks the first time coastal life has been discovered living in the open ocean

The North Pacific Subtropical Gyre (or, as it's more commonly known, the Great Pacific Garbage Patch) is a 79,000-tonne mass of plastic waste, covering an area of 1.5 million km², floating between California and Hawaii. It's the largest of the world's five trash-filled gyres. They form when plastic and other forms of waste are swept out to sea by surface currents, before being trapped and gathered together into great masses by rotating currents. Now, a study carried out by researchers at the Smithsonian Environmental Research Center (SERC), the University of Hawaii and the Ocean Voyages Institute have found many coastal species – including anemones, hydroids and shrimp-like amphipods – making their homes on the North Pacific Subtropical Gyre's mass of plastic waste. The researchers have dubbed these communities neopelagic, from neo, meaning 'new', and pelagic, meaning 'open ocean'. "The open ocean has not been habitable for coastal organisms until now," said SERC senior scientist Greg Ruiz, who heads the SERC's Marine Invasions Lab. "Partly because of habitat limitation – there wasn't plastic there in the past – and partly, we thought, because it was a food desert." Using current models created by researchers at the University of Hawaii to target the locations where plastic waste was most likely to pile up, the Ocean Voyages Institute team collected 103 tonnes of plastic and other waste from the North Pacific Subtropical Gyre. The SERC team then analysed this material.

"The issues of plastic go beyond just ingestion and entanglement," said Linsey Haram, lead author of the study and former postdoctoral fellow at SERC. "It's creating opportunities for coastal species' biogeography to greatly expand beyond what we previously thought was possible." The team is still unsure how the neopelagic colonies are finding food. It's possible they're drifting into existing food hotspots, or perhaps the plastic itself is acting as a reef and attracting food sources to it, they suggest. Neither is the team sure how common the colonies are, or if they even exist outside the North Pacific Subtropical Gyre. As the production of global plastic waste continues to increase, however, the team thinks it likely that these colonies of coastal rafters will continue to grow.

"The issues of plastic go beyond just ingestion and entanglement."

A member of the Ocean Voyages Institute team retrieves plastic collected from the North Pacific Subtropical Gyre in 2020 (left). Various coastal species have colonised the plastic debris (above).

ANTONINO VAZZANA/BONES LAB, SMITHSONIAN INSTITUTION, OCEAN VOYAGES INSTITUTE 2020 GYRE EXPEDITION

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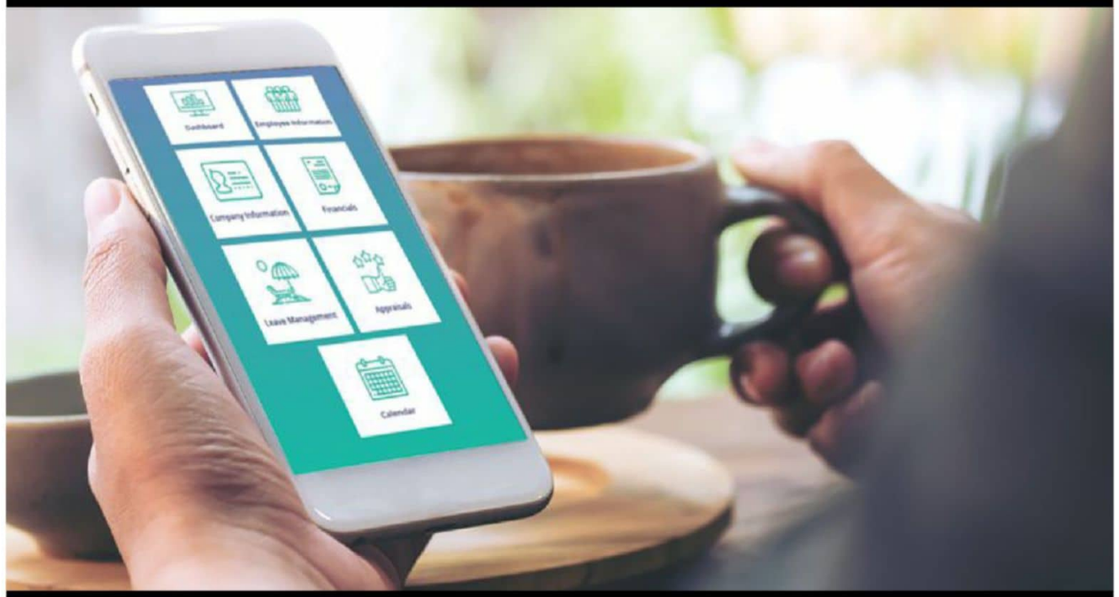

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Ants on the attack

Here, a colony of ants swarms an unlucky hornet. Officially, they're of the species *Liometopum microcephalum*, but are more generally referred to as velvety tree ants. This is due to their soft abdomens and because they nest in hollow areas of live trees, explains Dr Douglas Booher, an ant expert at Yale University.

These ants are omnivores, and when foraging, have been found travelling up to 70m from their nest in the hollow of a tree. "It is not uncommon for them to hunt larger live prey, and when they do, they will aggressively swarm. They have strong mandibles – making them good at [killing] – but in this case it's likely the hornet was scavenged dead, or was dying and unable to escape," says Booher. While the ants don't sting, they can be aggressive, Booher warns. "They will swarm quickly if their nest is disturbed, and they have an obnoxious-smelling alarm pheromone with a scent like rotten coconut."

PETR BAMBOUSEK/CUPOTY03

Q&A
Questions & Answers

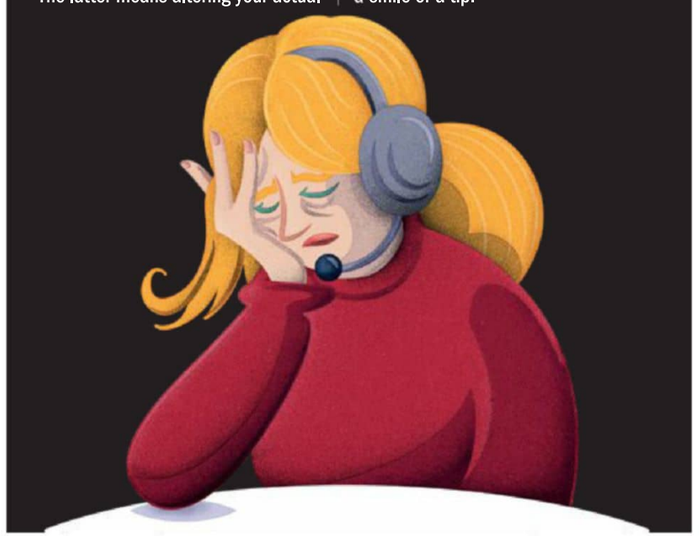
Got questions you've been carrying around for years? *Very Interesting* answers them! Mail your questions to VI@panorama.co.za

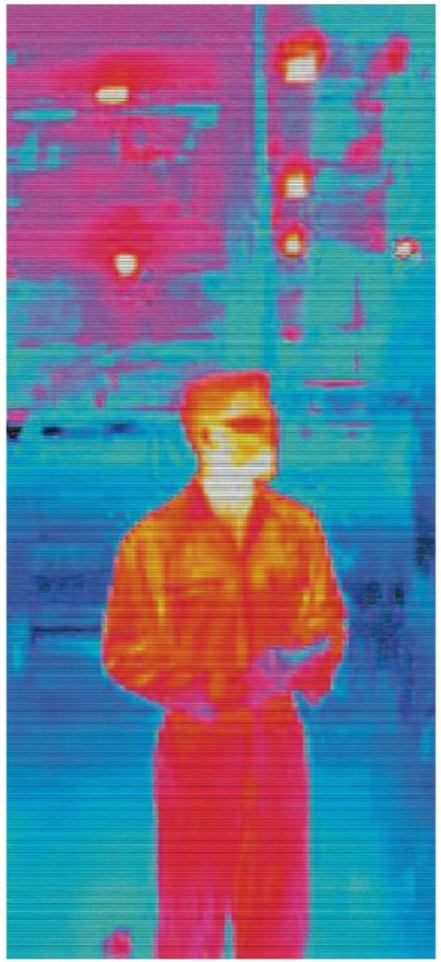
DEAR DOCTOR...
HEALTH QUESTIONS DEALT WITH BY OUR EXPERTS

I work in customer service. Why is being polite all the time so exhausting?

Sniziwe Mkhize, Johannesburg

Being polite at work when you don't feel like it is similar to any situation in life that requires you to make the effort to mask your true feelings. That could be feigning gratitude for that revolting meal your partner just spent hours making for you, or putting on a brave smile for the birthday socks from your aunt that you really didn't want. It's exhausting, especially if your job means you have to do it all day long.
In a work context, psychologists call it 'emotional labour', which involves either 'surface acting' – concealing your true feelings – or 'deep acting'. The latter means altering your actual underlying feelings, which can be achieved by various means, such as reappraising the scenario.
For example, by taking the perspective of an irate customer, and so genuinely sympathising with their situation.
Due to the effort and emotional regulation involved, both forms of emotional labour can be tiring.
But there's some evidence that the deep acting version is better for the employee and customers – probably because it's more convincing and it creates a virtuous feedback loop in which the employee is rewarded by their customer's satisfaction, such as a smile or a tip.

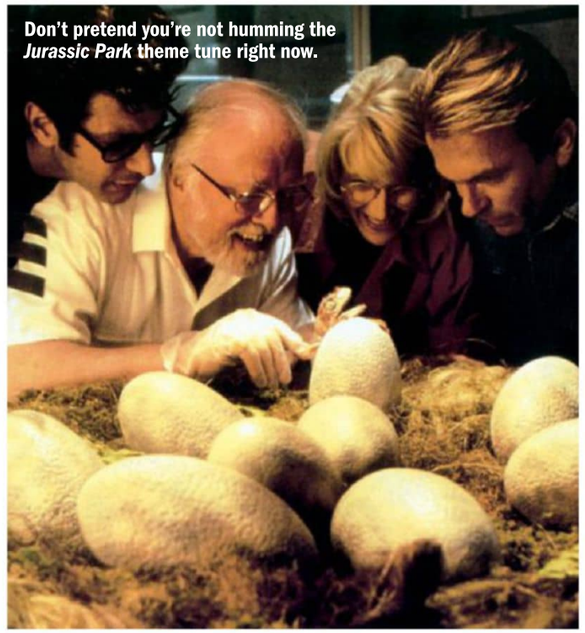




Does human body temperature impact global warming?

Tom Cooper, Cape Town

Humans typically radiate around 100W of heat, equivalent to an incandescent light bulb. In a confined space, people's body heat can raise the ambient temperature, but on a global scale, this effect is negligible, especially compared to the vast amount of heat energy the planet receives from the sun, for example. In general, global warming is not caused by heat sources on Earth, but rather by greenhouse gases in the atmosphere which prevent heat (mostly from the sun) from dissipating into space. As humans, we therefore have a far greater impact on the climate through burning fossil fuels and therefore creating greenhouse gases than we do from our body heat.



Don't pretend you're not humming the *Jurassic Park* theme tune right now.

How long did it take dinosaur eggs to hatch?

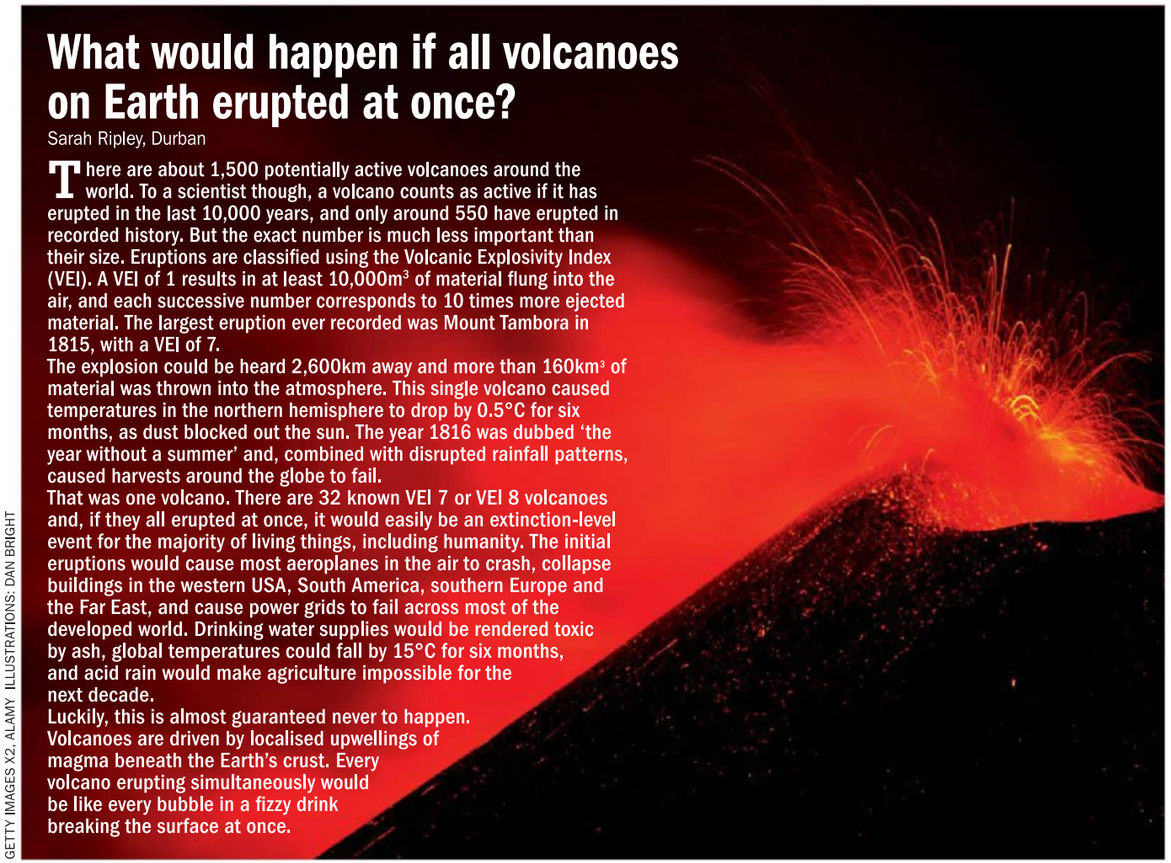
Trevor Mcube, Tshwane

As far as we know, all dinosaurs reproduced by laying eggs. Some species, like the giant long-necked sauropods, laid dozens of eggs in a small nest, which they essentially abandoned and left to hatch on their own. Others, like the feathered raptors closely related to birds, laid a smaller number of larger eggs, and actively sat on their nests to provide protection.
But how long did it take dinosaur eggs to hatch? Until recently, palaeontologists had no idea. A study published by Dr Gregory Erickson and colleagues answers this question for two particular dinosaurs: the duck-billed herbivore hypacrosaurus and protoceratops, a horned dinosaur closely related to triceratops. By studying the growth lines in the microscopic teeth of embryos found inside fossilised eggs, Erickson and his team determined that protoceratops eggs took about 2.8 months to hatch, while those of hypacrosaurus incubated for 5.8 months. Modern-day reptiles incubate their eggs for a similar period of time – often many months. Birds, on the other hand, hatch very quickly, usually within two months, and sometimes even within two weeks. Today's birds descended from dinosaurs, but they must have evolved their hyper-fast hatching rates much more recently.

What would happen if all volcanoes on Earth erupted at once?

Sarah Ripley, Durban

There are about 1,500 potentially active volcanoes around the world. To a scientist though, a volcano counts as active if it has erupted in the last 10,000 years, and only around 550 have erupted in recorded history. But the exact number is much less important than their size. Eruptions are classified using the Volcanic Explosivity Index (VEI). A VEI of 1 results in at least 10,000m^3 of material flung into the air, and each successive number corresponds to 10 times more ejected material. The largest eruption ever recorded was Mount Tambora in 1815, with a VEI of 7.
The explosion could be heard 2,600km away and more than 160km^3 of material was thrown into the atmosphere. This single volcano caused temperatures in the northern hemisphere to drop by 0.5°C for six months, as dust blocked out the sun. The year 1816 was dubbed 'the year without a summer' and, combined with disrupted rainfall patterns, caused harvests around the globe to fail.
That was one volcano. There are 32 known VEI 7 or VEI 8 volcanoes and, if they all erupted at once, it would easily be an extinction-level event for the majority of living things, including humanity. The initial eruptions would cause most aeroplanes in the air to crash, collapse buildings in the western USA, South America, southern Europe and the Far East, and cause power grids to fail across most of the developed world. Drinking water supplies would be rendered toxic by ash, global temperatures could fall by 15°C for six months, and acid rain would make agriculture impossible for the next decade.
Luckily, this is almost guaranteed never to happen. Volcanoes are driven by localised upwellings of magma beneath the Earth's crust. Every volcano erupting simultaneously would be like every bubble in a fizzy drink breaking the surface at once.



GETTY IMAGES X2, ALAMY ILLUSTRATIONS: DAN BRIGHT

THE BIGGEST BLACK HOLES

Since just after the Big Bang, ancient black holes may have been shaping the universe as we know it. Now, scientists are tantalisingly close to glimpsing these mysterious objects for the first time

BY COLIN STUART

Out there among the stars lies a hidden swarm of black holes. They have been around ever since the dawn of time, quietly and not so subtly influencing the evolution of the universe. Without them there would be no stars, no planets and no life to marvel at the universe's wonders. Now, for the first time, we may finally have the tools to find them.

Black holes are one of astronomy's most famous objects. Their gravity is so extreme that escape is impossible if you venture too close. There are different sizes of black holes, but they are normally gargantuan monsters considerably more massive than our own sun. They usually remain hidden from view because no light can escape to reveal them to us.

Gravitational wave detectors such as VIRGO could help us find signals from primordial black holes.

Yet we have seen them, thanks to gravitational wave detectors like LIGO and VIRGO that have detected signals from colliding black holes. We've never been more confident that these cosmic trapdoors exist.

However, there is one type of black hole that still remains theoretical – one that could solve a long-standing cosmological conundrum to boot.

Immediately after the Big Bang, there were small fluctuations in the new universe's density – regions that had slightly more or less mass than the average. Where the mass was above the norm, material could have collapsed to form mini black holes. As they've been around for pretty much as long as the universe itself, these black holes are called 'primordial' black holes.

According to theoretical models, primordial black holes can have a wide range of masses. They could be lighter than an eyelash or heavier than a star. So far, we've been able to rule out some masses through observations, opening up two possible mass ranges or 'windows' for primordial black holes.

"The two windows are less than one lunar mass [one lunar mass = mass of our moon] and a few tens of solar masses [one solar mass = mass of our sun]," says Prof Sohrab Rahvar, an astrophysicist and cosmologist from Sharif University of Technology in Iran.

"You can explain all of the dark matter through primordial black holes."

If this hidden population of miniature black holes exists, then they could account for some or all of the dark matter – the invisible glue that astronomers think helps hold galaxies like our own Milky Way together. It's an idea that fell out of favour, but is now gaining traction again – particularly as traditional notions of what dark matter is made of continue to draw a blank.

Small but mighty

With one eye on dark matter's true identity, PhD student Gabriele Franciolini, from the University of Geneva, Switzerland, has been re-modelling the production of primordial black holes after the Big Bang in more detail. The upshot? "There could be hundreds of times more primordial black holes out there," he says. "You can explain all of the dark matter through primordial black holes." That's if they have a mass in the lower window, below that of the moon, which would make them less than one-tenth of a millimetre in diameter – about the width of a human hair.

In this case, each primordial black hole would be tiny, but together they could provide enough gravity to keep a galaxy from flying apart. If galaxies like our Milky Way are chock full of teeny adhesive black holes, then they should be everywhere.

Amir Siraj, a theoretical astrophysicist from Harvard University, believes there's even a chance that one is lurking in the outskirts of our solar system.

For a decade or so, astronomers have been

GETTY IMAGES X2, NASA, SCIENCE PHOTO LIBRARY, ESA

THE FOUR TYPES OF BLACK HOLE

PRIMORDIAL

(A RANGE OF DIFFERENT MASSES)

These are as-yet-unconfirmed relics from the formation of the universe in the Big Bang. So far, we've been able to rule out their existence in certain mass ranges, but the door is still open to the possibility that the universe is littered with tiny black holes. Together, they could explain the dark matter mystery – the fact that there appears to be an invisible glue binding galaxies together.

STELLAR MASS

(5 TO 100 SOLAR MASSES)

These are your so-called 'ordinary' black holes. When the most massive stars die – those more than 30 times the mass of the sun – they explode into a supernova. The star's core collapses into an infinitely small, dense point called a singularity. The gravity is so strong that anything venturing within a certain distance of the singularity – a region called the event horizon – cannot escape its clutches.

INTERMEDIATE

(100 TO 1,000,000 SOLAR MASSES)

For decades, astronomers puzzled over the fact that there are stellar mass black holes and supermassive ones, but seemingly very little in the middle. This was odd because big black holes are thought to be constructed through mergers of smaller ones. There was a missing link in this construction chain. But in March 2020, a 50,000 solar mass black hole may have been spotted by the Hubble Space Telescope. That was followed six months later by the announcement of the GW190521 event (see main article).

SUPERMASSIVE

(GREATER THAN 1,000,000 SOLAR MASSES)

These leviathans are found in centres of major galaxies and are the seeds around which the galaxies are constructed. The one at the heart of our own Milky Way is called Sagittarius A* (pronounced 'A star') and tips the scales at around four million times the mass of the sun. That pales in comparison to the supermassive black hole in the galaxy M87, which weighs in at a whopping seven billion solar masses.

