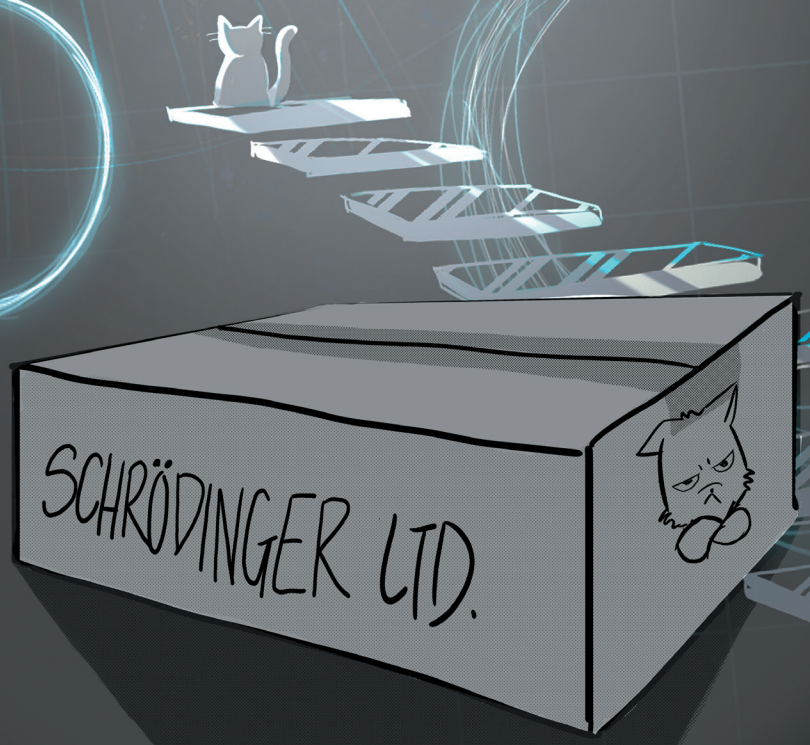
I, SCIENCE

THE SCIENCE MAGAZINE OF IMPERIAL COLLEGE



MYSTERY

SUMMER 2021

I, SCIENCE

THE SCIENCE MAGAZINE OF IMPERIAL COLLEGE

EDITORS-IN-CHIEF
AKILA RAGHAVAN
ALEXIA YIANNOULI

MAGAZINE EDITOR
LEIGH WEST

PICTURES EDITOR
ALIENOR HAMMER

ACCESSIBILITY OFFICER
ARIANA LOEHR

WEB EDITOR
NAOMI DINMORE

NEWS EDITOR
KEEGAN SCHROEDER

ONLINE FEATURES EDITOR
KAYLEE GREGOR

REVIEWS EDITOR
FATIMA SHERIFF

RADIO EDITOR
POLLY COHEN

RADIO PRODUCER
LILY HAYWARD

TV EDITOR
JAY BALAMURUGAN

MARKETING MANAGER
GEMMA RALTON

EVENTS MANAGER
SOPHIE BURLEY

SOCIAL MEDIA MANAGER
USHASHI BASU

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ANNA BASSADONE
ISOBEL CHANDLER
ALICE HIRST
KATHARINE LANG
GABRIELLA LINNING
DAVE WARRELL

COVER ILLUSTRATION:
DANIEL GONZÁLEZ-FRANCO
VITTORIA GINEVRI

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ARTWORK: JACOB GABLE, BLACK HOLE

I, SCIENCE

Dear Reader,

The past year and a half has undoubtedly been one of the most challenging times any of us have ever faced in our lifetimes. But, with restrictions easing and the weather cooperating, there appears to be some light at the end of the tunnel!

We are especially excited to have put together this issue for you, largely because it is the first issue the I, Science team of '20/'21 has been able to physically print!

Our theme for this issue is *Mystery*. One of our basic human instincts is to be curious. Curious about the unknown, the intriguing, the unsolved, the unfathomable .... the mysterious.

Once again, our fantastic writers have astounded us with their interpretation of this topic and have come at it from a number of different ideas and angles.

We begin our journey into Mystery right at the beginning, the very beginning - the origins of life. Read on to discover what is currently known about black holes, why we have an inherent fear of the unknown, and whether or not a serial killer gene exists. Further on, you can delve into the science behind hallucinations and whether there is any merit to the field of cryptozoology. We then cover the reasons behind our need for sleep as well as human pathology and the advances of medical treatments.