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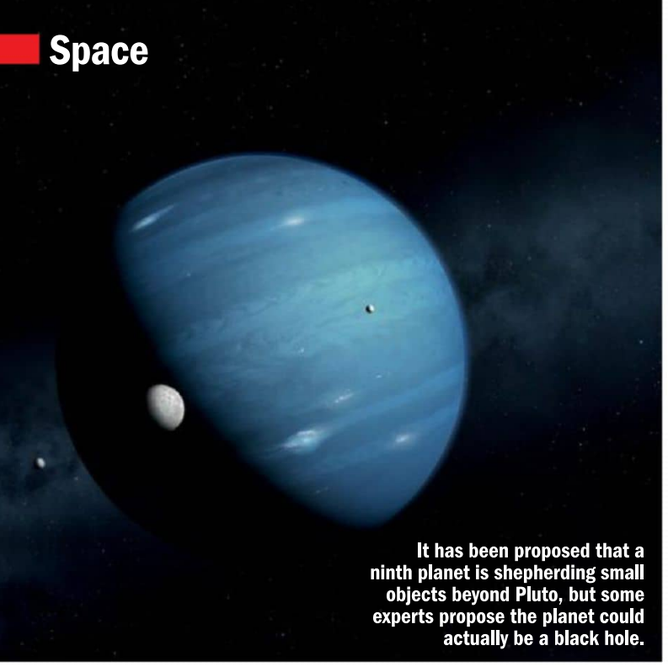
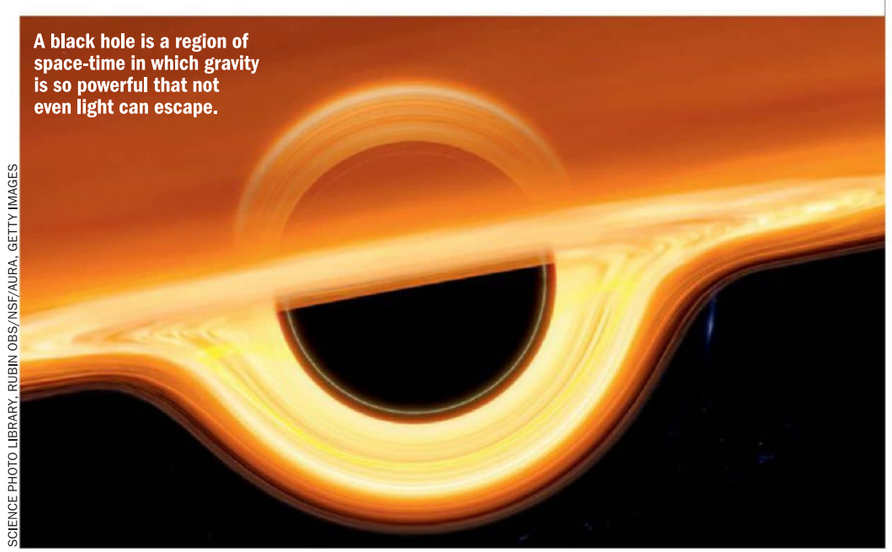


It has been proposed that a ninth planet is shepherding small objects beyond Pluto, but some experts propose the planet could actually be a black hole.

puzzled by the orbits of small objects beyond Pluto. Their paths around the sun should be pretty random, but they appear organised. It's as if something is shepherding them onto similar trajectories. But what? "It's most likely a planet," says Siraj. Dubbed Planet Nine, it would be the first newly discovered planet since Neptune was added to the register in 1846 (Pluto was called a planet upon discovery in 1930, but later demoted to dwarf planet status in 2006). However, extensive ongoing searches have failed to find any visible sign of such a world.
"If direct searches continue to fail, then a primordial black hole becomes an option," Siraj says. After all, as Arthur Conan Doyle's fictional detective Sherlock Holmes famously said, once you eliminate the impossible, whatever remains, no matter how improbable, must be the truth.
We know how much gravity we need to account for the clustered orbits of the objects beyond Pluto.
If that gravity is being provided by a primordial black hole, then it is merely the diameter of a grapefruit. Yet, despite its small size, it would still be approximately 10 times heavier than the Earth.
If this is really what's going on, then it's no surprise that telescopic trawls of the outer solar system have so far come up empty.
Siraj thinks there is a way we could see it, though. It's an idea that came to him during the first COVID lockdown while he was staying in his childhood bedroom at his parents' house.
"The black hole should produce the occasional accretion flare," he explains. In other words, we should see a flash if the grapefruit-sized object gobbles up a passing comet. Such an event would release a few per cent of the energy of the atomic bombs dropped on Japan at the end of WWII. The flash may be intense, but it is happening a long way away in the backwaters of the solar system. That makes the light pretty faint by the time it reaches Earth. Still, there is a new telescope about to come online that should be up to the job.
"The flares are right on the detection limit for the Vera Rubin Observatory," Siraj says. "It's the perfect tool for ruling out a primordial black hole in the outer solar system." The observatory should start proper observations towards the end of 2023.
Should a primordial black hole turn out to be there, it likely entered the solar system due to the fact that the sun is dragging us through the minefield of the Milky Way as it orbits around the galactic centre. For some reason, this one got stuck, but could a primordial black hole go further and enter the inner solar system? Rahvar certainly thinks so. He's calculated the chances of a primordial black hole passing through the Earth during our planet's 4.54-billion-year history. "The probability is one passage per billion years," he says. If he's right, we've been struck by a primordial black hole on four separate occasions. Rahvar's calculation assumes 100% of dark matter is made of sub-lunar mass primordial black holes. Even if they make up just a quarter of dark matter, Earth has still encountered a primordial black hole once before, and is likely to do so again.

The Vera Rubin Observatory becomes fully operational in 2023 and should be able to detect signs of a primordial black hole in the outer reaches of our solar system.

"Earth getting hit by a black hole sounds apocalyptic, but it isn't necessarily. We're still here, after all."



A black hole is a region of space-time in which gravity is so powerful that not even light can escape.

SCIENCE PHOTO LIBRARY, RUBIN OBS/NSF/AURA, GETTY IMAGES

Hello, darkness

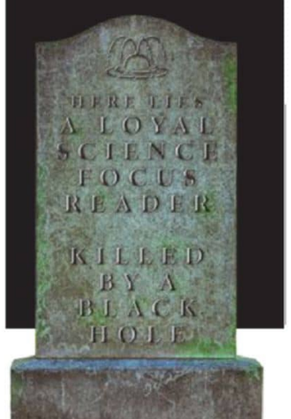
Our planet getting hit by a black hole sounds apocalyptic, but it isn't necessarily. We're still here, after all. The worst outcome is that the primordial black hole settles in the Earth's core. "Then the black hole starts to swallow all the matter of the Earth, grows and, after a finite time, the Earth will collapse into the black hole," Rahvar explains. Fortunately, Rahvar's calculations reveal that the probability of trapping a black hole inside the Earth is almost zero. What is far more likely is that the black hole passes straight through the planet and emerges on the other side to continue its journey through space. If it happens to pass through you, however, the results aren't pretty (see 'What if' box).
How can we tell if a black hole really has passed through the planet? "During its passage through the Earth, it can heat the planet's interior," says Rahvar. This could show up as melting traces in rocks along the straight line that represents the black hole's path. However, Rahvar cautions that, as this has only occurred a maximum of four times in Earth's entire history, it would be extremely difficult to discover these traces.
So, how else could we

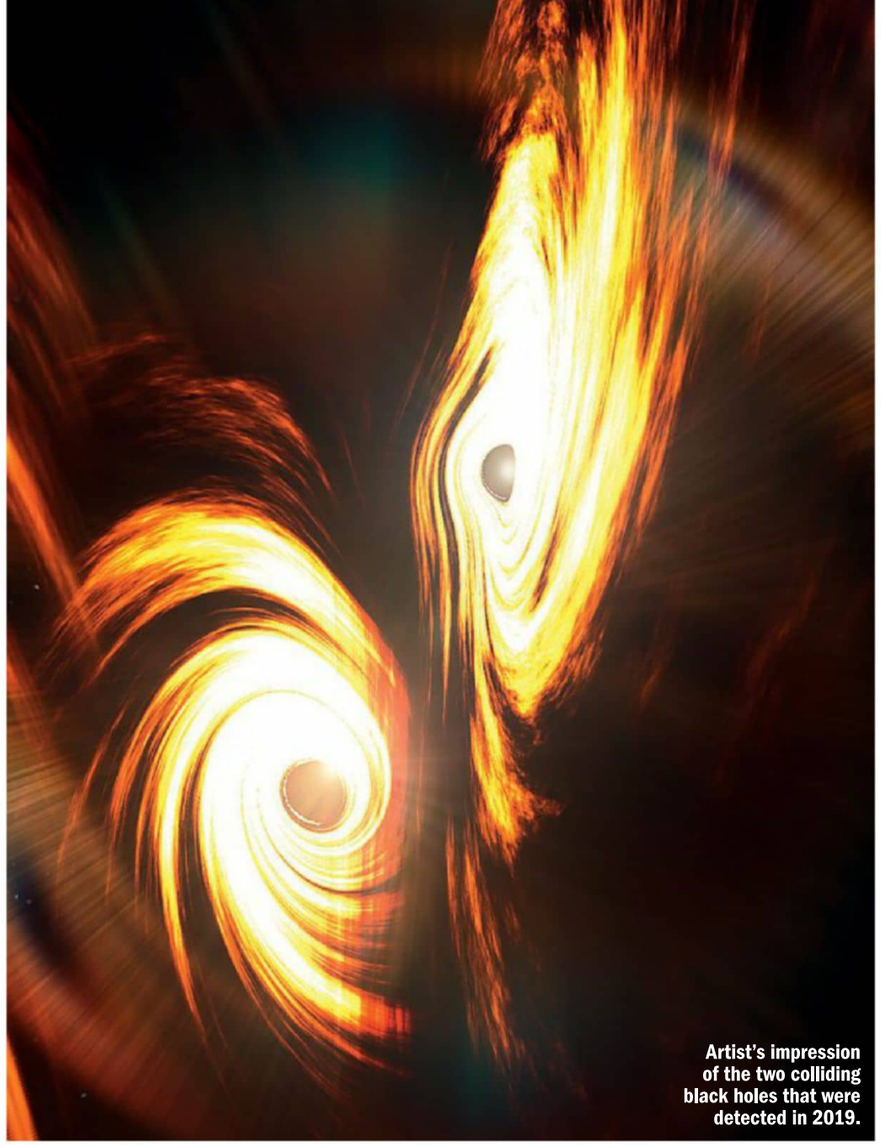
WHAT IF...

WHAT WOULD HAPPEN IF YOU WERE HIT BY A PRIMORDIAL BLACK HOLE?

Well, first off, you'd probably be the unluckiest person in human history. According to Prof Sohrab Rahvar, an astrophysicist and cosmologist from Sharif University of Technology in Iran, Earth has only been hit by a maximum of four primordial black holes in its entire 4.54-billion-year existence. For one to pass through the Earth during your lifetime is almost impossible. For it to pass through the narrow 1m corridor that coincides with where you are is off-the-scale unlikely.

That said, you're in for a torrid time should you be fortune's fool. The primordial black hole will only be in your body for 10 microseconds, but will be travelling at 160km/s (0.05% of the speed of light). Although the black hole is only 1,000 times wider than an atom, it comes with its famous brand of intense gravity. According to Prof Avi Loeb, the esteemed theoretical physicist from Harvard University, it's enough to shrink your body by a couple of inches. All of your internal organs will become distorted as the black hole warps the fabric of space in which they reside. It would lead to an agonising death. Still, imagine the epitaph: 'Here lies [insert your name] – killed by a black hole'.



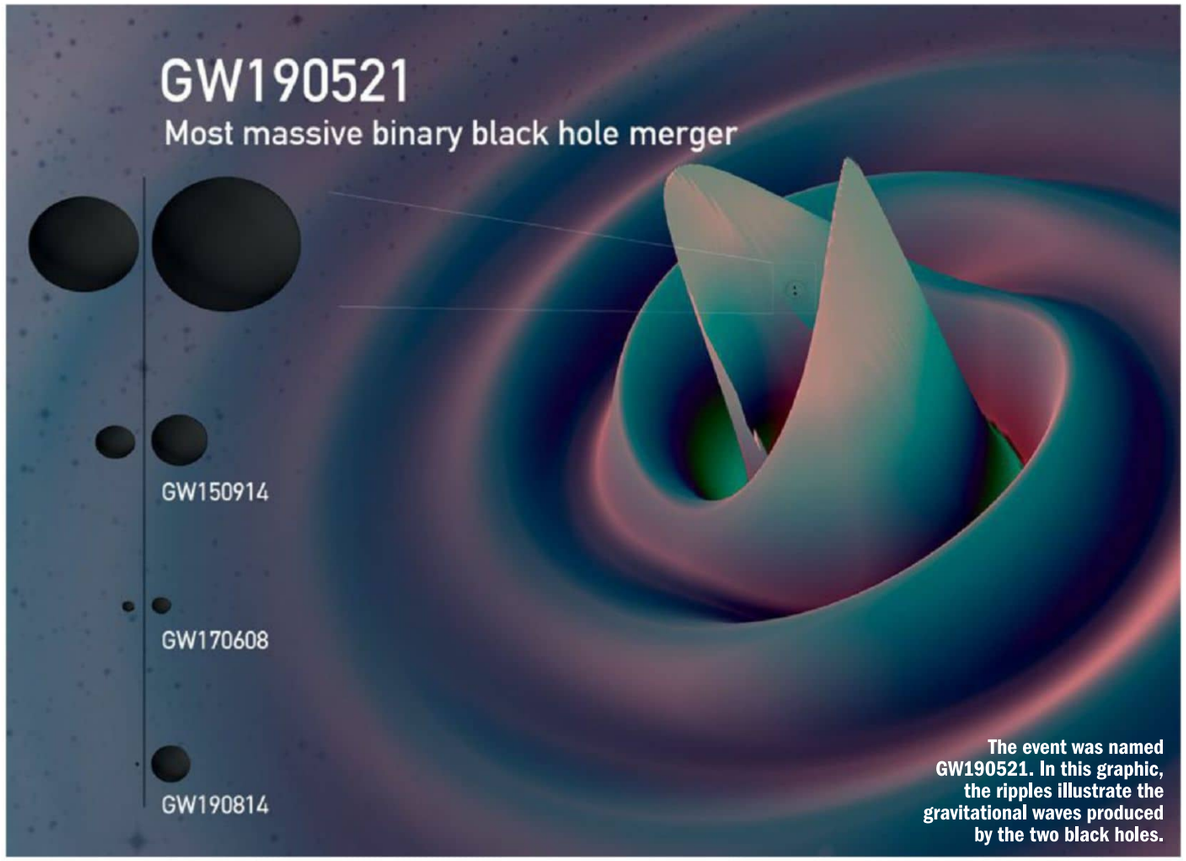


Artist's impression of the two colliding black holes that were detected in 2019.

GETTY IMAGES, MARK MYERS/ARC/OZGRAV, NSF/LIGO/VIRGO

"The data supports the idea that primordial black holes are there, but we need more data and more work on the theory side."

prove that primordial black holes really exist? Franciolini thinks that the answer is the same way we proved that ordinary black holes exist: gravitational waves. Observed for the first time in 2015, gravitational waves are ripples in the fabric of the universe itself, caused by events happening within it. The gravitational waves that we've detected so far have come from collisions between compact objects like ordinary black holes and neutron stars. Or at least that's the conventional wisdom. Franciolini isn't quite so sure. "A significant fraction of the events could be of primordial origin," he says.



The event was named GW190521. In this graphic, the ripples illustrate the gravitational waves produced by the two black holes.

Now we're talking about primordial black holes in the upper mass window – those weighing in at tens of solar masses. We know from an effect called 'gravitational lensing' that primordial black holes in this mass range cannot make up more than 10% of dark matter. Gravitational lensing is where a foreground object (say a black hole) magnifies the light of a background object (like a star). If there were lots of big primordial black holes around, then we'd see more of these events than we do – hence the 10% ceiling.

According to Franciolini, if large primordial black holes represent just 0.1% of dark matter, then they would merge with each other at the same rate as ordinary black holes do. If we've been able to see the latter, there's a good chance we've also already seen the former. In other words, we've already spotted two large primordial black holes colliding and wrongly assumed it was two ordinary black holes instead. "You have to disentangle the two scenarios," says Franciolini. "That's the challenge."

One recent gravitational wave event is particularly intriguing: GW190521. It takes its name from the fact that it was detected on 21 May 2019, and the discovery was subsequently announced in September 2020. This particular merger of two black holes produced a single black hole that tips the scales at 140 solar masses. That's big enough to class it as an intermediate black hole. According to Franciolini, it's harder to explain the existence of such a monster merger with ordinary black holes. That opens the door to the possibility of a primordial origin instead. "The data supports the idea that primordial black holes are there," Franciolini says, "but we need more data and more work on the theoretical side."

We might not have to wait too long for that deluge of data, as we're already building out our network of gravitational wave detectors. The Kamioka Gravitational Wave Detector (KAGRA) in Japan will soon join forces with LIGO and VIRGO, after some setbacks due to the COVID pandemic and Hurricane Ida. Plans are underway for a new LIGO detector in India later this decade. With four detectors spread around the globe, astronomers will be able to pinpoint gravitational wave events across the entire sky. Right now, they are limited to just half of the heavens. The new gravitational wave detectors should bring more black hole merger events with more precise data. Researchers like Franciolini are eager to comb through that data for any signs of primordial black holes. Perhaps then we'll know whether these ancient, invisible relics have been silently steering the evolution of the universe, binding galaxies together and setting the stage for us to build gravitational wave detectors in the first place. ■

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Colin Stuart is an astronomy author and speaker. Get a free ebook at colinstuart.net/ebook. Follow him on Twitter: @skyponderer.

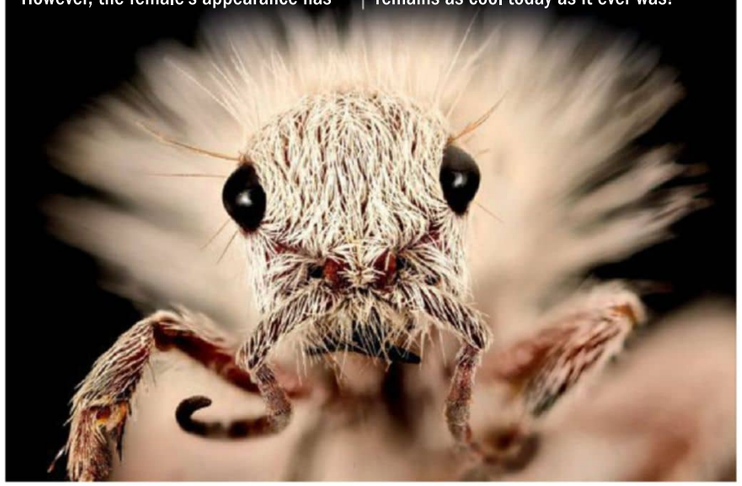
Q&A
Questions & Answers

Got questions you've been carrying around for years? *Very Interesting* answers them! Mail your questions to VI@panorama.co.za

NATURE'S WEIRDEST CREATURES...

Thistledown velvet ant

This creature is a misnomer wrapped in a cloak of punky, white fuzz. It's a misnomer because the unusual critter is not an ant, it's a parasitic wasp that's native to the desert regions of the American Southwest. The white, fluffy females are wingless, and so superficially ant-like. In contrast, males have wings and a classic wasp livery of orange and black. This vibrant attire warns potential predators that the wasps are not to be crossed – velvet ants have one of the longest stingers (relative to body length) of any bee or wasp.
However, the female's appearance has been something of an enigma. Females look like the fuzzy seeds of the scrubby creosote bushes that grow where the wasps live, so experts had presumed that the insects had evolved their appearance as a form of camouflage. But genetic analyses revealed that the wasps preceded the arrival of the creosote bush to the American Southwest by around five million years. Cue experiments placing white-coloured and vibrantly coloured ants under heat lamps, and it seems that the female's white spiky coat helps it to not overheat. Proof, beyond doubt, that the punk look remains as cool today as it ever was!



Which is more hygienic: paper towels or hand dryers?

Jerry Skosana, Rustenburg

Although headlines on the hygiene of paper towels versus hand dryers might be seductive, scientists have tried and failed to come to a definitive consensus about which is really superior. When you look at the studies behind the headlines, you'll often find they are funded by the paper towel or hand dryer industry. It's difficult to compare the studies, too, as airblowers vary in efficiency, and paper towels vary in thickness.
In truth, it probably doesn't matter much. What's more important is washing your hands regularly with soap and water for 20 seconds, then using whatever is available to dry them.

How is caffeine removed from decaffeinated coffee?

Jeffrey Roman, Johannesburg

The original process, developed by Ludwig Roselius in 1903, used benzene to dissolve the caffeine from the unroasted beans. Benzene is carcinogenic, so it has since been replaced with much safer solvents, including dichloromethane and ethyl acetate, which evaporate when the beans are roasted.
High-pressure CO_2 is also used by mass market brands as an alternative to organic solvents.
A third system, used primarily in the US and Canada, is the Swiss Water Process. This passes very strong coffee solution through a carbon filter to remove the caffeine, and then uses this solution to remove the caffeine from unroasted beans by diffusion, without damaging their subtle flavour compounds.

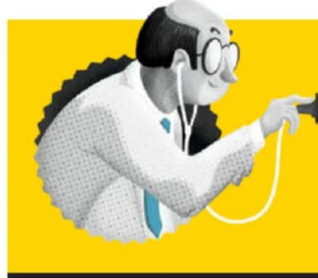
Q&A FLASH

- Decaffeinated coffee has almost as many antioxidants as caffeinated coffee.
- A cup of decaf still retains around 2mg of caffeine (versus 95mg in a normal cup of coffee).

Why doesn't Earth have rings?

Lindi Malibuwe, Cape Town

All gas giant planets (Jupiter, Saturn, Uranus and Neptune) in the solar system have rings, while the terrestrial ones (Mercury, Venus, Earth and Mars) do not. There are two theories about how ring systems develop. They may have formed from leftover material from the formation of the planet or be the remains of a moon that was destroyed by an impact, or was simply broken apart by the gravitational tugging of its parent.
It is unclear why only the gas giants have rings. However, the fact that gas giants formed in the outer solar system, while rocky planets formed only in the inner solar system, may be a clue. Perhaps the inner planets were shielded from the collisions that could have formed rings, or perhaps the higher incidence of moons in the outer solar system means rings also became more common there. Another factor may be that larger planets simply have a larger volume in which a ring system can form and remain stable.
Scientists believe the Earth did have a ring system in the past. Very early in its history, a Mars-sized object collided with the Earth, probably resulting in a dense ring of debris. However, unlike the outer planets, Earth's ring system soon coalesced to form the moon.



DEAR DOCTOR...
HEALTH QUESTIONS DEALT WITH BY OUR EXPERTS

What would happen to my sperm if I had a vasectomy?

Matthew Price, Rosebank

During a vasectomy, the tube which carries sperm from the testicles to the urethra (the tube in the penis) is cut. Once this happens, sperm can't get into the semen or out of the body. But where do they go?
Sperm are still produced by the man's testicles, but they are absorbed back into the body in a way that is harmless. The lining of the epididymis, the coiled tube behind the testes, absorbs most of the sperm, similar to if the man simply couldn't have sex for a long time. The testicles will continue to produce the male hormone testosterone, and a man's sex drive, sensation and ability to have an erection won't be affected – the only difference is that there is no sperm in the semen.
It's worth saying that this doesn't happen immediately – it can take several weeks to clear the sperm, because some stay in the tubes after the procedure. For most men, sperm will be cleared by around 12 weeks after the procedure, but contraception needs to be used until the semen is tested and found to be clear.

ALAMY X2, SCIENCE PHOTO LIBRARY, GETTY IMAGES ILLUSTRATIONS: DANIEL BRIGHT

OCTOPUSES ON PARADE

With three hearts, blue blood, eight bendy arms and intelligence that outsmarts other spineless animals, there's nothing quite like an octopus. Join us on a dive into their weird world…

TEXT: DR HELEN SCALES

GETTY IMAGES

BEAUTIFUL BUT DEADLY

Famous for being some of the world's deadliest animals, blue-ringed octopuses are usually quite docile and spend most of their time hiding in rubble and shells. There are between four and 10 species in the *Hapalochlaena* genus, living in shallow seas from Australia to Japan. They are all less than a handspan in size, and each has around 60 bright blue rings which flash as a warning when the octopus feels threatened. The rings contain multilayer reflectors, arranged to reflect blue-green light. The flashing is controlled by muscles that pinch in a surrounding layer of black pigmented chromatophore cells that cover the blue iridescence. When the muscles relax, the blue iridescence is exposed. The warning flashes come before the octopus deploys its deadly defensive bite. Bacteria living in their salivary glands make tetrodotoxin (TTX), the same toxin that makes pufferfish deadly to eat. Female blue-ringed octopuses cover their eggs in TTX to protect them from getting eaten.

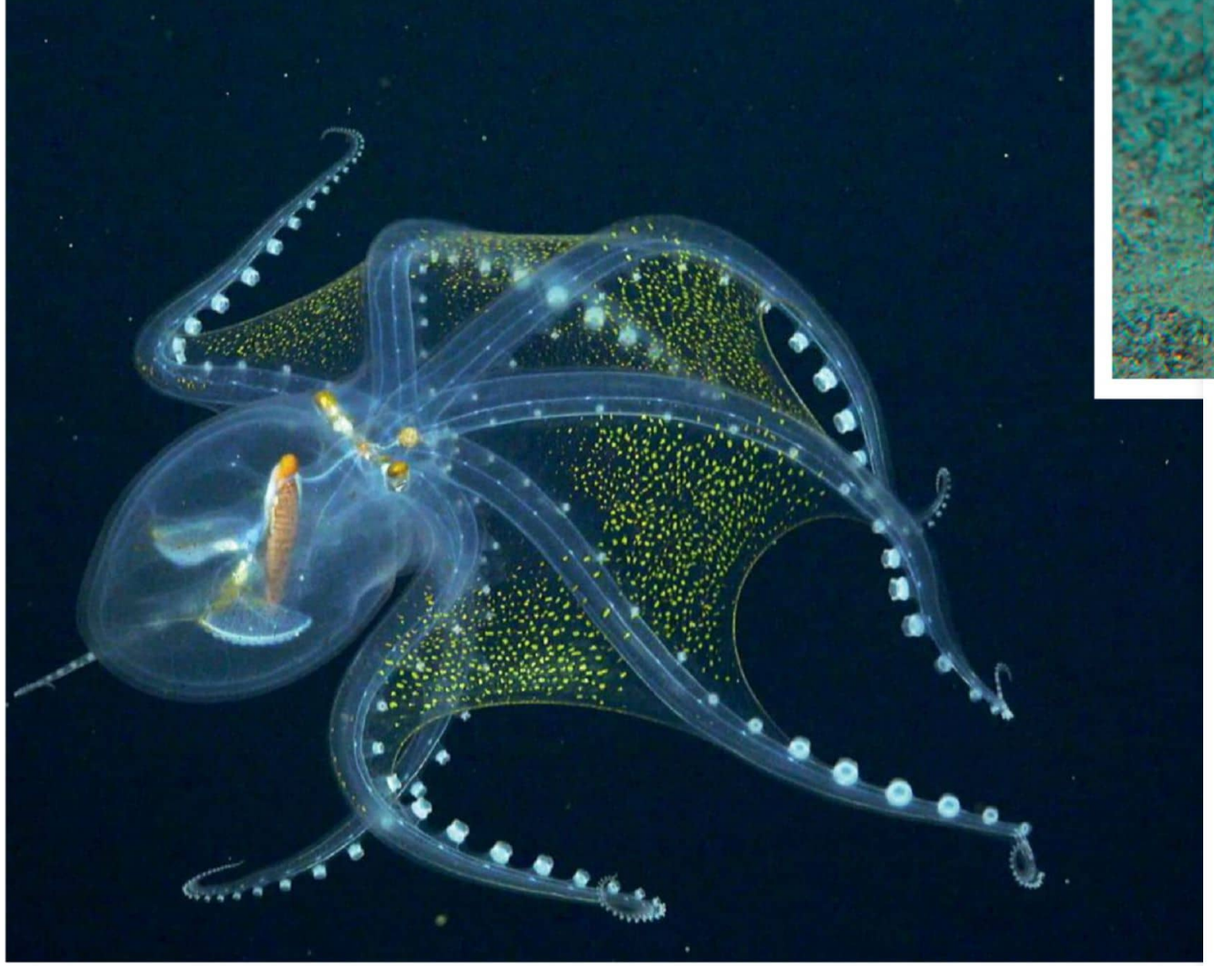
↓ SPECTACULARLY SEE-THROUGH

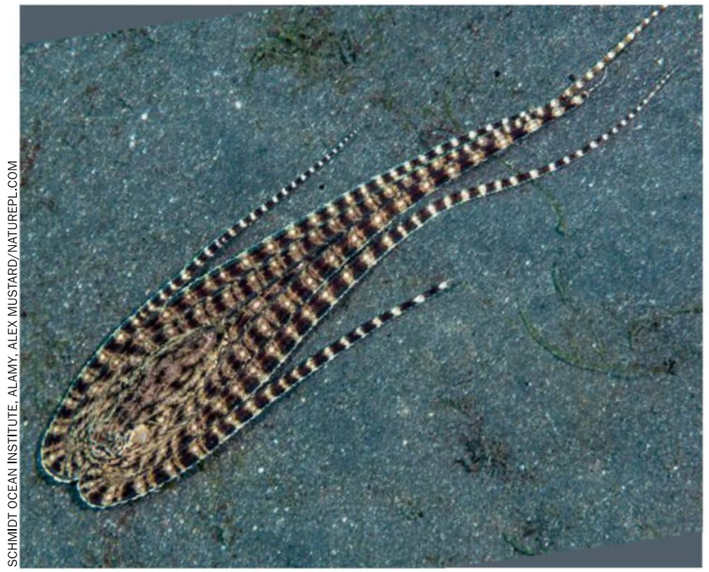
Living in mysterious deep waters down to at least 1,000m and with transparent gelatinous bodies, glass octopuses are some of the most elusive and least studied octopuses in the ocean. They've been spotted in tropical and subtropical waters all around the world, usually near giant underwater mountains called seamounts. The one in this picture was found by scientists on the Schmidt Ocean Institute's Research Vessel Falkor (named after the Luck Dragon from the 1980s movie *The Neverending Story*) during a 2021 expedition to the Phoenix archipelago in the Pacific. Exploring the deep sea with the remotely operated underwater vehicle, SuBastian, the team also found a second glass octopus. Footage of the two animals was a big hit on the internet.

Golden flecks visible on the webs between the octopus's arms are pigmented chromatophores. Their function in dark waters is not obvious, and they may just be something the species inherited from ancestors. The only other non-transparent parts are the eyes, optic nerve and digestive tract.

→ UNDERCOVER OPERATIVE

Working with tools is a well-known sign of higher intelligence in animals, as demonstrated a few years ago by a video that went viral of an octopus strutting across the seabed carrying half an empty coconut shell. It found another shell, assembled the two halves, and climbed inside its mobile, protective shelter. Octopuses are doubtless some of the smartest invertebrates. They have around 500 million neurons, compared to 100,000 for a lobster and 18,000 for a sea slug. Roughly half of an octopus's neurons are located in a doughnut-shaped cluster in their head, and the rest are in their arms. Does that mean an octopus's arm can think for itself? Recent research showed their arms are under some central control from the brain. Scientists trained octopuses to reach the correct way along a Y-shaped pipe to grasp food at the end. The octopuses could repeat the trick successfully with arms they hadn't used before, suggesting the brain must be involved.





SCHMIDT OCEAN INSTITUTE, ALAMY, ALEX MUSTARD/NATUREPL.COM

← NOPE, NO OCTOPUSES HERE!

The mimic octopus is a true master of disguise. In Indonesia, they have been seen with their arms held together in a leaf shape and swimming across the sand with an undulating motion. This makes them look a lot like a local species of spiny, venomous flatfish, which presumably deceives predators into leaving the soft octopuses alone. Not content with impersonating just one species, the mimic octopuses have a whole repertoire. They've been seen trailing their arms behind them, possibly mimicking a highly toxic lionfish. A mimic octopus can also turn itself into a sea snake. It stuffs six arms into a hole in the seabed, then sticks out two arms with black and white stripes and waggles them around in a distinctly snaky way. They seem to deploy their versatile powers of deception in response to particular threats. For instance, when attacked by a shoal of territorial damselfish, an octopus was seen putting on its snake 'costume' and the fish left it alone. Sea snakes are common predators of damselfishes.

THE NEXT DISNEY HERO?

Also known as umbrella octopuses, more than a dozen known species of dumbo octopuses all share the same adorable and unusual feature: a pair of flapping, ear-like fins just above their eyes, which they use to swim and steer through underwater currents. They were named after Disney's flying elephant, and most species live near the seabed, alternating between sitting and swimming.

Dumbos are the deepest-dwelling octopuses, all of them with ranges below 1,000m. In 2020, one was filmed at just shy of 7,000m inside the Java Trench in the Indian Ocean, extending the known maximum depth for octopuses by almost 2,000m.

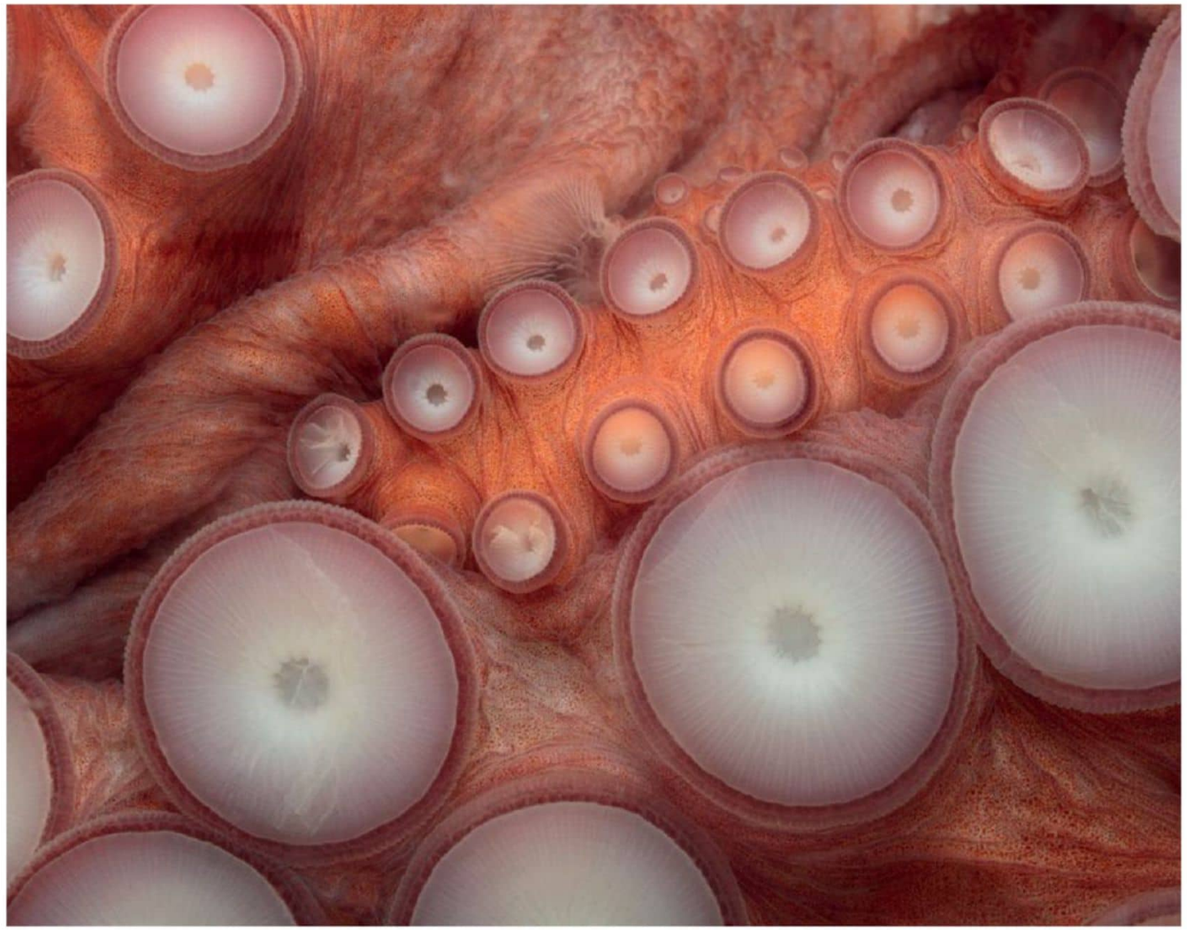
The latest species to be found was collected in a trawl net near the Emperor seamount chain in the Pacific Ocean. The specimen was in amazingly good condition, despite being dragged up thousands of metres. CT and MRI scans showed it had features distinct from all the known species. Scientists named it the Emperor dumbo.

↓ NOT A NAUTILUS

Argonauts are the only octopuses that make external shells. All the others gave up this ability in the distant evolutionary past, leaving the shell-making to snails, clams and their other molluscan relatives. There are seven known species of these curious little octopuses that occasionally wash up on beaches nestled inside a paper-thin shell (they are also known as paper nautiluses because they vaguely resemble another mollusc, the chambered nautilus).

Victorian scientists puzzled over argonauts. Some thought they weren't shell-makers, but piratical rascals that attacked other animals, ate them and made off in their empty shells, floating on the sea and holding two arms in the air to catch the breeze. The truth was revealed in the 1840s by the French marine biologist Jeanne Villepreux-Power, who discovered argonauts secrete shells from silvery webs on the ends of two arms. She also saw that only females make shells, using them as egg chambers in order to carry their unhatched young with them as they swim through open seas.

ALAMY, STEVEN KOVACS/BLUEPLANET ARCHIVE



↑ SERIOUS SUCKER

Of roughly 300 species of octopuses that inhabit seas worldwide, the giant Pacific octopus is one of the largest. Their arms can span as much as 6m and they're covered in suckers as large as 6cm in diameter, equipped with receptors that allow them to taste things they touch.
We're learning more all the time about the complex lives of octopuses, from rare colonies of many octopuses living together (they're normally solitary and quite hostile towards each other) to the females that throw shells and mud at males that are harassing them. Scientists recently discovered sleeping octopuses change the colour and texture of their skin – quite possibly while they're dreaming. Great mysteries remain, including how octopuses came to be such brainy molluscs with far more sophisticated nervous systems than their close relatives, the clams, oysters, slugs and snails.

BRANDON COLE/NATUREPL.COM, MAGNUS LUNDGREN/NATUREPL.COM X2

→ FANCY A HUG?

Fluttering membranes decorated with 'peacock eyes' help to make this female blanket octopus look bigger, presumably deterring predators. She can also defend herself by ripping the tentacles off a Portuguese man o' war and waving them around; somehow she is immune to the stings.
Female blanket octopuses grow up to 2m long. And at around 2.4cm, the smaller male in this picture is not to scale. Females can be 40,000 times heavier than the males, which is the biggest size difference between the sexes of any animals.
The male's large eye may help him locate a mate. When he does, he only needs to come briefly into contact with her. He amputates his specialised sperm-bearing arm, the hectocotylus, and gives it to the female. It's likely the male then dies, because none have ever been found with a regenerated arm. A female can store multiple dismembered arms inside her body and uses them to fertilise her eggs, which she carries until they hatch. ■

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**Dr Helen Scales is a marine biologist, writer and broadcaster.
Her latest book is *The Brilliant Abyss*.
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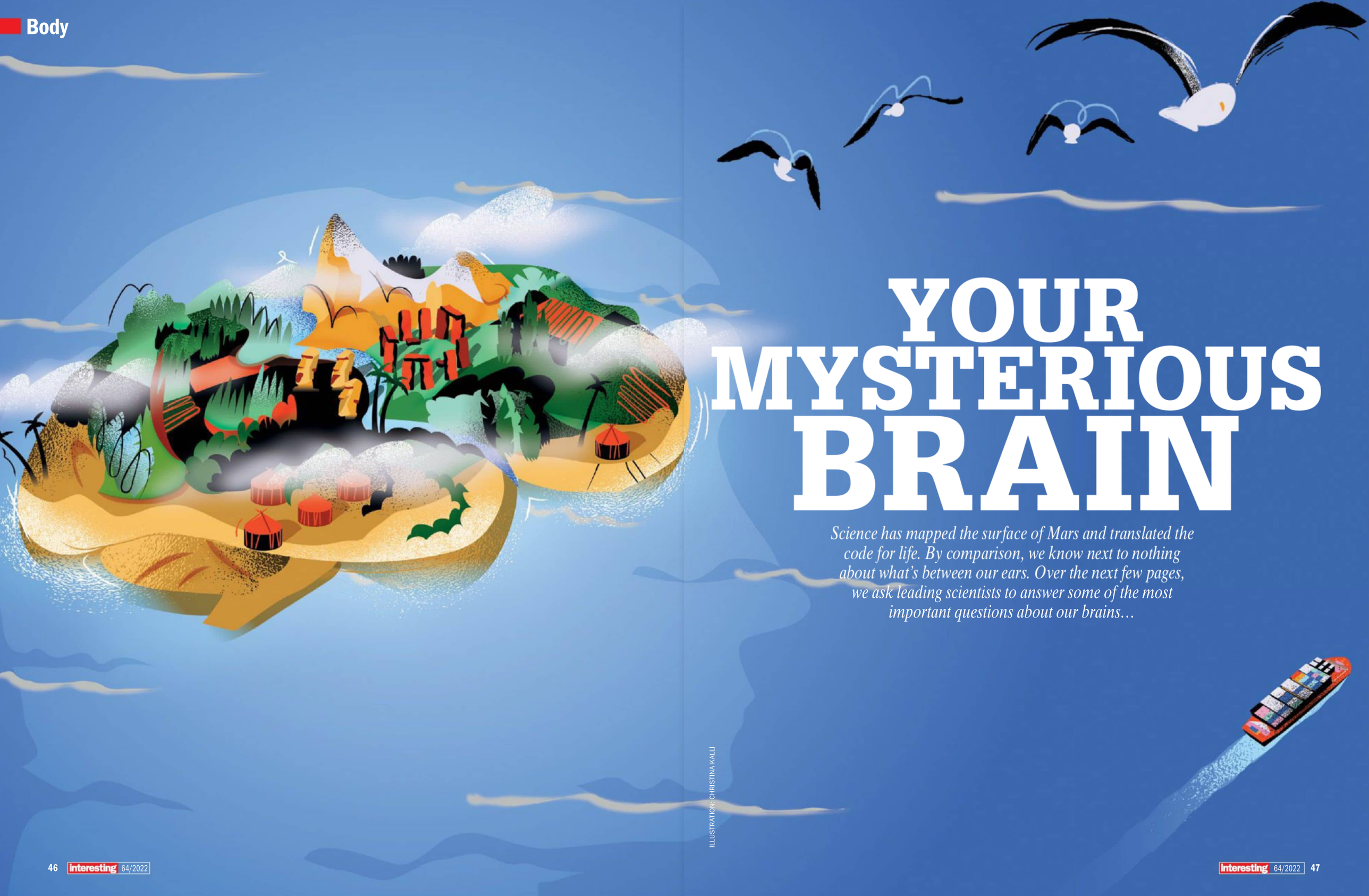


YOUR MYSTERIOUS BRAIN

Science has mapped the surface of Mars and translated the code for life. By comparison, we know next to nothing about what's between our ears. Over the next few pages, we ask leading scientists to answer some of the most important questions about our brains…

ILLUSTRATION: CHRISTINA KALLI

Do we really have free will?

The question of free will is still hotly debated. On the one hand, we clearly experience ourselves as able to make choices and freely act on them. If you fancy some crisps, you can choose to walk into a shop, buy a packet and eat them. Or you can choose to eat a pastry, a salad, or nothing at all. This certainly feels like free will. On the other hand, neuroscience evidence clearly shows that the brain usually initiates our actions before we're aware of them. Here's what I mean. Your brain's primary task is to regulate the systems of your body to keep you alive and well. But there's a snag: your brain spends its days locked in a dark, silent box (your skull) with no direct access to what's going on inside your body or outside in the world. It receives ongoing information about the state of your body and the world – 'sense data'– from the sensory surfaces of your body (your retina in your eyes, your cochlea in your ears, and so on). These sense data are outcomes of events in the world and inside your body. But your brain does not have access to the events or their causes. It only receives the outcomes. A loud bang, for example, might be thunder, a gunshot, or a drum, and each possible cause means different actions for your brain to launch.

How does your brain figure out the causes of sense data, so that it prepares the best actions? Without direct access to those causes, your brain has to guess. And so, in every moment, your brain remembers past experiences that are similar to your present circumstances, to guess what might happen in the next moment, so it can prepare your body's next action. Guessing (and potentially correcting mistakes) is more efficient than reacting from scratch. These predictions are, in effect, your brain changing the firing of its own neurons to prepare your body to act, a second or so before the movements actually occur. This predictive process happens completely outside your awareness, but it is continuous throughout your life, and a growing number of scientists are now pretty sure that it's a primary driver of your actions.

From this perspective, your brain's decision to eat a packet of crisps was launched as a plan for action before your brain made itself (you) aware of this plan. So this action, like most of your actions, was guided by predictions that were under the automatic control of your memory and your current surroundings. This description of your brain's inner workings certainly seems to suggest an absence of free will.

And so we arrive at the point where the free will debate has lingered for a long time. We won't settle the debate here, but I'll highlight one puzzle piece that is often ignored. Your brain predicts (in large part) by reassembling your past experiences that are similar to the present moment. That means every new experience you cultivate for yourself – every new thing you read, every new person you talk to, every new thing you learn – is an opportunity to change what your brain will predict in the future, and which actions you may take. In other words, your brain (meaning you) can nudge its future predictions in various directions, right now, by investing in new experiences.

You are continually cultivating your past as a means of controlling your future. This may be a form of free will, but it's extended over time and therefore different from how we usually think about free will in the moment. If you practise a skill, whether it's riding a bicycle, or talking to someone who believes things that you abhor, you hone your brain's predictions until that skill becomes automatic and likely to be repeated.

With practice and a little investment of energy, you can make some automatic behaviours more likely than others and have more control over your future actions. Perhaps not as much control as you might want, but more than you might think.

Dr Lisa Feldman Barrett is a professor of psychology at Northeastern University. Her latest book is *Seven And A Half Lessons About The Brain.*

ILLUSTRATIONS: CHRISTINA KALLI

Do genetics affect mental health?

When it comes to things that protect or harm our mental health, the role of our genes is often an afterthought. After all, mental health disorders and issues are products of our minds and brains, whereas our genes are microscopic elements of our DNA. It may seem a bit of a reach to assume that the two are connected.

This is wrong, though. Scientific research has revealed that many mental health disorders have a significant genetic component, which undoubtedly shapes our understanding and treatment of them.

If you step back and look at it logically, it makes perfect sense that our genes would influence our mental health. After all, as intangible as they may be in so many ways, our minds, consciousness, thoughts and emotions are all products of activity in the brain, of the countless complex signals being sent and received by billions of brain cells, also known as neurons. And these signals depend on intricately complicated brain cells working as they should. The good functioning of cells is reliant upon the molecules that make them up. And these molecules, particularly proteins, are determined by our genes.

This means that if there's a flaw or issue with the code in a specific gene, the molecules it produces won't be quite the right shape. And for proteins in particular, their shape is a crucial aspect of their ability to interact with other molecules in the appropriate way, which is what they're for. This means that any cell that has these flawed proteins will be less able to function properly. And if these cells are neurons, then the processes that lead to the formation of our minds can be affected, sometimes in ways that are disruptive, or at least unhelpful.

So, although it's via several steps, it's easy to see that our genes can play a role in our mental health. This isn't to say that they're the sole factor determining our mental health. It's not the case that some people have a specific 'depression gene' or 'anxiety mutation', and that those with these genetic traits develop the eponymous disorder, and those without them never will. In truth, the brain is far too complex for that, particularly when it comes to the parts that result in our mind. There are so many components at work, so many systems combining to give rise to consciousness, and so much redundancy and adaptability in your typical brain, that a single atypical gene automatically producing a (complex and versatile) disorder is extremely unlikely, just like how a single poorly installed circuit in an electricity grid doesn't inevitably lead to blackout.

However, genetic factors can increase the risk of mental health issues, or make us more vulnerable to developing them, by reducing the brain's ability to deal with or compensate for traumas and other disruptions. This is presumably why many mental health problems are seemingly hereditary, and why some mental health conditions seem to have similar genetic attributes.

Overall, it's fair to say that genes play a significant role in our mental health. But so do many other things. And that's where it gets confusing.

Dr Dean Burnett is a neuroscientist and author. His latest book is *Psycho-Logical.*

Can you improve your brain with food?

Your brain is hungry. In fact, it is the hungriest organ in your body. Despite making up only around 2% of your overall body weight, your brain consumes about 20% of your body's total energy requirement. But it is a mistake to think that it's only energy that the brain needs to function well; a full complement of micronutrients in sufficient quantities are essential for a healthy brain.

Evidence is growing that deficiencies in these nutrients contribute to poor brain and mental health. Moreover, there is not a single point in the lifespan, from conception to old age, where nutrition doesn't play an important role in brain structure and mental health. For example, we know that it is important for women trying to conceive to take folic acid (a B vitamin) to prevent neural tube defects conditions such as spina bifida. Of course, it's not just folic acid that the developing brain needs.

The essential omega-3 fatty acids form the structural building blocks of brain cell membranes. One of these fats, DHA, makes up between 10 and 20% of the brain's total fatty acid content. DHA promotes healthy neuronal morphology and cell signalling, allowing brain cells to communicate efficiently. During pregnancy, accumulation of DHA in the brain and retina is necessary for proper brain development and visual function.

The body is unable to synthesise adequate amounts of DHA, so it must come from the diet. Fortunately, it is abundant in seafood and oily fish such as sardines, mackerel, salmon and trout, and one 140g serving of mackerel supplies enough omega-3 for a week.

Consequently, greater maternal seafood consumption during pregnancy is associated with improved brain development and cognitive function in children, including better scores on assessments of verbal intelligence and fine motor control. Lower blood levels of omega-3 in children are connected to poorer behaviour, worse verbal learning and poorer reading skills.

In adults, higher blood levels of DHA are associated with reduced risk of dementia, which is the leading cause of death in the UK. Mild cognitive impairment (MCI) is the age-related decline in cognitive function that can be a precursor to Alzheimer's disease, the dominant form of dementia. A randomised controlled trial of elderly individuals with MCI found that supplementation with B vitamins combined with high blood levels of omega-3 resulted in a 40% slower rate of neuronal atrophy.

The protective effect of omega-3 intake on neurodegeneration is good news, but the bad news is that fish consumption in the UK is below recommended levels. Fewer than 5% of UK children are consuming adequate amounts of oily fish.

Polyphenols are another class of nutrient with profound beneficial effects on brain function. Polyphenol-rich foods include tea, coffee, dark chocolate, berries, herbs, spices and wine. In placebo-controlled trials, polyphenol-rich foods increased brain blood flow and enhanced performance on tests of attention, memory and processing speed.

There is even good evidence that improved nutrition can support emotional wellbeing. A landmark Australian study showed that increasing fresh fruits, veg, wholegrains and oily fish in the diet reduced depression severity.

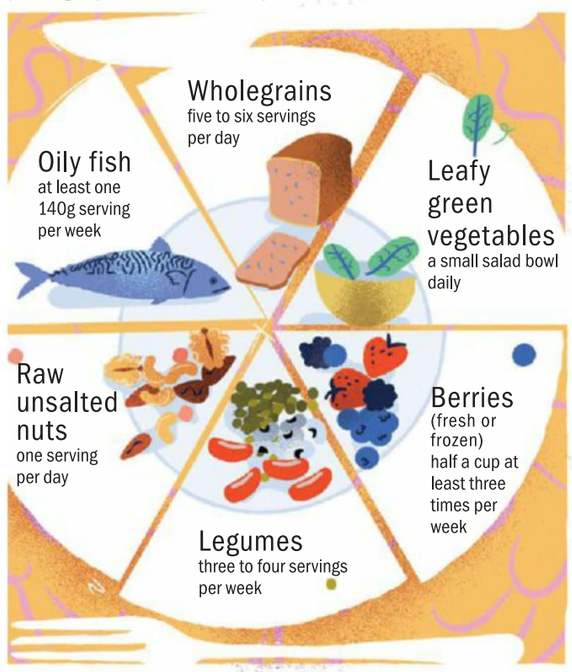
But what about foods to avoid? There seems to be no good news about sugar-sweetened beverages. In healthy young men these drinks rapidly increase markers of inflammation. In animal studies they seem to impair hippocampal function, which has negative effects on learning and memory. Human studies have shown that the typical Western diet can have negative effects on the brain within a week. So, we should try to think of sweets, refined cereals, fried food, fast food, processed meats and sugary drinks as 'extras' or 'fun foods' and limit their consumption.

In conclusion, your brain is hungry, and not only can you feed it, for the sake of children's brain development and adult mental health, it is imperative that you do.

Kimberley Wilson is a chartered psychologist, author and visiting lecturer, with a degree in nutrition. Her first book, *How To Build A Healthy Brain,* is available now.

Brain food

Fill your plate with these to keep your grey matter healthy



ILLUSTRATIONS: CHRISTINA KALLI

What is brain fog?

If you've ever felt muggy-headed, as if you can't concentrate or focus – perhaps you've been forgetful and accident-prone too – then you've experienced what is often termed 'brain fog'. Basically, it's a vague and colloquial term for when you feel scatter-brained and mentally impaired.

The term crops up a lot in medical research literature where it's used to capture the experiences of cognitive difficulties described by various patient groups, from people with chronic fatigue syndrome to patients undergoing chemotherapy (for whom it's sometimes dubbed 'chemobrain') to women transitioning to menopause. Recently, as you have likely heard, COVID-19 has also been blamed for causing brain fog, including in the context of 'long COVID' after the initial infection has actually passed.

Because 'brain fog' is such a catch-all term, it follows that there can be countless possible causes. For instance, there is speculation that the SARS-CoV-2 virus that causes COVID-19 might reach the brain and directly interfere with brain function. Similarly, there is tentative evidence that the drugs used in chemotherapy might have a direct, detrimental physical effect on the brain, thus contributing to brain fog.

To take the context of menopause, it's possible that hormonal changes could directly affect brain function. However, in all these contexts and others, it's also possible that there are emotional and social contributors to brain fog. For instance, it's telling that many people who have not been infected by coronavirus have nonetheless reported feeling more tired and distracted than usual during the pandemic, perhaps because of the stress and demands of lockdowns and homeworking.

Likewise, one of the main causes of chemobrain is thought to be the stress involved in coping with the illness and treatment. When it comes to menopause, too, there could be indirect contributors to brain fog, such as the effects of poor sleep or the general stresses of navigating a challenging phase of life.

In some situations, such as during pregnancy, the causes of brain fog could even be the mere expectation of mental impairment, fuelled by popular beliefs, rather than there being any underlying direct harmful effect of pregnancy on the brain, or indeed any objective impairment to cognitive function. In this sense, brain fog can be caused by a nocebo effect (a negative placebo effect).

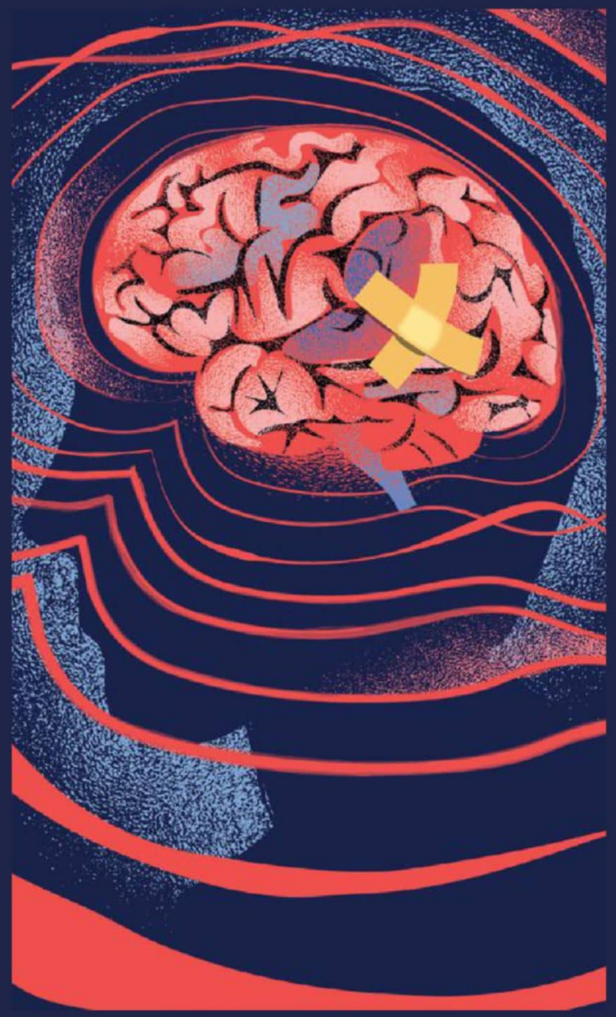
Where the causes of brain fog are due to direct, physically harmful influences on the brain, some of the most effective ways to cope will be compensatory, such as using digital reminders to help support your memory or making greater use of lists and other planning aids.

If you believe your brain fog might have more psychological or circumstantial causes – perhaps you've been feeling chronically overloaded by having to juggle work responsibilities with parenting, for instance – it might help to make an extra effort to impose some structure on your life, so that you're not constantly multi-tasking. Focusing on one challenge or responsibility at a time will help to clear the fog.

Similarly, basic lifestyle changes can improve your mental alertness, such as avoiding too much alcohol and fast food, practising good sleep hygiene (try to establish a regular bedtime routine and avoid working or drinking caffeine too late in the evening), and carving out sufficient time to relax and unwind – even a quick nap could help clear your mind.

As a general rule, when we're in a better mood, our mental performance tends to improve, in part due to feeling more energised and motivated. One implication of that is that anything you can do to improve your mood will likely have knock-on benefits for your mental alertness, from meeting a friend for a chat to taking a walk in the countryside. Indeed, exercise is a well-known mood-booster – aim for a moderate intensity that is fun but not overly arduous. Running, in particular, is a fantastic way to optimise your mental function and clear the fog. Martial artists also show heightened cognitive function compared with controls. Find what works for you, but any activity that you enjoy and that gets your heart pumping is likely to help clear that fuzzy-headed feeling.

Dr Christian Jarrett is a neuroscientist and deputy editor of *Psyche* magazine. His latest book is *Be Who You Want.*



Can the brain heal itself?

Some animals have incredible regenerative abilities, growing new legs and tails to replace lost ones. Fish and salamanders can even grow new brain cells to repair damaged portions of their brains. As mammals, though, our capacity for regeneration is more limited, particularly where the brain is concerned.

"Lower vertebrates keep on replacing neurons quite happily throughout their life, but mammals don't," explains James Fawcett, a neuroscientist at the University of Cambridge. "We stop making new neurons before birth, pretty much, except for one or two small parts of the nervous system."

This means that while we can repair a cut to our skin by growing new skin cells, we can't recover from a brain injury in the same way. Instead, our brain's only option is to work with the existing neurons – cells that carry all the information required for us to think, move and perform our normal bodily functions. If the odd brain cell goes offline here or there, it's not usually a problem, but the impact of a major brain injury depends on the type and site of injury, and how many neurons have been lost.

To some extent, what's left can be remodelled – the brain has what we call 'neuroplasticity'. Think of your brain as if it were Google Maps or another route planner. If one of the roads on the quickest route is being dug up, Google Maps will find you another route, even if it takes a bit longer. Similarly, because each brain cell has thousands of different connections, your brain is capable of some fairly extensive re-routing of its signalling, says Mark Ashley, CEO of the US-based Centre for Neuro Skills, which helps patients to recover from brain and spinal cord injuries. "We may lose a highway or two, or several highways, but theoretically, we could find other highways."

This means when the brain is injured, it can try to bypass the damaged cells by forming new connections between neurons in order to drive the lost functions.

Neuroplastic processes also occur when we're learning new skills, but with a major brain injury it can result in some dramatic remodelling, even to the extent of entire functions being transferred to different parts of the brain – hearing, for example, can be taken over by the visual cortex, and vice versa. Neuroplasticity relies on the nerve cells themselves, as well as support cells called glial cells that help make new connections and repair myelin, which is the protective covering around a nerve fibre that speeds up nerve impulses.

The nerve fibres (axons) that carry the signals do also have some capacity for sprouting new branches, when the main body of the nerve cell is still intact. As Fawcett explains, though, regeneration of nerve fibres that have been cut, as in a typical spinal cord injury, is restricted by the formation of scar tissue – which hinders regrowth – and normal changes during maturation that stop them regenerating their axons. "There's some genetic programme that goes with maturation that turns off regeneration," Fawcett says. His team of researchers have made some headway in regeneration of axons in the spinal cords of mice and rats, but the fibres are much longer and trickier to regrow in humans.

Rehabilitation programmes focus on getting the most out of the brain's natural neuroplasticity and could involve up to 17 hours per day of therapy – the more intensive the better, Ashley says, as this constant 'demand for function' encourages the brain to rebuild in order to respond. However, our understanding of the brain is limited enough that trying to predict how a patient will recover based on brain imaging can be futile. "I've adopted the notion that the early predictions of recovery are far more likely to be incorrect than correct," says Ashley, who adds that he's often "pleasantly surprised" by what's achievable, given access to the right treatment.

Hayley Bennett is a science writer based in Bristol.

ILLUSTRATIONS: CHRISTINA KALLI

Do we really have brain regions?

There's more than one way to carve up a human brain. We could draw lines based on what we see with the naked eye: your brain has two hemispheres, left and right. Or we could peer more deeply with a powerful microscope or sophisticated brain-imaging tools: your brain is a network of nearly 200 billion interconnected brain cells. About two-thirds of them, called neurons, continually talk to each other via electrical and chemical signals throughout the network. The other third, called glial cells, have multiple functions that scientists are still learning about.

We could examine a brain structurally. Neurons can be organised in layers, like in the cerebral cortex, which is traditionally divided into different lobes — frontal (at the front), occipital (at the back), temporal (roughly over your ears), and parietal (the rest). Neurons can also be organised into clumps, which scientists call nuclei, that sit beneath the cerebral cortex; for example, you might recognise the name 'amygdala', which is actually a cluster of 13 nuclei deep within each temporal lobe of your brain. We can also carve a brain up by looking at genetic material inside the brain cells, which reveals something about how your brain evolved and how it was assembled when you were a developing embryo.

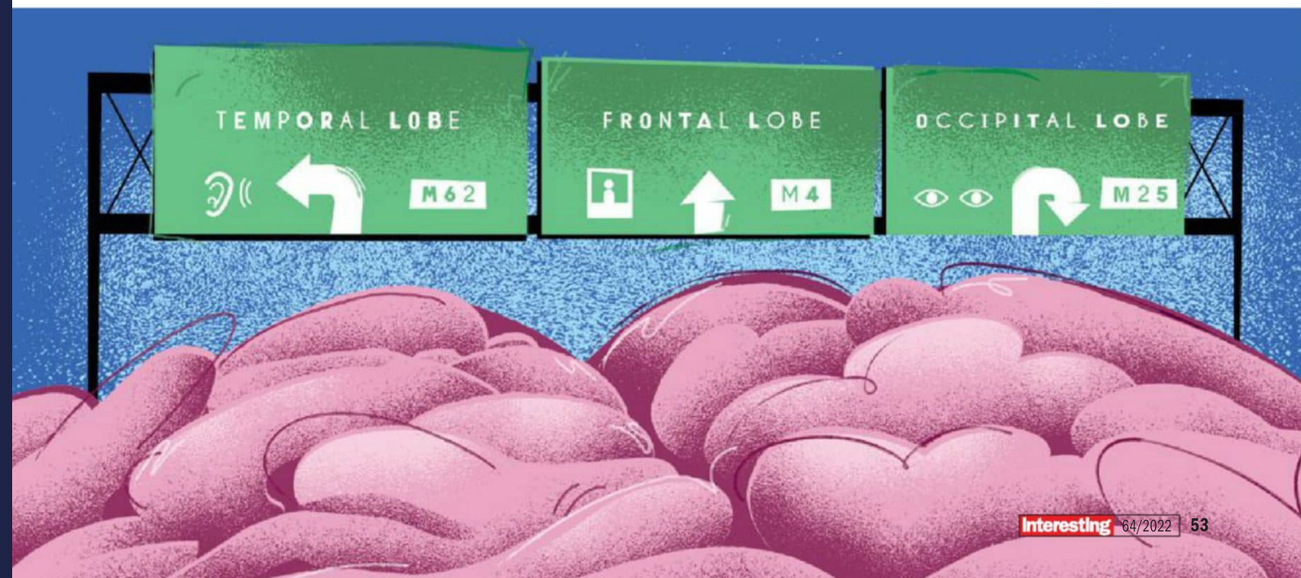
Another popular way to slice and dice the brain is by function. An obvious approach is to search for the bits of the brain that allow you to think thoughts, feel emotions, see and read these words, hear music, move your arms and legs, and do all the other things that make you who you are.

Thousands of studies reveal that this approach has not worked well, because these sorts of functional designations — such as cognition, emotion, perception, action, and so on — do not represent firm boundaries in the brain. The left side of your brain is not the source of logic, and the right side is not the wellspring of creativity. Rationality does not live in your cerebral cortex, and emotions are not lurking in an ancient beast within the subcortical parts of your brain. At this point, it's fairly safe to say that no psychological function lives in a single part of your brain. Most of your neurons do more than one thing, psychologically speaking. For example, the parts of your brain most associated with your ability to see, known as the visual cortex (in your occipital lobe), also carry information about hearing and touch. Likewise, some neurons outside of your visual cortex help you to see. Thoughts, emotions, perceptions, imagination, dreams and the rest are better viewed as whole-brain events.

Still, it's possible to carve up a brain by function, but in a different way, based on the information that neurons send and receive. For example, a part of your frontal lobe, called the anterior insula, routinely plays a role in making your emotions, deciding between options, paying attention to certain things and ignoring others, being aware of yourself, and a host of other mental events. Whatever these neurons are doing, they are always integrating sight, sound, smell, touch, taste, and all the sensations from inside your body, into multisensory summaries that allow your brain to regulate the systems of your body to keep you alive and well.

No matter which way you carve up a brain, it's important to realise that none of these organisations is 'true' in any absolute way. Each organisation is better or worse, depending on the goal you have in mind and what you want to explain. And no organisation alone tells the full story of how your brain, in constant conversation with your body and the world around you, creates your mind.

Dr Lisa Feldman Barrett is a professor of psychology at Northeastern University. Her latest book is *Seven And A Half Lessons About The Brain*.



What is intelligence and is it inherited?

Given how it's often discussed and described, particularly in the more brazen and annoying ads for puzzle-based app games, you'd be forgiven for assuming that intelligence is something well understood and easily measured, like your weight or height.

The truth is far more complicated, confusing, and even controversial. For one, while the dictionary definitions are fairly straightforward, describing intelligence as, for example, 'the ability to acquire and apply knowledge and skills', the scientific consensus on what intelligence actually is, regarding how it should be defined and assessed, is still disputed.

For a lot of recent scientific history, there was much debate as to how many intelligences the human brain possessed. As in, do we have one general intelligence that does everything, or several different types of intelligence that are used for more specific tasks? Like spatial intelligence, musical intelligence, linguistic intelligence, and so on.

Both models were the subject of much study. At present, evidence leans more in favour of us only having the one general intelligence, but as ever, the picture is more nuanced than that.

Distinctions can also be drawn between fluid and crystallised intelligence. The latter is the information you know and have access to, stored as memories in your brain. The former is your ability to use and apply information, whether derived from memory, or from what you're perceiving in the moment. A professional quizzer who wins contests thanks to their vast general knowledge is utilising impressive crystallised intelligence. Alternatively, Sherlock Holmes, who uses the information available from a crime scene, combines it with what he's got in his head, and applies it to a situation to work out solutions and explanations, is relying more on fluid intelligence. In a sense, crystallised and fluid intelligence are like your computer's hard drive and CPU, respectively.

Evidence suggests that crystallised intelligence keeps building up for as long as we've got a working brain, while fluid intelligence declines as we get older, as the complex but intricate parts of our brain that support it wear down over time.

While there is still much debate over what intelligence actually means, few dispute that your genes play an important part. This isn't to say that there is an established intelligence gene, which directly determines how smart you'll end up being. Our environment, upbringing, education and experiences all shape our adult intellect.

But even so, our genes clearly play a role. Exactly what this role is remains to be pinned down, but it's undeniable that intelligence has a hereditary component, meaning your eventual intelligence will skew towards that of your biological parents, even if you have a substantially different upbringing (by being adopted, for example). There's also the surreal link between height and intelligence, meaning tall people tend to be more intelligent on average.

Of course, one of the reasons it's hard to be specific or certain is because intelligence it so hard to pin down and measure. You might be surprised about this, because isn't that what we have IQ tests for? Technically yes, but the use and application of IQ tests has long been mired in controversy, given how no two scientists can seemingly 100 per cent agree on what intelligence actually is. And there have long been scandals and problems with IQ tests, largely because they're created by scientists who are prey to their own biases and prejudices.

Nobody is arguing that intelligence isn't a thing, it's just that there's a lot of debate around what sort of thing it is, how it works, how it's influenced, and how it should be measured. About the only thing anyone can agree on is this; IQ and intelligence definitely can't be determined by how well you do on a rudimentary puzzle game, no matter how many ads for apps insist otherwise.

Dr Dean Burnett Dean is a neuroscientist and author. His latest book is *Psycho-Logical*.

The best habits to keep your brain healthy, happy and sharp

If you've ever had the feeling that you aren't as sharp as you used to be, it might have given you pause for thought about your brain's fitness and whether it's all downhill from here. The brain typically finishes developing in our 20s, after which there is a gradual cognitive slowing with age. Later in life, there is also the risk of dementia, caused by diseases such as Alzheimer's. Inevitably, countries with ageing populations are now witnessing rising rates of dementia. Thankfully, cognitive slowing and dementia are influenced by what experts call 'modifiable risk factors'. In short, there are habits you can adopt to maintain your brain's sharpness and protect yourself from the risk of dementia.

Dr Christian Jarrett Christian is a neuroscientist and deputy editor of *Psyche* magazine. His latest book is *Be Who You Want*.

Be mentally active

Psychologists and gerontologists refer to a concept known as 'cognitive reserve', which is essentially your brain's ability to adapt in the face of ageing or illness. For instance, if a person has high cognitive reserve, then even if they show some of the biological markers of Alzheimer's (such as the clumps of protein that accumulate and harm brain function), it's possible they will still perform well on tests of their mental performance – it's as if they have spare mental capacity that allows them to cope with the damage.

Importantly, there are many activities you can adopt that are considered to build this precious attribute, such as reading, playing musical instruments or singing, completing puzzles, learning a second language and travelling.

Socialise

You will have seen the brain-training apps that purport to keep your grey matter sharp. The problem with these apps is you'll get better at the games, but you won't see your gains spill over into other aspects of your life. They might even be harmful if they divert you from socialising, which is the ultimate brain-training activity. As a team of researchers at the University of Groningen in the Netherlands put it in their recent comprehensive review of this topic, "People with less social participation, less frequent social contact and more feelings of loneliness have an increased risk to develop dementia." Seek out company and lively conversation when you can – it will give your brain a great workout and the feelings of belonging will be a boon for your mental health too.

ILLUSTRATIONS: CHRISTINA KALLI

Exercise often

Your brain depends on oxygen and other nutrients to function well and so it follows that the better your cardiovascular health, the fitter and healthier your brain will be too. At the same time, a sedentary lifestyle and obesity are both associated with speedier cognitive decline and an increased risk of dementia. So, try to build an active lifestyle into your routine.

Running, cycling, swimming or similar exercise classes will do the trick, but if that's not your thing, you could try regularly walking, or taking the stairs more often. You can even stay more active through gardening or frequently taking part in some other kind of hobby that gets your heart pumping, such as dancing or choir singing.

Eat healthily

It's good for your brain if you can sustain a healthy diet. Plenty of fruits and green vegetables will provide your body with ample antioxidants that help cleanse the brain of 'free radicals' – a kind of harmful by-product of various biological processes. To meet these goals, the World Health Organization recommends the so-called 'Mediterranean Diet', which is high in fruit, vegetables, legumes (such as lentils, beans and peas), nuts, cereals, fish and olive oil, while being low in saturated fats, sugary foods and meat. If that's all a bit too overwhelming, make a start by aiming to eat one more item of fruit a day and avoiding too many takeaways or supermarket ready meals. Read more about healthy eating for your brain on p50.

Stay curious

Perhaps surprisingly, there are links between personality and brain health. People who score higher in Openness to Experience (one of the so-called 'Big Five' traits that's associated with curiosity, creativity and a willingness to try out new things) tend to be sharper and at lower risk of dementia. As a team at the University of Georgia put it, "Higher Openness was related to better psychomotor speed, cognitive flexibility, and working memory in depressed and non-depressed older adults." There are habits you can adopt to boost your Openness to Experience, such as seeking out more awe (by taking walks in stunning surroundings or watching nature documentaries), travelling to unfamiliar places, and enjoying mind-expanding cultural experiences (such as live theatre).

Think positive

Once you've established the range of positive habits suggested here, you'll hopefully be feeling optimistic about your brain's future, especially as you get older. This is the final piece of the jigsaw because a growing amount of research suggests that your attitudes toward ageing can have real consequences for your neural health. If you expect to become slow and forgetful, that could well become a self-fulfilling prophecy. But if you realise that your brain health is to some extent in your own hands, and that's it's possible – with the right lifestyle and routines – to remain mentally agile through life, then that's likely to benefit your brain. So, seek out positive older role models if you can, and seize the chance to train your brain like a muscle – you may yet unlock your full potential.

Are people in comas conscious?

In July 2005, Carol was hit by two cars while crossing a busy road. She survived, but suffered a massive brain injury, which left her in a vegetative state with little hope of meaningful recovery. Carol's life would never be the same again. Two cars and a moment's distraction had redefined the rest of her existence; a shocking reminder of how vulnerable we are, and how the trajectory of our lives can change in an instant.

The vegetative state is often described as 'wakefulness without awareness'. These patients open their eyes and will often have sleeping and waking cycles, although they remain non-responsive to any form of external prompting or stimulation. They are both 'there' and 'not there', lingering in the indeterminate space between life and death. For decades, it was assumed that such patients lack any awareness, including who they are, where they are, and the predicament they are in.

Several months after her accident, we put Carol into a fMRI scanner at Addenbrooke's Hospital, Cambridge, and asked her to imagine waving her arms in the air, as if she was playing a vigorous game of tennis. Amazingly, a part of her brain known as the premotor cortex 'lit up' in exactly the same way as it does in healthy people, when asked to imagine the same series of actions in the scanner. This startling result told us that Carol must have understood the instructions and, furthermore, she had been able to turn them into a response; not a physical response, like squeezing a hand or blinking an eye, but a conscious brain response that confirmed beyond doubt that Carol was not vegetative at all, but conscious and aware, even though she had been physically non-responsive for more than five months.

After a few more years of scientific tinkering, we took the technique one stage further and successfully communicated with a young man called Scott who had been apparently vegetative for 12 years following a near-fatal collision with a police car. By changing his pattern of brain activity in the scanner to indicate a 'yes' or a 'no', Scott was able to tell us that he knew where he was, how long he'd been there, what he enjoyed watching on TV, and whether or not he was in any pain (he wasn't). Nevertheless, at the bedside, Scott remained non-responsive whenever he was examined by his doctors and care staff.

By 2016, more than 1,000 patients around the world had been scanned using variations on the brain-imaging technique we had developed, and an independent scientific review concluded that between 20 and 25% of them were like Carol and Scott; conscious and aware, despite their outward appearance, trapped in their immobile bodies, listening silently to every conversation at their bedside, and every decision that had ever been made on their behalf. While no one knows exactly how many vegetative-state patients there are in the world (in the United States, it has been estimated that there are between 15,000 and 40,000), these figures confirm that hundreds of thousands of them may not be what they appear to be at all.

Despite this astonishing series of discoveries, the various regulatory bodies that determine whether the findings will be used to benefit the lives of all patients with 'disorders of consciousness', like the vegetative state, continue to drag their feet. Earlier this year, the Royal College of Physicians revised the UK guidelines on the management of these patients, stating that "once a patient is in a prolonged disorder of consciousness … repeat imaging is not routinely required".

For too many years, patients who are diagnosed as being in a vegetative state have been warehoused – an unfortunate term that is frequently used to describe how they are often 'written off', denied the expertise of professionals who can carefully assess their mental functioning over time and spot subtle signs of emerging awareness. Yet we now know that many of these patients have been completely conscious all along. This thought still makes me immensely uncomfortable.

To fail to test for consciousness using technologies like fMRI is to deprive tens of thousands of brain-injured patients worldwide of an important benefit: the opportunity to make themselves heard, to communicate with their clinical team and their relatives, and to contribute to decisions about life-preserving treatment, rehabilitation and other interventions. By failing to make these scans available, we abandon them. They are voiceless, yet we have created technologies that can give them a voice. It is high time we allow them access to these technologies so they might once again take their place among us in the land of the living. ■

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Dr Adrian M Owen
Adrian is a British neuroscientist working in Canada. He is the author of *Into The Grey Zone: A Neuroscientist Explores The Border Between Life And Death.*

ILLUSTRATIONS: CHRISTINA KALLI

More chocolate! More tea!

Flavonoids, which are found in foods like chocolate, berries and tea, play a key role in heart health

A diet rich in flavonoid compounds is linked to lower blood pressure, according to a new study. The association is partly explained by an improved gut microbiome. Flavonoids are compounds found in plants. Foods rich in flavonoids include vegetables, fruits such as apples, pears and berries, and chocolate, tea and wine. In the body, they act as antioxidants, and prevent damage to cells. They are broken down by the gut microbiome.

"Our gut microbiome plays a key role in metabolising flavonoids to enhance their cardioprotective effects, and this study provides evidence to suggest these blood-pressure-lowering effects are achievable with simple changes to the daily diet," said Prof Aedín Cassidy at Queen's University in Belfast, Northern Ireland, lead investigator of the study.

The World Health Organization lists cardiovascular disease (CVD) as the leading cause of death worldwide in 2019. Previous research has reported differences in the composition of the gut microbiome between those with and without CVD, and that flavonoids may reduce the risk of heart disease.

The team of researchers, based at Queen's University and Kiel University, Germany, examined the link between eating flavonoids, blood pressure, and the gut microbiome. They studied 904 adults from Germany's PopGen biobank, 57% of whom were men, and asked them to evaluate their food intake with a self-reported questionnaire. The team also analysed their gut microbiome through bacterial DNA in stool samples and measured their blood pressure. In addition, the researchers asked the participants about several other factors, including BMI, family history of CVD, physical activity and medication use. After taking all of these into account, they found that those with the highest intake of flavonoids had lower blood pressure and a greater diversity in their gut microbiome.

Eating 1.6 servings of berries a day reduced systolic blood pressure by 4.1mmHg, while 2.8 glasses of red wine per week brought a reduction of 3.7mmHg. The team found that up to 15.2% of the reduction in blood pressure could be explained by the increased gut microbiome diversity.

Five ways to improve your gut microbiome

Increase your fibre intake
Aim for more than 40g per day – about double what the average person consumes. Wholegrains, pulses and veg are good sources.

Eat a wide variety of fruit and veg
Variety is important, as the chemicals and types of fibre will be different, and each supports different microbial species.

Choose food and drinks with high levels of polyphenols
Polyphenols are fuel for microbes. Nuts, seeds, berries, olive oil, coffee and tea are good sources.

Avoid artificial sweeteners such as aspartame
These disrupt the metabolism of microbes and reduce gut diversity.

Stroke animals
Studies have shown that people living with dogs have more microbial diversity.

GETTY IMAGES X4, ALAMY X2, HISTORICAL BIOLOGY

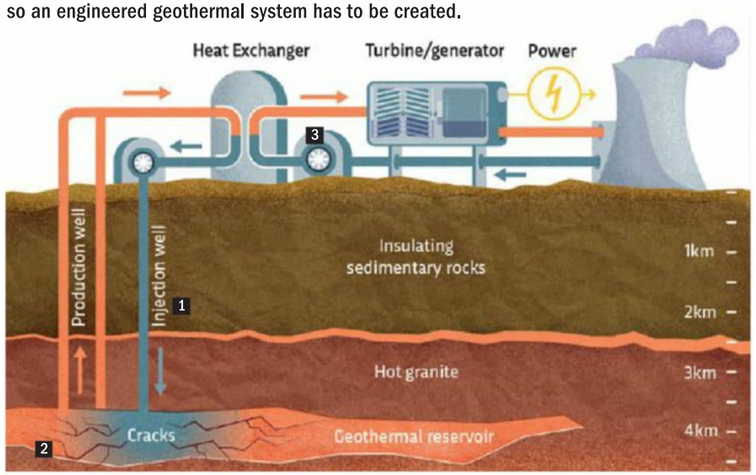
Q&A
Questions & Answers

Got questions you've been carrying around for years? *Very Interesting* answers them! Mail your questions to VI@panorama.co.za

How does geothermal energy produce electricity?

Helen Madsen, Pietermaritzburg

In volcanic regions, reservoirs of hot underground water will rise up a borehole under their own pressure and turn into steam to drive a turbine at the surface. But in most of the world, the rocks within reach of drilling equipment are dry, impermeable rocks such as granite, so an engineered geothermal system has to be created.



1 COLD WATER PUMPED IN
Cold water is pumped at high pressure into an injection well. The water forces natural cracks in the strata to expand, allowing the water to seep sideways through the hot rock. This is similar to the fracking process used for oil and gas extraction, but doesn't require harmful solvents.

2 HOT WATER EXTRACTED
Several 'production wells' are also drilled nearby to allow the heated water to flow back out of the rock. Drilling these wells involves a certain amount of luck, because they must hit one of the fissures – typically less than 5cm wide – in order to extract the water. Modern geo-imaging technology has improved the hit rate to as high as 80%, compared with only 25% a few years ago.

3 ELECTRICITY GENERATED
At the surface, the hot water is passed through a heat exchanger to boil a secondary fluid, such as butane, which creates high-pressure gas to drive a turbine, generating electricity. The cooled water is pumped back into the rock strata in a closed loop.

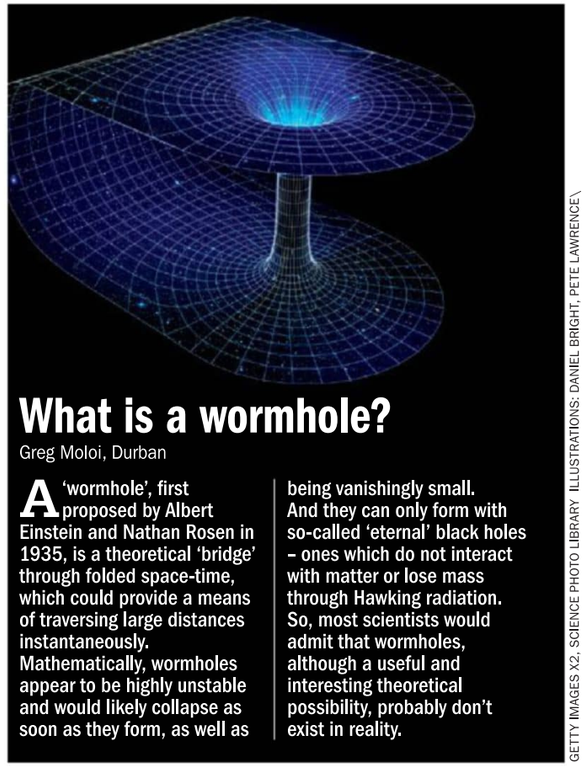
Are you more likely to get chest infections if you don't have tonsils?

Sally Schutte, Johannesburg

In 2018, a large study hit the press that looked at over one million Danish children, and found that there was a link between removal of the tonsils in childhood and contracting upper respiratory tract infections as an adult. This is a tricky one, because association does not mean causation. In other words, did those children have an underlying issue with their immunity that meant they might have got more infections later anyway?
In any case, we shouldn't be operating unless we really need to, but that's always been the case – there are clear guidelines outlining when severity is bad enough to warrant surgery, and the benefits are likely to outweigh the risks.

Q&A FLASH

- **Tonsils were once removed in a (ludicrous) attempt to stem bed-wetting.**
- **Frog fat used to be used as a treatment for swollen tonsils.**



What is a wormhole?

Greg Moloi, Durban

A 'wormhole', first proposed by Albert Einstein and Nathan Rosen in 1935, is a theoretical 'bridge' through folded space-time, which could provide a means of traversing large distances instantaneously. Mathematically, wormholes appear to be highly unstable and would likely collapse as soon as they form, as well as being vanishingly small. And they can only form with so-called 'eternal' black holes – ones which do not interact with matter or lose mass through Hawking radiation. So, most scientists would admit that wormholes, although a useful and interesting theoretical possibility, probably don't exist in reality.

GETTY IMAGES X2, SCIENCE PHOTO LIBRARY ILLUSTRATIONS: DANIEL BRIGHT, PETE LAWRENCE\

Are electric cars definitely greener than petrol?

Ann Gable, Kyalami

At first glance, electric cars can seem like the perfect antidote to petrol and diesel vehicles, whose fumes choke up towns and cities with air pollution. But they can still have detrimental effects on the environment.
As far as greenhouse gas emissions are concerned, electric cars are only as green as the energy used to manufacture them and to charge their batteries. However, a recent study by the International Council on Clean Transportation concluded that over their lifetime (including manufacture), electric vehicles are responsible for fewer greenhouse gas emissions than their petrol counterparts. But this difference was far greater in some places than others.
In Europe, an electric car generates up to 69% less CO^2 equivalent per kilometre than a petrol car. However, in India this figure is 34%. The disparity comes down to how electricity is sourced in each country. One of the lowest-carbon places in the world to charge an electric car is France, where only 9% electricity comes from burning fossil fuels. But many countries still produce most of their electricity from coal, oil and gas, so plugging in an electric car in China or India can indirectly generate a large quantity of greenhouse gases.
Electric vehicles' lithium-ion batteries can be an environmental hazard if disposed of carelessly, although they are considerably less toxic than traditional lead-acid car batteries. Unlike lead-acid batteries, lithium-ion batteries are tricky to recycle and liable to explode if disassembled incorrectly. Currently only 5% are recycled. Many car manufacturers, such as Tesla, are stepping up their recycling programmes, but it remains to be seen if they will be able to cope with skyrocketing demand as the electric vehicles on the road today reach the end of their lifespan.

Is it healthier to eke out a box of chocolates, or eat them all in one massive binge?

Paul Marney, Randburg

If healthy people binge for one day, the body will work a bit harder to deal with the calories and it is unlikely to cause weight gain. Making chocolates last a bit longer may be more damaging to the waistline, but there are positive aspects to daily chocolate consumption. Perhaps unsurprisingly, a Nestlé study of 90 Dutch people in 2012 suggested that eating chocolate every day may reduce anxiety levels. A number of studies point to potential health benefits of regularly eating small amounts of dark chocolate, including lower blood pressure and cholesterol levels. So, consider asking for dark chocolates and eke them out.

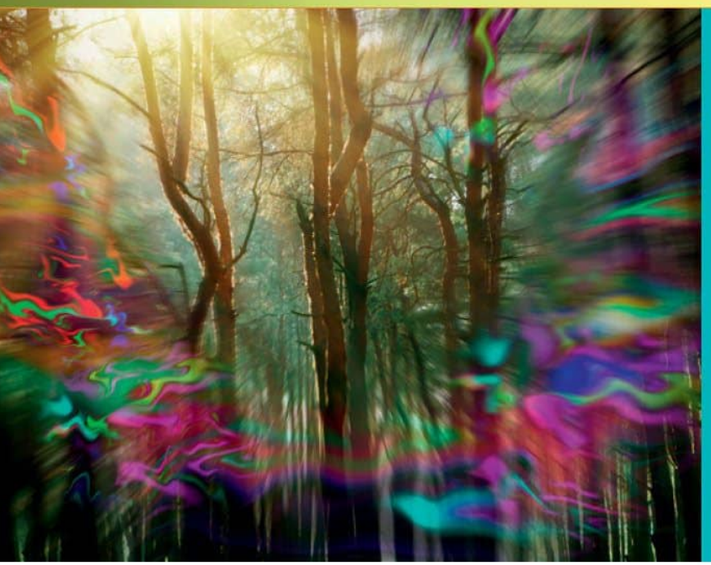
BEARING WITH A SORE HEAD

What hurts in your skull – and why

TEXT: DR KATY MUNRO

What's the difference between a headache and a migraine?

A headache is a neurological symptom, and the underlying cause needs to be established. A migraine is a genetic, neurological condition often causing headaches, but is also associated with many other symptoms including heightened sensitivity to light, sound, movement and smells, as well as dizziness, brain fog, abdominal pain, speech difficulties, visual disturbances, nausea, vomiting, fatigue and irritability. But this list is not exhaustive. Migraine is a spectrum condition, so some people have infrequent, mild attacks, while others have more severe, frequent episodes. Some suffer daily impact from the effects of migraine on their brain.



What happens during a migraine?

During migraine attacks, neurochemicals trigger a wave of electrical depolarisation at cell surfaces, known as 'cortical spreading depression', which spreads out over the brain. The effects of neurochemical disturbances may vary from person to person, from attack to attack, and throughout a person's life.

'Aura' are neurological disturbances during the hour before the headache hits and affect about a third of sufferers. Aura are often visual with zigzag lines, flashing lights, blurred vision or blind spots. In the next phase, symptoms such as headache, brain fog and fatigue can occur.

Cognitive problems are common. The vagus nerve, which runs from the brain to the gut, is also affected. This slows down the emptying of the stomach, which can lead to nausea and sometimes vomiting, and delays absorption of helpful medications and may prolong attacks.

Pain during a migraine attack may be felt anywhere on the head, neck or shoulders. Abdominal pain is common in children.

SHUTTERSTOCK, SCIENCE PHOTO LIBRARY, GETTY IMAGES X2

How can you manage a migraine?

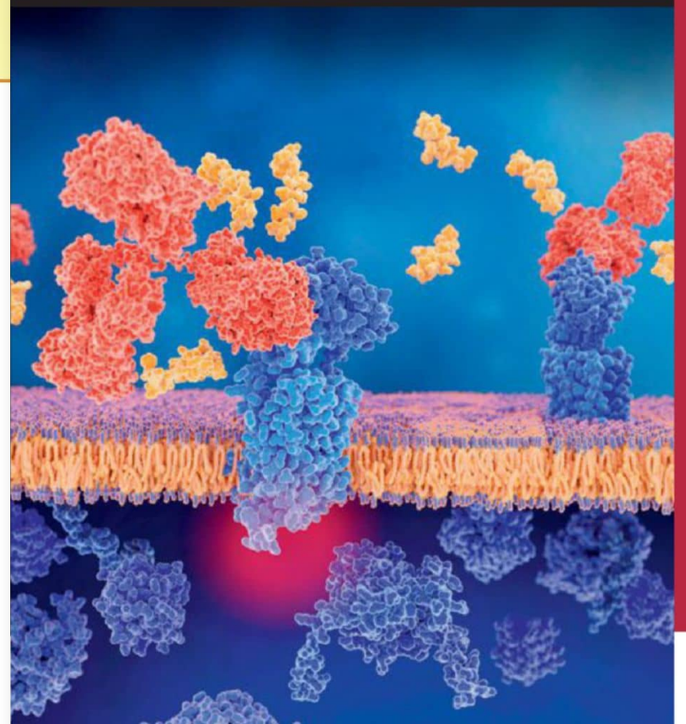
People hunt for that one thing they can do to stop attacks. They eliminate certain foods, stop caffeine and alcohol, searching for the key to switch off attacks. Sadly, it is not that simple. But you can try to keep track of what changes in the 48 hours before an attack. Using a simple headache diary may help identify some things to control in future and limit attack impact.

Diagnosis is on the history of symptoms. A migraine family history helps confirm the diagnosis, but is not essential and often unknown for various reasons.

Effective treatment requires the right medication in the right place at the right time. When a migraine attack starts to roll, it gathers momentum, much like a snowball rolling down a mountain. Treating early is crucial, and discussing with a GP or headache specialist which combination of medications will suit you is so important.

Often, a simple anti-nausea medication with a painkiller will help if taken early enough, but it may be necessary to add in migraine-specific medications called triptans. There are seven currently available. If one does not suit you, try a different one. The effect of each varies from person to person. These should not be taken on more than 10 days in a month, as overuse of acute migraine medication aggravates the brain. Avoid codeine and opiates, which can quickly worsen migraine.

If you get more than about five attacks per month, explore preventive methods. There are many available, including supplements, medications, neuromodulation devices and injections. The newest are anti-calcitonin gene-related peptide (CGRP) self-administered injections. CGRP is a pain neurochemical implicated in triggering attacks in some people. These monoclonal antibody injections block either CGRP neuropeptides, or receptors on cells. They can be extremely effective in reducing migraine attacks.



What causes migraine attacks?

Migraine genes set the brain to be less able to process sensory inputs and make the brain vulnerable to attacks. But that is not the whole story. Epigenetics, the interaction of genes with our behaviours and environment, is important too. The more the brain is challenged by these stimuli, the more pain neurochemicals are produced. Migraine threshold theory suggests that combinations of changes irritate the brain and trigger attacks once pain neurochemicals reach a certain level.

'Change' is a key word. The migraine brain is more sensitive to internal body changes, such as blood sugar levels, sleep routines, hormones or stress, and external environmental factors – light glare, strong visual patterns like stripes, stuffy air quality, and even weather.

Some things seem to be particularly likely to lead to attacks. Skipping meals leading to fluctuating blood glucose levels is one. Regular snacking may help. People with migraine are often sensitive to carbohydrates though, so low GI foods are preferable. Broken or extended sleep can aggravate attacks – this is especially hard for teenagers, who wake early for school but then lie in at weekends.

Hormones play a major role. Many teenagers have worsening attacks during the turbulent hormonal times of puberty, with growth spurts and menstrual cycles contributing. Many women find they have more attacks with their period and during perimenopause. Oestrogen levels change erratically before periods stop completely and often for some years afterwards.

Any type of change can lead to attacks worsening – a new job, moving house, travelling abroad. But so can stress reduction. 'Let-down' or weekend migraine attacks are commonly described – frustrating for people relaxing after a stressful time. ■

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Dr Katy Munro is a GP headache specialist at the National Migraine Centre in the UK. She hosts the podcast *Heads Up*, and is the author of *Managing Your Migraine*.

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PALATES AND PERAMBULATIONS

Outside of the major resorts, there are a myriad activities worth investing in for a day out in Mauritius

TEXT AND PHOTOGRAPHY: BRUCE DENNILL

Market value

Port Louis, the Mauritian capital, is well worth a visit, with the shopping options useful for any visitor looking for a souvenir or gift and new additions to the infrastructure – aquariums, museums and more – adding texture and interest for tourists with different tastes.

The Central Market bustles with activity and radiates a rainbow of colours. There's not a great deal of range in the stall offerings, with fruit and vegetables taking up most of one half of the space and crafts, curios, clothing and accessories (handbags and the like) the other. If you've been before, you'll be able to save yourself the hassle of haggling with every single trader by making a beeline for wherever your favourite locally grown vanilla tea or other destination-specific treat is on sale. The confidence you'll display as a result may be enough to stop endless re-tellings of the same story about 'the best deal ever'.

Eat and walk

If you've built up a hunger while beginning your sightseeing, consider combining furthering both agendas with a food tour of the city – Taste Buddies offer a great option. The concept is excellent value for money, as the tour includes a guided walking tour around town, taking in Port Louis' history, architecture and culture, as well as inside knowledge of what's good to eat, with options cherry-picked from the cosmopolitan local communities.

We begin with a delicious vegetarian *roti* at the Company Gardens, watched by an unbothered fruit bat hanging off the banister of the bandstand adjacent to where we sit. Up the road, in a shaded property reached through a non-descript door you'd have otherwise completely ignored, there's a tasty dessert – the guide likes to alternate between savoury and sweet – in the signature banana tarts from a highly regarded patisserie.

We continue to a similarly concealed food trailer for *dholl puri* – light pancakes with red lentil paste – enjoying the dish in a tiny courtyard between houses and leaning forward to avoid having the crimson sauce drip on clean T-shirts. By now, we've wandered back towards the market, where we refuel with a freshly squeezed sugar cane cocktail. Throw in lime and coconut water, and it's hugely refreshing.

The tour ends in Chinatown, where the walls are filled with bright, vibrant street art and plastic bottles recycled into dozens of sculptures, including rooftop dragons extending over multiple buildings. Try *boulettes* – a kind of *dim sum* made with rice and available in a number of earthy flavours. Or if you have a sweet tooth, wait for the chance to try *gato zinzli:* rice flour and sweet potato with a filling of black lentil paste and an outer coating of sesame seeds.

Food, exercise and a multi-faceted cultural experience. Time well spent.

Inaction displaced

There's more of that (minus the exercise) at the magnificent Eureka House in the nearby village of Moka, in the shadow of the striking Le Pouce mountain – that name pronounced in a way that will never, ever fail to make a South African smirk…

Eureka House is a Creole mansion built in 1830 and occupied over the years by generations of a couple of well-to-do colonial families, the last of which had to move out because there wasn't enough space for the 17 children and more than 100 grandkids – in a house with 109 doors and windows! Incidentally, when the family *did* live there, they split the top floor of the building into a dormitory for all the younger relatives – girls on one side, boys on the other, and a small room for a no doubt overworked nanny in the centre.

The staff stage a food preparation demo in the front garden, with different teams creating side dishes using time-honoured Mauritian recipes. It's an interactive experience – chopping, mixing and peeling as a bowl of pumpkin mash with ginger starts to take shape – that has its pay-off when you sit down for an indulgent lunch on the house's main verandah and are served your own handiwork as part of the spread.

Walk off that excess with a short hike to the gorge at the bottom of the main garden, where multiple waterfalls and dense foliage make it almost unbelievable that you're close to the island's main city. Also leave time for a guided walk around the interior of Eureka, a museum often used as a film set. The huge rooms, decorated with grand pianos, antique furniture and historic imported artefacts, all abut each other with no central corridor, which must make for some fantastic single-take shots. Especially now that there are not entire squadrons of children bombing around. ■

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For more information, go to facebook.com/za.mauritius, veranda-resorts.com, tastebuddies.mu and eureka-house.com.

TASTE AND SEE

According to restaurants.mu, a major Mauritian restaurant guide, the 10 most popular Mauritian meals are:

1 **Bol renversé:** A rice-based dish similar to chop suey, topped with a fried egg.
2 **Boulettes:** Not unlike *dim sum*, and made with fish, meat or tofu.
3 **Briyani:** Basmati rice, herbs and spices, plus potatoes and beef, chicken or seafood.
4 **Dholl puri and roti:** Flatbreads with various fillings, available at street vendors everywhere.
5 **Gateaux piment:** Chilli cakes made with split peas, spring onions and green chillies.
6 **Mine frite:** Fried noodles with vegetables and chicken or shrimp.
7 **Riz frite:** The same as above, but with fried rice instead of noodles.
8 **Sept cari:** Seven different kinds of vegetable curry, served with fried flatbread.
9 **Rougaille:** A tomato-based sauce with garlic, onions, chillies, thyme and coriander.
10 **Vindaye:** Something like an Indian vindaloo with fish or octopus chunks.

THE MEANING OF $E=mc^2$

Einstein's most famous legacy shows just how much potential there is, should we figure out a way to convert matter completely into energy

TEXT: JOS GRAINDOR

Einstein's famous formula $E=mc^2$ is well known to most people interested in science, but its meaning and extent are not often understood. What it really means is that energy equals mass. As c^2 is merely a constant, we could write E=m or m=E. To understand the consequences of this statement, we need to understand a few basic principles.

Scientific notation

To write large numbers out in full would be difficult: 2 billion would be written as 2,000,000,000 and this is still a very small number on the scale of the universe. It might be easier to say: a 2 followed by 9 zeros. But that is not scientific. To make it easy to use in calculations, this is therefore written as 2×10^9 or to shorten it as 2.10^9.

Units in Einstein's formula

- 'E' symbolises energy. It is expressed in Joules and in WattSecond, so that 1 Joule [J] = 1 WattSecond [Ws]. Before rationalisation of the metric system, it was expressed in calories, usually kilocalories [kcal]. Take a stove plate of 1kW (1,000 Watt). If it is not switched on, it consumes no energy. If it is switched on for one second, it consumes 1kWs and, if it burns for one hour, it consumes the energy of 1kWh (1,000 Watts during one hour).
- 'm' is mass, so 1g or 1kg.
- 'c' is the speed of light = 299,792,458m/s

Calculation of energy in matter

- c = 299,792,458m/s ≈ 300,000,000m/s = 3.108m/s

This is merely a conversion of the speed of light into scientific notation. Now, let us try to calculate how much energy is present in 1kg of matter.

Applying the formula $E=mc^2$ with m=1 and c=3.108 we get:

$E = 1 \times (3.10^8)^2 = 9.10^{16}$ Ws or J

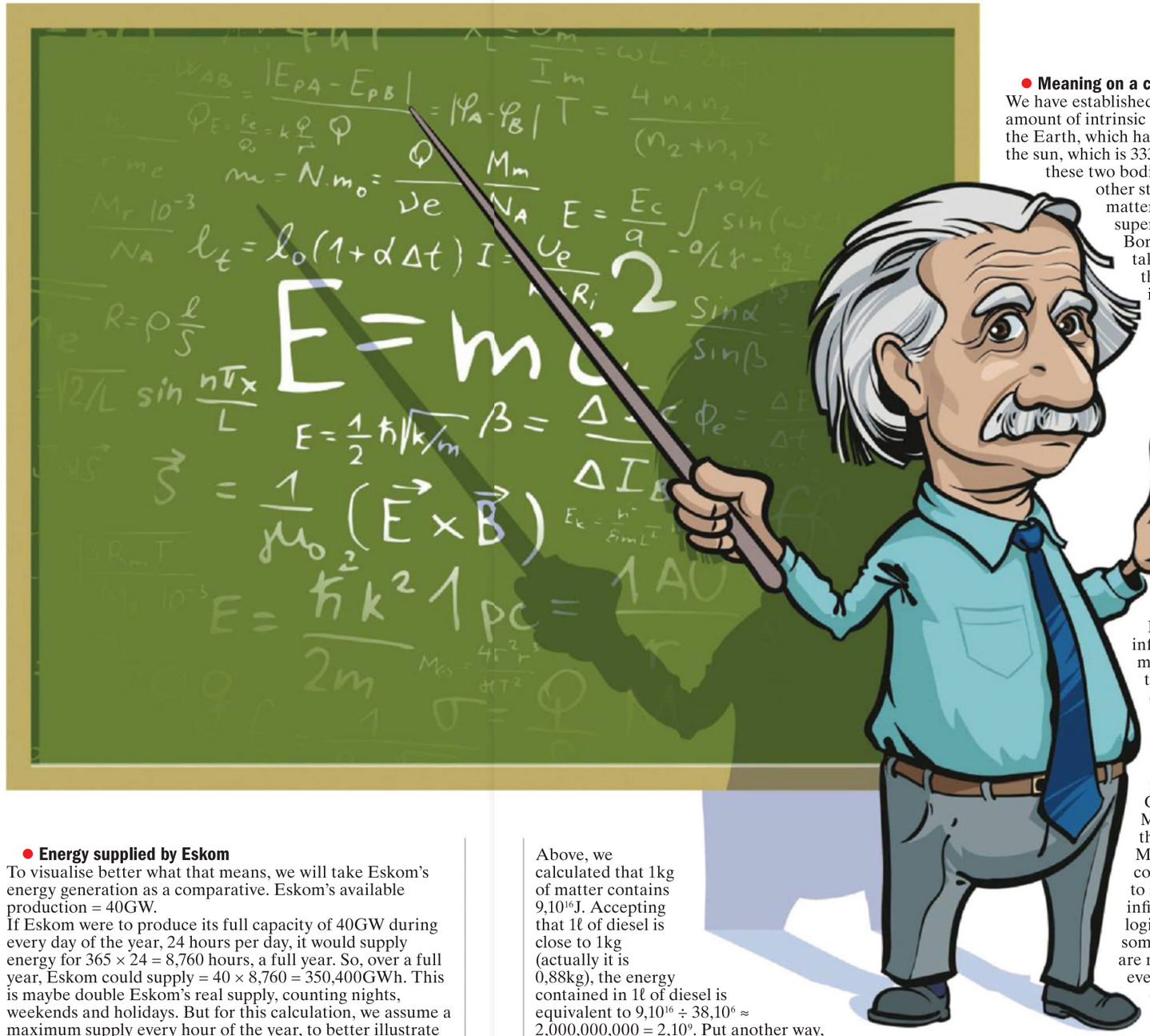
$= 9.10^{13}$kWs (divide by 1,000 as k = kilo = 1,000)

$= 25.10^9$kWh (divide by 3,600 as there are 3,600 seconds in an hour)

$= 25.10^6$MWh (divide by 1,000 as M = Mega = 1,000k)

$= 25.10^3 = 25.000$GWh (divide by 1,000 as G = Giga = 1,000M)

This can be called the intrinsic energy of matter: 25.10^3GWh per kilogram of matter.



Energy supplied by Eskom

To visualise better what that means, we will take Eskom's energy generation as a comparative. Eskom's available production = 40GW.

If Eskom were to produce its full capacity of 40GW during every day of the year, 24 hours per day, it would supply energy for 365 × 24 = 8,760 hours, a full year. So, over a full year, Eskom could supply = 40 × 8,760 = 350,400GWh. This is maybe double Eskom's real supply, counting nights, weekends and holidays. But for this calculation, we assume a maximum supply every hour of the year, to better illustrate the enormous energy contained in matter.

Above, we calculated that 1kg of matter contains 25,000GWh. Thus, matter needed for 350,400GWh = 350,400 ÷ 25,000 = 14kg. Thus: converting 14kg of matter into energy would provide the whole of South Africa with electrical energy for a full year.

Matter needed to run a car

One litre of diesel contains $38,10^6$ Joules of chemical energy. This is merely a scientific fact. If you burn 1ℓ of diesel, you will have generated $38,10^6$J of energy.

Above, we calculated that 1kg of matter contains $9,10^{16}$J. Accepting that 1ℓ of diesel is close to 1kg (actually it is 0,88kg), the energy contained in 1ℓ of diesel is equivalent to $9,10^{16} \div 38,10^6 \approx 2,000,000,000 = 2,10^9$. Put another way, this means that the intrinsic energy of 1ℓ of diesel is equivalent to the chemical energy of two billion litres of diesel.

Car consumption in a car's lifetime can also be worked out. Assuming a lifetime of 10 years, driving 40,000km/year at 10ℓ per 100 km: 10 years × 40,000km/year ÷ 10km per litre = $40,000 = 4,10^4$ℓ of fuel. Thus, the matter needed for the car's lifetime = $4,10^4 \div 2,10^9 = 0,02$g = 20mg.

So, if we could make a cell that can convert matter completely into energy, we would use only 20mg of matter during the total expected lifetime of a car!

Meaning on a cosmic scale

We have established that matter contains an enormous amount of intrinsic energy. Just imagine how much energy the Earth, which has a mass of 6.10^{24} kg, would contain, or the sun, which is 333,000 times larger than the Earth. Yet, these two bodies are miniscule in comparison with other stars, dust clouds, galaxies, clusters and all matter of the universe. The biggest supercluster known is the Hercules-Corona Borealis Great Wall. It's so big that light takes about 10 billion years to move across the structure. Can you imagine how much intrinsic energy such a massive body contains? If you were to calculate the energy that the total mass of the visible universe represents, it would be so large that it would come close to infinity. But that visible mass is only about 5% of the total universe. The other 95% consists of dark matter and dark energy, which are difficult to define or to measure. If we include it all together, maybe the energy the universe contains is indeed infinite.

The Big Bang

We have a clear picture of the intrinsic energy of the measurable universe, plus dark matter, plus dark energy. This amount is close to infinity. But scientists do not like to work with infinity. It makes their formulas meaningless and results undefined. For that reason, tricks are applied to circumvent these infinities. This is called 'renormalisation'. These tricks consist of simplifications, rounding off of results and omitting troublesome extremes. But avoiding infinities does not mean that infinities do not exist. Clearly, we do not know everything. Maybe, there are other kinds of energy that supplement the known energy. Maybe, that final unknown form of energy complements the known energy sufficiently to state that the sum of all energy is indeed infinite. And that is a necessity for the logics of the classic question: Why is there something, rather than nothing? Maybe, we are now entering the field of philosophy and even of religion, but to accept that there is only a finite amount of energy would immediately generate the question: why that specific amount of energy? How did that specific amount of energy come into existence? If there is an infinite amount of energy, then it is easy to conclude: it is what it is! That is saying nothing and that is saying everything. The Big Bang is then a conversion of part of that infinite energy into matter. And that matter probably converts back into energy as part of the constant fluctuations of all there is in the universe. ■

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Jos Graindor is a retired engineer in electronics.

FAME AND FADS

Why are famous stars so drawn to the allure of questionable health products and trends?

TEXT: DEAN BURNETT

In 2019, Josh Brolin, celebrated actor and star of the Marvel Cinematic Universe, ended up with a sunburnt anus.

This unlikely but true sentence was made possible by the bizarre wellness fad of 'perineum sunning' (exposing the patch of skin between the anus and genitals to direct sunlight). It's just one of the countless wellness fads, fashionable diets, and questionable products and procedures that claim to improve your health and appearance that are everywhere in our modern world. Others include 'vampire facials' (injecting your own purified blood into your face), coffee enemas (self-explanatory) and the treasure trove of dubiousness that is Gwyneth Paltrow's Goop company. Such fads and practices often make grand claims about the health benefits they offer, but seldom offer any robust evidence for them.

And yet, despite all this, they persist. If anything, they're more popular than ever. It's a bleakly regular occurrence for an A-list actor, high-profile celebrity or now even Instagram influencer to claim that they've discovered some new way to improve health and wellness, or restore lost youth. And, despite it typically being extremely unscientific, ridiculous, embarrassing, even actively harmful, and the person advocating it having no medical training or expertise whatsoever, countless people embrace it – as if it were the elixir of life and the fountain of eternal youth combined.

This persistent phenomenon of celebrities having more influence over how people understand health and wellbeing than most doctors may seem nonsensical, and in many ways it is exactly that, but it's also likely inevitable. There are numerous fundamental properties of our brains that mean celebrity wellness fads are likely to be around for many years to come.

First, the human body is incredibly complex. Doctors have to train for nearly a decade to get to the point where they can competently intervene and improve people's health, and even then, there's a lot they don't know. Your average non-medical person will have nowhere near this degree of insight and understanding, so wouldn't necessarily be able to accurately differentiate between helpful health interventions and pseudoscientific fashionable nonsense, particularly when the latter is presented uncritically by 'official' media sources, which they regularly are.

There's also the way the human brain instinctively prefers options that provide the biggest reward for the least effort. Constant exercise, healthy diets, or powerful medications? These are hard work, and/or unpleasant. So, if someone tells you that there's a way to make you healthier that involves less work than the usual methods, a lot of people will subconsciously want to believe it's true and be motivated to try it out.

The fact that such wellness fads are blatant nonsense is less important than you'd think. Or hope. Once we've decided to do something, our brains are often reluctant to change course or question our choices, even when there's ample evidence that contradicts them.

Granted, many health fads seem far-fetched – even embarrassing. Indeed, many involve inserting weird things on or into our more intimate regions. Shouldn't that put people off? Maybe it does in many cases. But for others, it might make it more convincing.

"Why have I not encountered this before? Oh, because it involves putting things up one's [insert orifice of choice], and people are too squeamish. Well, not me!" It may seem a bit much, but our brains are often fine with carrying out such mental gymnastics.

Why is it always celebrities who champion these fads? Because such individuals are popular, admired, and even worshipped. Celebrity endorsements are a long-established tool of marketing and advertising.

It's important to remember that, for much of our evolutionary history, our main source of information was other humans. This is why, as much as scientific and rationalist types may object, anecdotal evidence is still persuasive, particularly when it's from someone who is 'higher status'. We're inclined to do what they do, own what they own, to make ourselves seem higher status as a result. This is why endorsements work.

We're also more inclined to trust those we're emotionally connected to. While doctors and scientists have rules and regulations about not getting emotionally attached or engaged with others, celebrities have no such limitations, meaning their claims are bound to carry more weight than even the most accomplished expert in the eyes of the typical person.

And why do celebrities end up creating or embracing such far-fetched fads in the first place? There are many possible reasons, but one is that our thinking and worldview are heavily shaped by the people around us, and what they think and say. Our brains take all this in and incorporate it into our own conscious processes.

However, while I've never been an A-list celebrity myself, it seems to involve being surrounded by people dedicated to your wellbeing, comfort and happiness. Essentially, if your life consists of everyone telling you you're right all the time, you could easily end up with a massively inflated sense of your own wisdom and understanding. Believing and promoting dubious health fads is just one possible outcome of that.

So yes, there are plenty of reasons why health and wellness fads remain popular and widespread, despite being completely contradicted by science. And a lot of this is thanks to how our brains work. So, be aware of this next time you're presented with the latest dubious-sounding claims about how to boost your health or enhance your wellbeing, because you could end up getting burnt. And in a very intimate place, too. ■

"The fact that such wellness fads are blatant nonsense is less important than you'd think. Or hope. Once we've decided to do something, our brains are often reluctant to change course."

Gwyneth Paltrow's lifestyle brand, Goop, has come under fire for selling pseudoscientific wellness products.

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Dean Burnett's latest book, *Psycho-Logical*, is out now.

GETTY IMAGES, RAY-BAN/FACEBOOK

Q&A
Questions & Answers

Got questions you've been carrying around for years? *Very Interesting* answers them! Mail your questions to VI@panorama.co.za

EXISTENTIAL CRISIS OF THE MONTH...

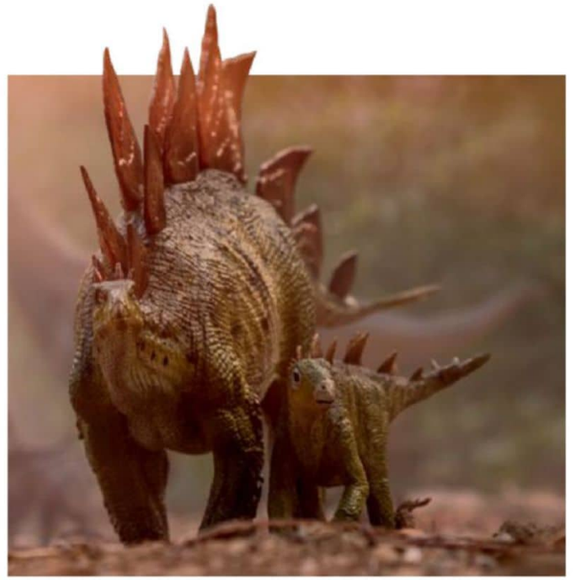
Are we too late to stop climate change?

Polly Khunou, Johannesburg

It can be hard not to be despondent about climate change. It's already impacting extreme weather events around the world, from heatwaves to hurricanes, and this impact is expected to grow as more warming gases are added to the atmosphere. We need to cut yearly global emissions roughly in half by 2030 compared to 2010 levels to stay on track to limit temperature rise to 1.5°C above pre-industrial levels, but current Paris climate pledges put us on track for emissions to be 16% higher in 2030 than in 2010.

As David Attenborough said earlier last year: "No matter what we do now, it's too late to avoid climate change." So, we will need to adapt to it to some extent. However, we still have plenty of scope to limit the worst impacts. Since the Paris Agreement was signed six years ago, there has been a strong shift in climate ambition. Renewables have fallen massively in price and climate change has shot up political agendas. While the latest round of Paris climate pledges this past year still fall well short, they are an improvement on pledges five years ago: they put the world on track for a 2.4°C rise by the end of the century, rather than 2.7°C. We also know we have a plethora of existing climate solutions which can rapidly cut emissions, if only we choose to use them.

And it will never be too late to stop climate change, because it will always be better to keep temperature rises as low as possible. Limiting it to 2°C is better than 2.5°C; better than both of these is keeping it below 1.5°C.



What were the spinal plates on stegosaurus for?

Desmond Aggrey, Tshwane

Stegosaurus is one of the most recognisable dinosaurs, for one main reason: the big, triangle-shaped plates lining its neck, back and tail. They are arranged in two rows of alternating pairs, and at the tip of the tail they transition into a line of foreboding spikes, each more than 30cm long. The largest plates, located over the back and hips, are the size of coffee tables. Seen in side view, stegosaurus cuts a unique profile. But it is hardly alone – such plates are a defining feature of a wider group called the stegosaurs, comprised of stegosaurus and its closest fossil relatives like kentrosaurus and huayangosaurus.

Ever since the first stegosaurus skeletons were found in western North America during the 'Bone Wars' of the 1870s, palaeontologists have debated the function of the plates. One idea was that they were defensive structures – armour to fend off the bites of the hatchet-skulled apex predator allosaurus. However, some questioned whether protective plating sticking up from the back, rather than guarding the flanks, would actually be effective.

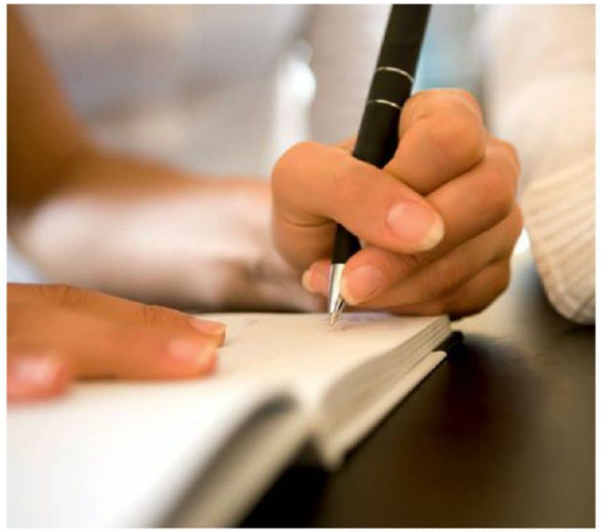
More recently, researchers have posited other explanations.

Q&A FLASH

- A stegosaurus's brain was around the size of a Brazil nut.
- The majority of dinosaurs were human-sized or smaller.

Stegosaurs vary widely in the size, shape and distribution of their plates, which hints that they may have been used as display structures, to signify species membership, attract mates, or intimidate rivals. Histological thin sections of the plates show their outer layer is engulfed with channels for blood vessels and nerves, which may have enabled them to act as solar panels and heat dumps, to help control metabolism. However, the dense vascularisation may have simply been used to help the sheath that once covered the bony plate – made of keratin, the same stuff as our fingernails – grow rapidly or even change colour, which would be useful for display.

Although there is no firm answer, it seems display and perhaps thermoregulation are more likely functions than defence.



Are there more left-handed people in societies where the written word flows right to left?

Althea Aldus, Durban

Quite the reverse. Various surveys have found that the highest incidence of left-handedness is in Western countries. The Netherlands, USA and Canada lead, with around 13% of the population being left-handed. The countries that use right-to-left writing systems are predominantly Arab and Asian and they all have left-handedness rates below 6%. In Muslim countries, the advantage of smudge-free handwriting is outweighed by the fact that the left hand is considered unclean. Writing, eating and shaking hands is all done with the right hand, and naturally left-handed children are taught to use their right hands for these tasks from an early age.

Why do water droplets remain on plastic items after they've gone in the dishwasher?

Cindy Shabani, Cape Town

Dishwashers work by spraying jets of water and detergent at up to 68°C – much hotter than you would use for washing-up by hand. At the end of the washing cycle, the hot, clean crockery dries itself just by evaporation. But, although everything inside the dishwasher starts off at the same temperature, plastic items cool down much quicker. This is because they have lower 'thermal mass'. The plastic of a food storage container is thinner than a cup or plate, and plastic is a lower density material, so for a given temperature, its molecules hold less heat energy. As the water evaporates from the surface, it quickly cools the plastic down and this slows the rate of evaporation. Heavy plates and pans hold their heat much longer and are still quite warm even after all the water has been evaporated away. China, glass and metal are also much better heat conductors than plastic. This means that all the heat in the vertical sides of an upturned bowl or cup can flow quickly to supply heat to the horizontal surfaces, to evaporate any water that has puddled. The heat in a plastic container spreads more slowly, so small water droplets remain on the surfaces.

GETTY IMAGES X2, SHUTTERSTOCK ILLUSTRATION: DAN BRIGHT

The pilot programme of vaccinations against malaria has been underway since 2019.

SHUTTERSTOCK

MEDICINE

World's first malaria vaccine

The World Health Organization's Director-General hails 'historic moment' as mass immunisation of African children begins

Malaria is the leading cause of childhood illness and death in sub-Saharan Africa, killing more than 260,000 under-fives every year. For context, that means one child dies of malaria every two minutes.

Now, following a successful pilot scheme that involved giving at least one dose of the RTS,S/AS01 malaria vaccine to more than 800,000 children across Ghana, Kenya and Malawi, the World Health Organization (WHO) is recommending a widespread immunisation programme for children aged five months or older living in sub-Saharan Africa. This marks the first time that a vaccine for malaria has been recommended for use across large swathes of the continent.

"This is a historic moment. The long-awaited malaria vaccine for children is a breakthrough for science, child health and malaria control," said WHO Director-General Dr Tedros Adhanom Ghebreyesus. "Using this vaccine on top of existing tools to prevent malaria could save tens of thousands of young lives each year."

Malaria is caused by the Plasmodium parasite, which is spread by female Anopheles mosquitoes. Once the parasite enters the host's bloodstream it travels to the liver, where it develops for a short period before re-entering the bloodstream and attacking the host's red blood cells. In a non-immune individual, symptoms usually appear 10 to 15 days after the bite and include fever, headache, chills and diarrhoea. If not treated within 24 hours, the disease can progress to become a severe illness and often leads to death.

Developing an effective vaccine has proved to be a serious challenge as the parasite is far more complex than a virus or bacteria.

The RTS,S vaccine works by introducing the immune system to a fragment of a protein that is present on the surface of the Plasmodium parasite. The protein triggers the production of antibodies and prepares the immune system to attack the parasite the next time it enters the body. It is administered to children via a schedule of four doses and, to date, more than 2.3 million have been given, with no significant side effects. WHO has reported a 30% reduction in the cases of deadly malaria since the pilot scheme began in 2019, even in areas where insecticide-treated nets are widely used, and people have good access to diagnosis and treatment.

Discussions about funding a broader rollout of the vaccine will now take place among the global health community, with individual countries making the decision on whether to adopt the vaccine as part of their national malaria control strategies.

"For centuries, malaria has stalked sub-Saharan Africa, causing immense personal suffering," said Dr Matshidiso Moeti, WHO Regional Director for Africa. "We have long hoped for an effective malaria vaccine and now, for the first time ever, we have such a vaccine recommended for widespread use. Today's recommendation offers a glimmer of hope for the continent, which shoulders the heaviest burden of the disease and we expect many more African children to be protected from malaria and grow into healthy adults."

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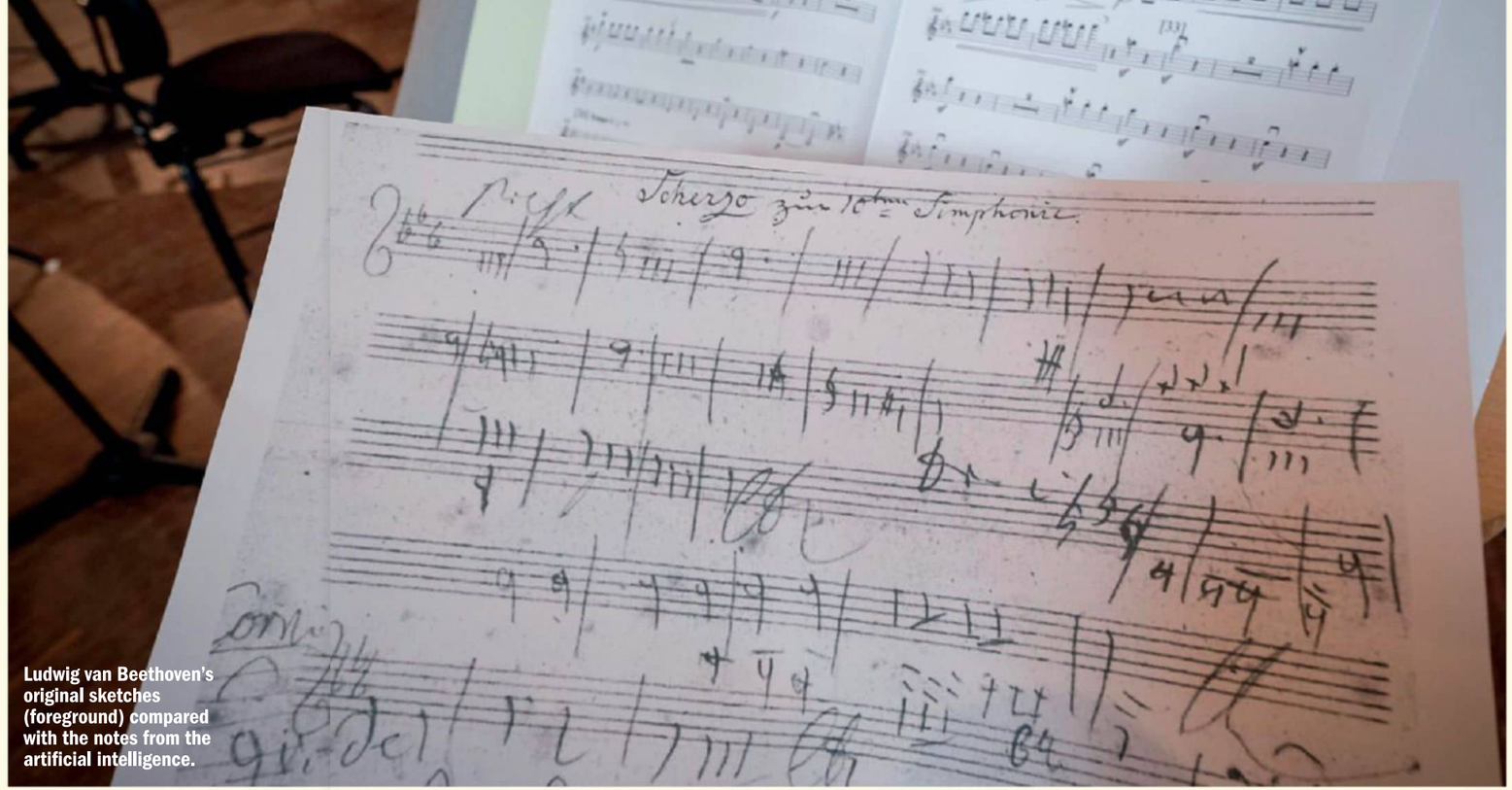
BEETHOVEN'S UNFINISHED *10TH SYMPHONY* COMPLETED BY AN AI

Computer scientists teamed up with historians, musicologists and composers to teach an artificial intelligence how to compose like Beethoven

TEXT: AHMED ELGAMMAL



Ludwig van Beethoven's original sketches (foreground) compared with the notes from the artificial intelligence.

DEUTSCHE TELEKOM

When he died in 1827 at the age of 56, Ludwig van Beethoven left his *10th Symphony* unfinished. Only a few handwritten notes briefly detailing his plans for the piece have survived, with most just being incomplete ideas or fragments of themes or melodies.

Now, a multidisciplinary team of computer scientists at Rutgers University-based startup Playform AI have trained an AI to mimic the great composer's style, and used it to write a complete symphony based on these initial sketches.

How much of Beethoven's manuscript was available for you to start from?

Beethoven left sketches in different forms, mainly musical sketches, but also some written notes with some ideas in as well. Previously, in 1988, [English musicologist] Barry Cooper used the majority of these sketches, about 250 bars of music, that were meant for a first movement [in his attempt to complete the symphony]. But what was left behind is really very little. So basically, like three bars of music here and four bars of music there and some rough sketches, which sound like basically the starting points of the main themes in the movements that he [Beethoven] wanted to write.

When you look at Beethoven and other classical composers, that's usually the case. They will work with a main theme and then develop it into a sequence of a couple of minutes and then another theme comes. That's the traditional way of composing, and that's exactly what the AI needed to learn: how Beethoven and other classical composers start with a theme and develop it. Like in the *Fifth Symphony* – 'da da da dah'. And then take that and evolve a whole movement around it.

How do you train the AI to develop interesting melodies based on just the one motif?

The way AI generates music in general is similar to the way your email tries to predict the next word for you. So, when you write an email, you find it jumps into suggesting what you might want to write next.

Similarly, the AI has to learn from a lot of musical data, and it asks what the next note would be after what you just wrote. And if you can predict the next note, then you can predict the next note and the next note and so on. That's the main concept.

But you soon realise with your email that, if you start picking up the suggestions for the next word and always write based on what the AI suggests, it doesn't really hold for a long time. And that's what happens with music. If you just give it a starting point and leave it to predict, then it can predict a couple of notes. But after that, it becomes nonsense more or less, and is no longer faithful to the main theme.

So that was the main challenge. How can we let the AI stick to the main theme and develop it? This is where the role of the human expert working with the AI comes in. We had to work with experts to annotate and label a lot of music for us to tell the AI what the theme was and where the development of the theme was in a lot of pieces of music. Basically, the AI learnt as a student. That made a big difference, because then the AI could really keep sticking to the theme.

Also, the AI had to compose the music in a specific musical form. So, if you are composing for a scherzo movement or a trio part of the movement or a fugue, each of these musical forms has a specific structure. The AI had to learn how to write a scherzo, how to write a trio, and how to write a fugue.

Did you train the AI by listening exclusively to Beethoven or did you use other composers as well?

It was challenging, because Beethoven only wrote nine symphonies. That's a small dataset compared to the scale of what the AI needed to do. The way we approached this was to first imagine ourselves like a young Beethoven learning about music. What would he have listened to? So, we trained our first version of the AI as if it was somebody living in the 18th Century listening to baroque music like Bach, as well as Haydn and Mozart. That was the first version of the AI. And then we took that AI and trained it specifically on old Beethoven sonatas, concertos, string quartets and the symphonies.

"Beethoven's nine symphonies were a small dataset for what the AI needed to do."

We first trained the AI to generate the composition as two lines of music, not as a full symphony. So then, we had another AI that would take that composition and learn how to orchestrate it. I believe this is very similar to the way humans learn – you cannot really master fourth-level college without going through the first and second and third levels first. It's always incremental.

How did you get the AI to take the melody that you created and then harmonise it as Beethoven would have?

The way we harmonise music is very similar to how we use AI to translate languages. When you use Google Translate or another AI to translate a sentence from one language to another, these models learn a lot of background sentences. So, what is the sentence in German? What is the sentence in English? And from that, they try to learn how to translate them. So basically, imagine you have these models [for harmonisation]. You put the melody in one side, and on the other side you put in how Beethoven would harmonise, so the AI learns how to translate a melody line into harmonised music. The thing about music is that it's very structured and follows a lot of rules. But this is hard for us to capture and write down. You have to have a PhD in musicology with a speciality in Beethoven to really understand that. But the machine is able to capture that statistically and mathematically in a very implicit way and be able to use that to give us this harmonisation.

What has the response been like from musicians and composers?

Their response is mixed. There are people who loved this very much and love the idea of having an AI that understands music and can help you finish your composition, or have you explore different musical ideas. But on the other side of the spectrum, there are people who reject even the concept of being able to complete a Beethoven symphony using AI. They are afraid of AI taking their jobs.

Is it possible that we could get an AI to make a completely original work?

Yeah, I have no doubt about that. We did that in visual art a couple of years ago, where we developed an almost autonomous AI artist. We had it look at the last 500 years of Western art, then the task was basically to generate new artworks that didn't follow any existing style. If the AI generated an Impressionist or a Picasso kind of art or a Renaissance-style artwork, it could realise, and so it would have to learn how to create something new.

The challenge with our project was actually the constraints – the fact that the AI was not generating music by itself, but generating music that is based on Beethoven's genius and following the sketches. This makes it more difficult. But I think that generating music autonomously is an easier task. ■

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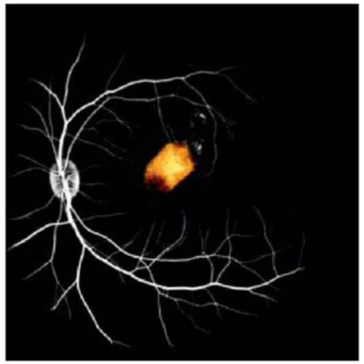
Prof Ahmed Elgammal is a professor of computer science at Rutgers University in New Jersey and the lead researcher on the Playform AI project.

Quickies



MEDICINE

A blindness treatment is in sight

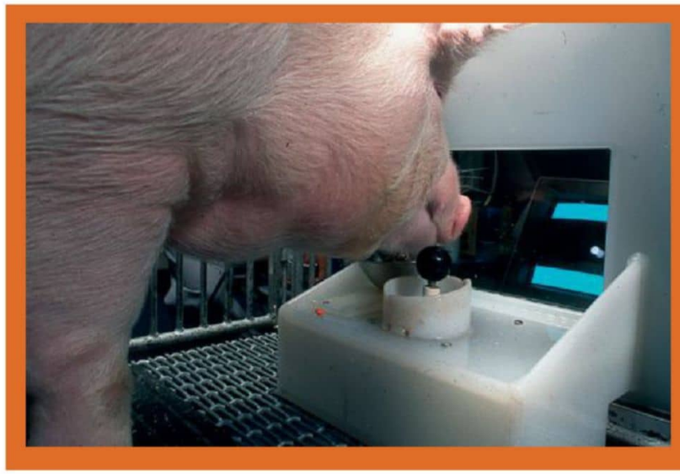
Hope continues to grow that we will soon be able to treat and reverse blindness, with a number of promising avenues of research showing progress.
In 2021, researchers successfully transplanted human retinal cells into the eyes of monkeys. The researchers who carried out the procedure found no signs of unwanted side effects, such as light sensitivity or dangerous immune responses. Grown from human stem cells donated to science, the cells began to take over control of some functions of the monkeys' eyes. Human trials may not be far away, but researchers at the Icahn School of Medicine in New York say that the technique needs to be tested on monkeys with impaired vision first.

The BiVACOR artificial heart relies on a pump that's suspended by magnets.

MEDICINE

Skipping to the beat of an artificial heart

Researchers have been trying to build an artificial heart for more than 50 years. Now, an Australian team is planning human trials for a design that could have huge implications for our health. BiVACOR is revolutionary because it doesn't attempt to work exactly like a real heart – it tries to one-up evolution instead, with an efficient and sustainable way to pump blood around the body. It utilises spinning disc technology, which sees a circular pump suspended between magnets in an artificial heart made of titanium. So far, the technology has only been tested in animals and temporarily in heart transplant patients, although a full human trial is on the horizon.



CULTURE

Swinecraft: experiment turns pigs into gamers

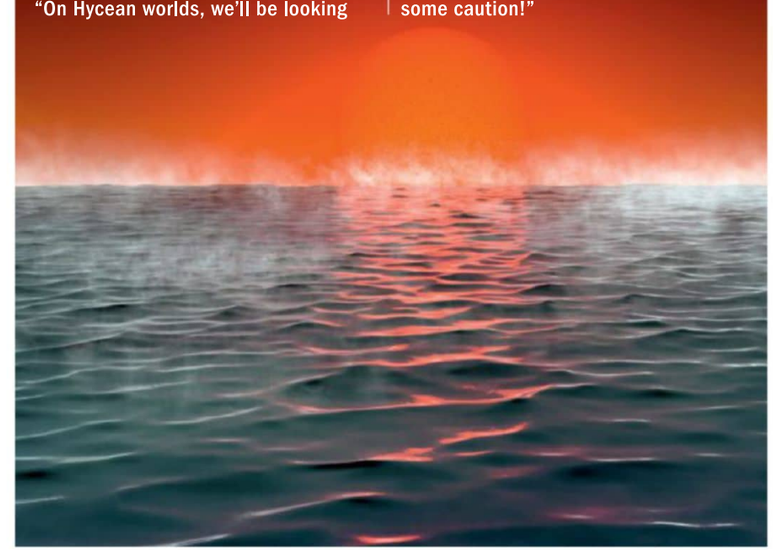
It sounds like total trotters, but pigs are smart enough to play video games. In a study at Purdue University in Indiana, four pigs moved a joystick with their snouts to direct a cursor to on-screen targets. Researchers noted that their performances were well above those that could be explained by chance, and that the pigs responded to food rewards and verbal encouragement. It's the latest work to hint at the breadth of porcine intelligence, with past research highlighting their learning, memory and problem-solving abilities. Don't you hate it when another player hogs the joystick, though?

PETER ADAMS, AMANDA SMITH/CAMBRIDGE UNIVERSITY, ALAMY, ESTON MARTZ/PENN STATE UNIVERSITY

SPACE

Not if, but when we find ET

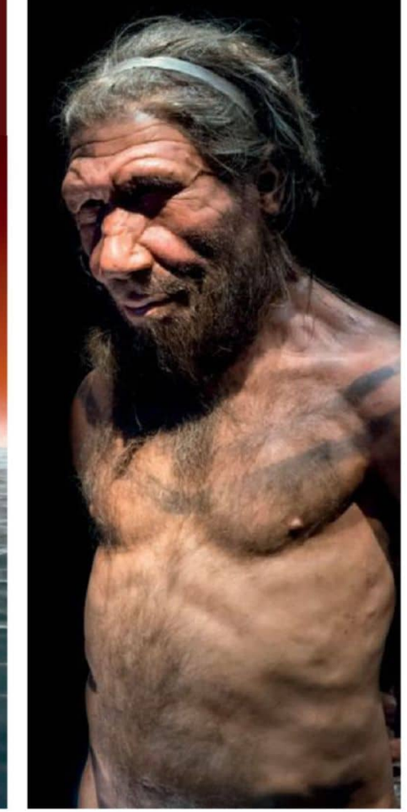
Somewhere out in the depths of the cosmos, life could be thriving on a strange kind of planet. Around 2.6 times the size of Earth, this alien world would be hot and covered in ocean, with an atmosphere that's rich with hydrogen. Humans couldn't survive there, but maybe we could detect the creatures who do. It's even possible we could make that detection – and confirm that we're not alone in the universe – in the next two or three years.
This radical idea comes from researchers at the University of Cambridge, who published a paper in August 2021, speculating on the existence of such a world.
Researchers have dubbed the category a world like this would belong to as Hycean planets. If the existence of Hycean planets is confirmed, it could turbocharge the search for extra-terrestrial life, because detecting biosignatures from such worlds is potentially a lot easier than doing the same for Earth-like planets. Plus, a lot of already known exoplanets could fall into this class.
"The fundamental advancement here is that this idea will expand and accelerate the search for life elsewhere," said study author Dr Nikku Madhusudhan. "In a practical sense, it literally increases our chances."
Traditionally, astronomers have scanned the skies for hints of oxygen, methane and other biomarkers produced in large quantities by microorganisms here on Earth.
"On Hycean worlds, we'll be looking for molecules such as methyl chloride and dimethyl sulphide," said Madhusudhan. These are also produced by life, but in much smaller quantities – something that's not a problem when it occurs on Hycean worlds.
"The observability of these [planets'] atmospheres would be so good that, even if these molecules are present at one part per million, they'll still be observable," he said.
Madhusudhan hopes to take advantage of the soon-to-be launched James Webb Space Telescope, the largest space telescope ever built. He believes that all it would take is a few hours trained on a Hycean planet for the telescope to pick up biosignatures using transit spectroscopy (a technique in which researchers measure the changes in starlight as it filters through the atmosphere of a planet that's passing in front of it).
As significant as such a discovery would be, it would also beg further questions. "One fundamental question would be: is life possible in such environments? And how would life originate on this planet? You need to do a lot more follow-up observations to robustly establish whether [what you're seeing] is indeed a signature of life," said Madhusudhan.
"I may be risking making a big statement here, but this could be our entry point to extra-terrestrial biology. But if you're quoting me on that, please make it clear I'm saying it with some caution!"



HISTORY

Neanderthals: All talk?

Big talk from palaeontologists last year, who claimed that Neanderthals had the capacity to hear – and possibly speak – just like us high-minded *Homo sapiens*. Once dismissed as uncultured knuckle-dragging cave-dwellers, perspective on our evolutionary cousins has been shifting in recent years. They may have worn ornamental dress, for example.
We certainly share DNA with them, and now researchers believe there's a good chance they were capable of sophisticated verbal communication.
The conclusion comes from researchers in Madrid, who created 3D models of the ear structures of Neanderthals, allowing them to model the frequencies at which they could hear. Neanderthal hearing was attuned to frequencies around 4-5kHz, which happens to match the majority of human speech sounds. Researchers believe if they could hear it, there's a good chance they could speak it.



TECH AND TOYS

AI ASTRONOMY

Minimum effort, maximum results. Loosely speaking that's the philosophy behind the smart telescope: input the cosmic object you wish to view, and the telescope pinpoints its location in the night sky. Then you can enjoy the view via the digital eyepiece or a smartphone app. From there you can take long-exposure images, process your images, or share them with the community of fellow astronomers. In particular, this update to the eVscope from Unistellar has added an impressive 'enhanced vision' mode that is designed to help counter the light pollution most of us live under.

Unistellar eVscope 2

R52,000, unistellaroptics.com

ASTRO ON PATROL

Astro does look like a tablet on wheels, but Amazon insists that its new bot is more than a roving Alexa. Though it doesn't look tough, Astro is intended as a kind of personal-assistant-cum-security-guard. It can go on patrols around allocated zones in your house and will alert you if someone has broken in, relying on its facial recognition to distinguish familiar faces from strangers. Astro's equipped with a perioscopic camera too, so it can check if you've left the gas on. You can pilot Astro via your phone.

Amazon Astro

R14,800, amazon.co.uk

DOOGEE HOW'S IT?

Smartphones are hard to tell apart, but this new handset from Doogee has a neat party trick. Thanks to a laser and sensor on the top of the phone, it can measure the length, area or volume of a room, up to a scale of 40m. It can even do a bit of Pythagoras to calculate diagonals. Inside there's good tech – an eight-core processor and 8GB of RAM – and it comes equipped with a 48-megapixel camera made by Samsung. Doogee also says it's drop-proof from 1.5m, will survive underwater up to a depth of 1.5m for 30 minutes, and can function below -55°C.

Doogee S97 Pro

R8,000, doogee.cc

SET TO FAST CYCLE

Dutch company Vanmoof says its new bike will top out at 50km/h. Though the company has been coy about what's powering the bike, it has two-wheel drive with motors at each wheel monitored by a traction control system. The extra battery needed to get to this top speed should also mean that the bike will have a huge range too. With similar speed limits in place across Europe and the US, it looks like this model has been built to force a conversation about the current regulation, with Vanmoof hoping e-bikes could entirely replace traditional, petrol scooters in cities around the world.

VanMoof V

R60,000, vanmoof.com

MEMORIES IN 3D

This odd-looking attachment is a first for cameras with interchangeable lenses. Snap it onto one of Canon's compatible cameras, such as the EOS R5, and it records stereoscopic 3D film that you can re-experience with a VR headset. Both lenses record to the single sensor inside the camera, then software inside the camera preps it for VR playback. Right now, this tech is quite expensive, but this innovation is a step in the right direction, as typically you need dedicated kit to record film for VR.

Canon RF 5.2mm F2.8l Dual Fisheye Lens

R42,000, canon.co.uk

CLOSE UP

Usually, a projector is a pain to use: it needs a large room, clear of anything that could get between it and the screen or wall it's throwing the image at. That's where a short-throw laser projector comes in. The Aura can beam out images 254cm across from as little as 20cm away; that screen grows to 381cm from 38cm away. Onboard are four speakers provided by Harman Kardon, Bluetooth and Wi-Fi connectivity, and an Android OS for things like Netflix and iPlayer. You can even hook up a gaming console via HDMI.

Xgimi Aura

R43,000, uk.xgimi.com

BOOKS AND FILM

RED NOTICE (PG13SVL)

A massive success story on Netflix, this star-heavy action flick – it stars Dwayne Johnson, Gal Gadot and Ryan Reynolds, which means the film comes up in about 87% of Google searches – is … absolutely fine. Reynolds and Gadot are art thieves and Johnson is an agent charged with catching them. So, think Indiana Jones with even more knowing asides and almost fourth wall-breaking pun-making alongside truckloads of unlikely action and a double-cross or three. Reynolds' charm slightly supersedes those of his equally screen-friendly colleagues, but everyone pulls their weight, and the outcome is viscerally, if not cerebrally, enjoyable.

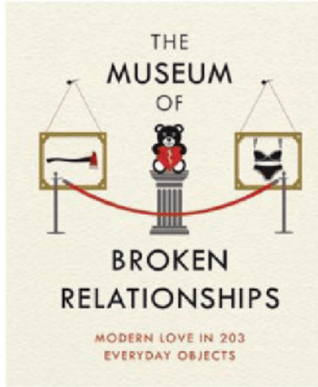
ENLIGHTENED (PG13LS)

An intriguing Showmax series, *Enlightened* is built around Laura Dern's Amy Jellicoe, a middle-aged career woman whose bad choices in relationships and other areas see her having a breakdown and then trying to rebuild her life. Her strongly-held values – some good and aspirational; some faintly ridiculous – and her way of expressing herself often makes her difficult to like, and in some way more relatable as a result. The scripts for each episode are thoughtful and challenging, with the humour often of that awkward sort felt when seeing someone make a fool of themselves. But ultimately, the show's title feels fitting.

DEADWATER FELL (16LVS)

He may not be the epitome of a leading man in the Hollywood sense, but David Tennant is, on his own, a fantastic reason to watch

anything he's in at the moment. Britbox drama *Deadwater Fell* is dark, unhurried and worrying, telling the story of a family and community decimated by a couple of everyday disasters. Tennant's Tom Kendrick is a doctor, but ironically not someone who appears interested in healing, as the unpacking of his true nature over four episodes underlines. Examining themes of abuse that ring sadly close to too many peoples' realities, this show is sobering but worth watching.

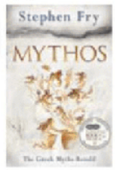


THE MUSEUM OF BROKEN RELATIONSHIPS BY OLINKA VISTICA AND DRAZEN GRUBISIC

Nothing gets examined in more ways through both fiction and non-fiction literature than love and its many facets. Unsurprisingly, then, a large proportion of that writing and those presentations is at best cliched and at worst banal or just downright awful. Finding a fresh angle is difficult, and it is both the imagination behind and the quirkiness of this collection that makes it interesting, moving and philosophically stirring. The authors are an ex-couple who noted that their relationship was dotted with physical markers and milestones that were particular to them – largely because nobody else would consider the keepsakes and possessions involved valuable. Their understanding that this phenomenon was not unique to them led the pair to collect scores of similar objects and snippets of stories from other ex-lovers, each of those folks with their own tales and styles of emotional processing. Vistica and Grubisic then presented those objects and stories in both physical (there are museums around the world) and printed form, with this hard-cover volume a journey into the hearts and minds of normal people around the world, all of them hurt but all of them handling their pain, guilt, confusion – or happiness! – in different ways. Each page has a picture of an object – bizarre things, like damaged keyrings or an inappropriate self-help book, for instance – and a paragraph or two from the person who sent it in. Some entries are funny, some are sad, many are somewhere in between, and a major takeaway is that many people – and the way they choose to interact with those they care about – are profoundly odd. Intriguing, poignant reading.

editor's choice

MYTHOS BY STEPHEN FRY



Classical Greek mythology is absorbing, multi-layered, bonkers and often incredibly confusing. Most will know about the A-listers, such as Zeus, Poseidon, Hades, Aphrodite, Apollo and a handful of others, but even then, their origin stories and contexts are convoluted and deeply strange. It takes a special mind to make sense of all the myriad threads, passed down over centuries, that form the fabric of this immense block of literature, and Stephen Fry is one of the few people who has the knowledge, eloquence and breadth of perspective necessary for the job. Excellent, intelligent writing with pacing that spikes adrenalin but implications that induce melancholy.

MIND GAMES

PIT YOUR WITS AGAINST THESE BRAINTEASERS BY DAVID J BODYCOMBE, QUESTION-SETTER FOR BBC FOUR'S *ONLY CONNECT*

We'd love to hear your feedback on these puzzles. Please email VI@panorama.co.za.

QUESTION 1

Which NASA rover recently celebrated 10 years on the surface of Mars?

a) Opportunity
b) Curiosity
c) Sojourner

QUESTION 2

According to psychologists in the US, at what age do our earliest childhood memories begin to fade?

a) Five years old
b) Seven years old
c) Nine years old

QUESTION 3

To find out what makes moles effective diggers, scientists put them through their paces in which substance?

a) Sugar
b) Couscous
c) Sand

QUESTION 4

What is visualised in this psychedelic image?

a) Magnetic field lines
b) The polar vortex
c) The polar jet stream

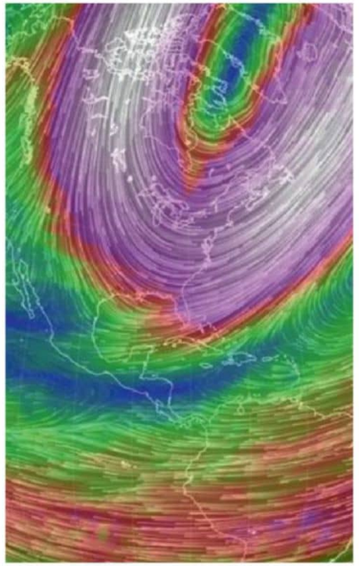
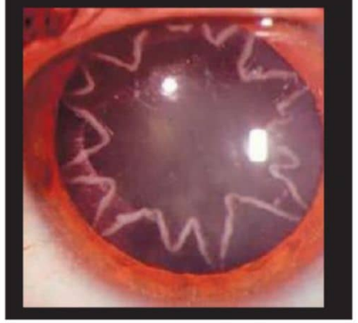


PHOTO: WELLCOME TRUST, EARTH.NULLSCHOOL.NET, BOBBY KORN/NEW ENGLAND JOURNAL OF MEDICINE

QUESTION 5

What gave this 42-year-old man star-shaped cataracts?

a) An electrical accident at work
b) Staring at the sun
c) Using a virtual reality headset non-stop for four days



QUESTION 6

Complete the recent news headline: "All human behaviour can be reduced to _____"

a) A simple computer model
b) Childhood experiences
c) Four basic emotions

QUESTION 7

UK doctors have carried out successful trials of a treatment for which common allergy?

a) Peanuts
b) Pollen
c) Dust mites

QUESTION 8

What's the name of the comet-chasing spacecraft that was recently woken up from a two-and-a-half-year hibernation?

a) Rosalin
b) Rosanna
c) Rosetta

QUESTION 9

According to recent research, what may have caused the extinction of the 3m-tall (10ft) *Gigantopithecus* great ape?

a) Tooth cavities
b) A supervolcano
c) Embarrassment at being so tall

QUESTION 10

The world's oldest flamingo has died in an Australian zoo. How old was it?

a) 43
b) 63
c) 83

QUESTION 11

In January 2014, astronomers spotted an exploding star in a nearby galaxy. Roughly how far away was it?

a) 12 million light-years
b) 22 million light-years
c) 32 million light-years

QUESTION 12

Complete the recent news headline: "Speedy cyclists are _____"

a) More likely to engage in doping
b) On the brink of extinction
c) Better looking

QUESTION 13

Which illness is represented by the frenzied beast in this 18th Century medical etching?

a) Schizophrenia
b) Tuberculosis
c) Fever

ANSWERS

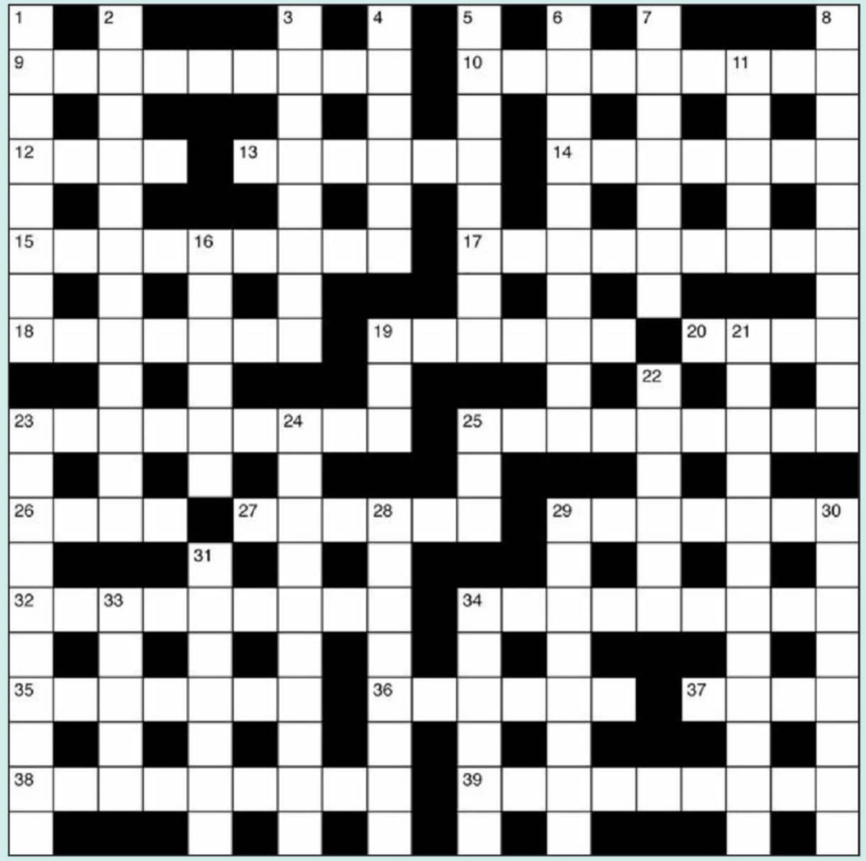
1a, 2b, 3b, 4b, 5a, 6c, 7a, 8c, 9a, 10c, 11a, 12c, 13c

HOW DID YOU SCORE?

0-4 White dwarf
5-9 Red giant
10-13 Supernova

THE Vi CROSSWORD

BY POPULAR DEMAND



ACROSS

9 Eyelet can be created with gas (9)
10 Ours spent money on bread (9)
12 Welshman takes school platform (4)
13 Mark about to turn quietly like a wolf (6)
14 Fast drama about actinon (7)
15 Move a cot along to get in shape (9)
17 Genuine thorn develops in a particular direction (4,5)
18 Fellow left snow leopard in storm (7)
19 Sob in despair at a part of Europe (6)
20 Healthy source of water (4)
23 When I get a child some land (4,5)
25 Dry places – useless for water clock (9)
26 Bring me back my award (4)
27 Terribly mean to the Spanish – that's hard (6)
29 Notes suggest an accumulation (7)
32 Thief gets one a plant (9)
34 Shout about name for place of light industry (9)
35 Baby mice used as a symbol (7)
36 Attack between pavements (6)
37 The Romans' champion (4)
38 Rule, alternatively, for routine to get trendy (9)
39 Email told about arsenic, say (9)

DOWN

1 Animal gets articles on road to flow backwards (8)
2 Development of sun worshippers (12)
3 Ordered set of queens to parade around church (8)
4 Antenna picks up song about English lake (6)
5 Dangerous substance boss eats when cooked (8)
6 Part of the program that a U-boat finds normal (10)
7 Leftover rum gives soldiers time (7)
8 Feature complaint on a rodent (10)
11 Remove front of steering, being a bit of a cow (5)
16 Little old man has European hereditary material (6)
19 Some pressure in the pub (3)
21 Leeks not done using internal framework (12)
22 Final case is only a woodlouse, say (6)
23 Bear suffered share of anomaly (10)
24 Cannon does work for a very short time (10)
25 Pass out of recollection (3)
28 Doctor has a snack by bend during ancient race (8)
29 Brilliant material, awfully animated (8)
30 Hid story about glands (8)
31 One man's penicillin is another man's bond (7)
33 Fellow finds new diet disgusting (5)
34 Church city with a reflective look (6)

ANSWERS

For the answers, visit veryinteresting.co.za/solutions. Please be aware the website address is case-sensitive.

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A DANGEROUS RELATIONSHIP?

Any of us can build a following online, but a large band of followers can make it tricky to navigate the turbulent waters of the digital world

TEXT: ALEKS KROTOSKI

When I was nine years old, I was desperately in love with a man who was at least 40 years my senior. Don't worry; it was entirely unrequited – in fact, Micky Dolenz of The Monkees didn't even know I existed, because he'd stopped being a Monkee 20 years earlier. But that didn't stop me from decorating my books with love hearts and 'AK + GMD' (little known fact – Micky Dolenz's real name is George Michael Dolenz) and entering a pre-teen trance every time I put *Pleasant Valley Sunday* on my record player.

The Monkees were entirely manufactured, I know this now. But as a product they were a success: they used the media to instil a bond between an audience member and her target. In their TV show, they regularly broke the fourth wall, throwing knowing winks to the camera. In magazine interviews, they shared intimate details of their hilarious behind-the-scenes lives. They made themselves vulnerable. They made us think we knew them, as a friend.

Recently, when making an episode of *Digital Human*, I discovered that this kind of 'parasocial relationship' has long roots in media. Radio characters like Lonesome Gal fashioned them by cooing into listeners' ears for 15 minutes of monologue once a week from the late-1940s to the mid-1950s. She started most episodes with, "Sweetie, no matter what anybody says, I love you better than anybody in the whole world," speaking directly to her listeners. Each individual felt he (predominantly a 'he') had her undivided attention. She was an entirely virtual girlfriend, at a time when the word had nothing to do with technology. And eventually, like anyone who cultivates those kinds of relationships, she began to sell things.

Parasocial relationships have become a means to an end in the digital age, now that selling yourself has become a way of life. Manipulating these relationships is how you gain followers, credibility and influence. But maintaining them is a challenge. At the beginning, it's necessary to put out the tendrils of connection as widely as possible. But once you start to gain a critical mass, the relationship necessarily transforms – at least in the eye of the digital personality. You can speak directly to one fan, or even five. But it's not possible to respond to the 10,000 people who subscribe to your TikTok. What was once an intimate relationship turns into a business transaction. Reaching out across the internet is how we feel connected; imagining we know the person behind the screen is our global folly. Rising social media stars have to manage themselves and their boundaries.

"What was once an intimate relationship turns into a business transaction."

That's one of the most untapped skills in the digital age. Today's parasocial relationships are surfing uncharted territory, so it is expected that they – we – will make mistakes.

A person scorned in the era of Lonesome Gal or Micky Dolenz had intermediaries to intercept; who is there to help when we've put ourselves out there online? ■

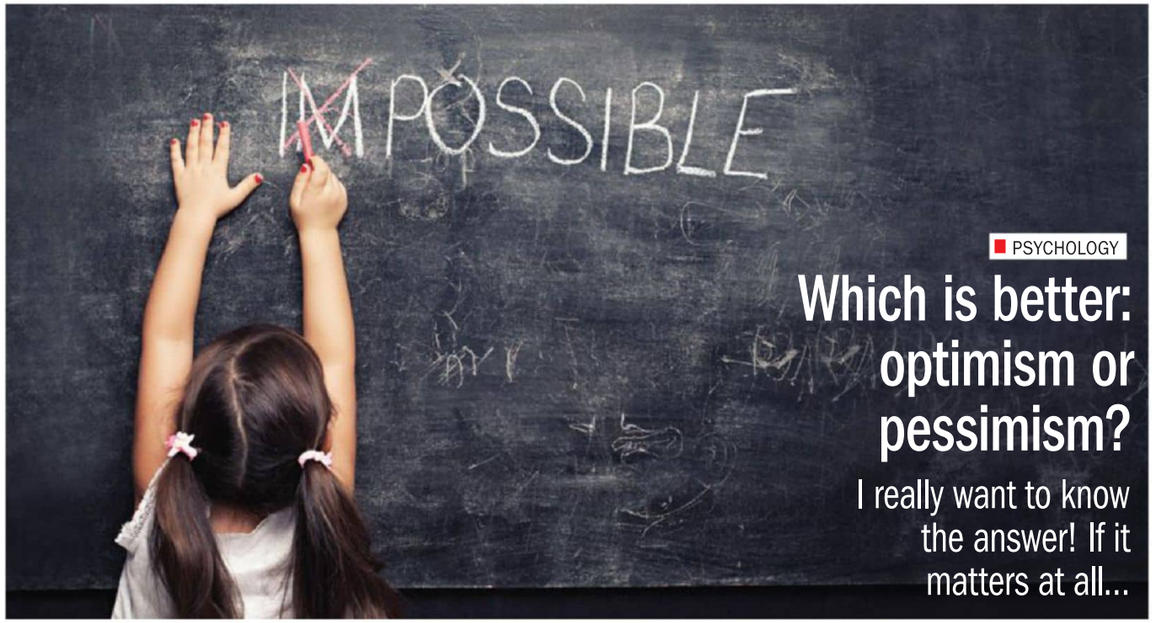
VI@panorama.co.za

Aleks Krotoski is a social psychologist, broadcaster and journalist. She presents *The Digital Human* on BBC Radio 4.

PORTRAIT: KATE COPELAND ILLUSTRATION: SCOTT BALMER

Next issue

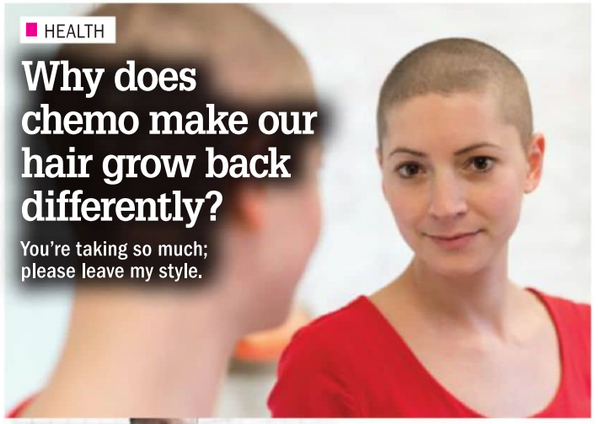
On sale from 22 April 2022.



PSYCHOLOGY

Which is better: optimism or pessimism?

I really want to know the answer! If it matters at all...



HEALTH

Why does chemo make our hair grow back differently?

You're taking so much; please leave my style.

BODY

Why do I have such a low pain threshold?

Also, why is the texture of this paper so spiky?

SPACE

Would Earth be different if it spun the other way?

Remember to plan your diary for last week.

ALSO IN THE NEXT ISSUE OF *VERY INTERESTING*: Much more about matters technological, psychological, historical, natural and scientific. Plus all your questions answered... What do you want to know? Mail **VI@panorama.co.za**

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