Next, we have our segment Science Behind the Art - an exploration into the scientific concepts behind two pieces of artwork. Further on, you will find an intriguing consideration of what fast radio bursts are and how they occur. Read on to discover what the actual nature of mystery is and why we as humans are so drawn to the mysterious. Next, have you ever wondered why banana sweets don't actually taste like bananas? Or how exactly our human consciousness comes to be? Keep reading to find out what the differences between detective work and the scientific method are, have every question you've ever had about cyanide answered, as well as what the condition of misophonia is. We also cover uncertainty in science, whether the hygiene hypothesis plays a role in asthma, and everything you've ever wondered about dark matter. Finally, we have a thematic review of a book.

We have thoroughly appreciated every moment of leading the I, Science team over the past year. It has been an honour to work alongside such talented writers and fellow editors in putting the magazine together. We're excited to see how next year's editorial team will continue to develop it.

So, dive right in! We hope you enjoy perusing this issue as much as we have enjoyed curating it! ■

Happy Reading!

AKILA RAGHAVAN
& ALEXIA YIANNOULI
CO-EDITORS-IN-CHIEF

We are always looking for new contributors for both the magazine and online. If you would like to get involved as a writer, illustrator, or photographer, please get in touch with us.

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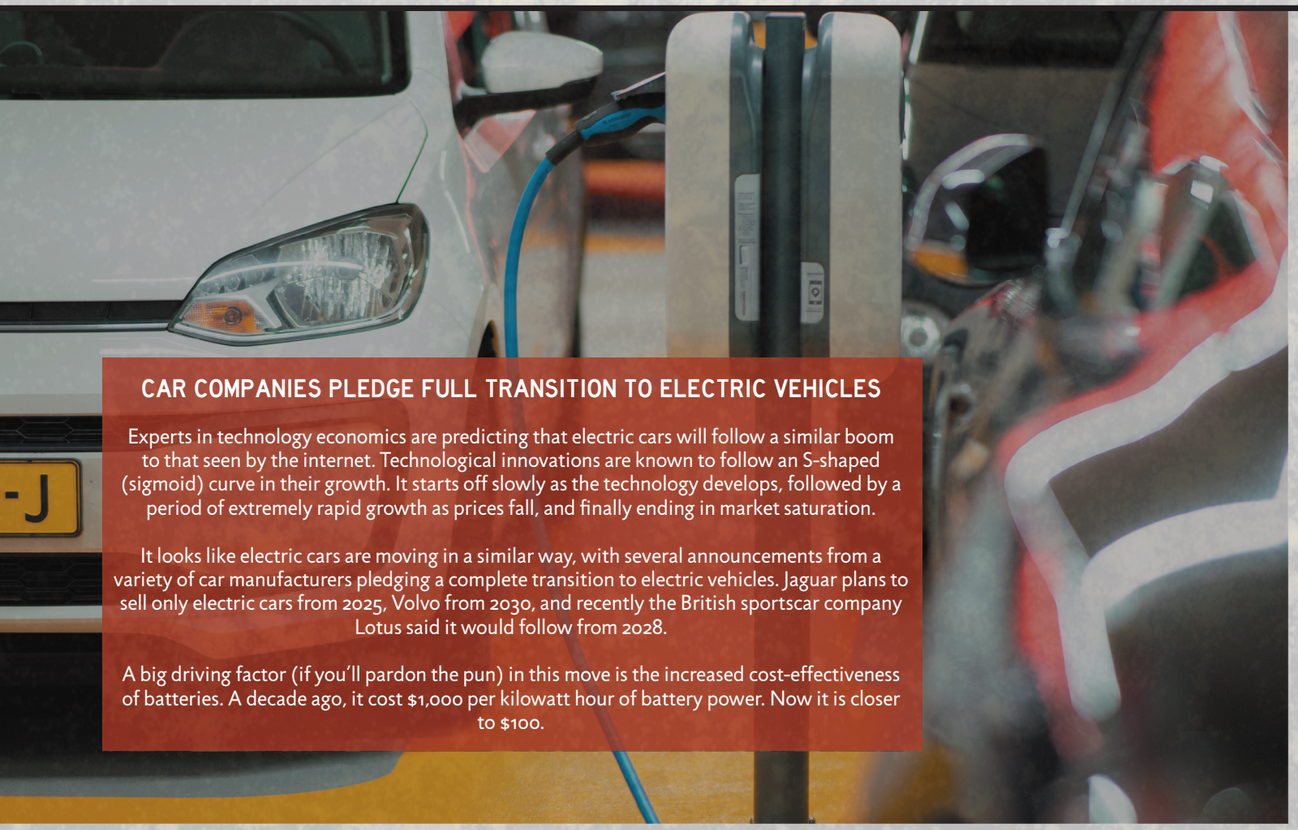
news.

Keegan Schroeder covers the latest.

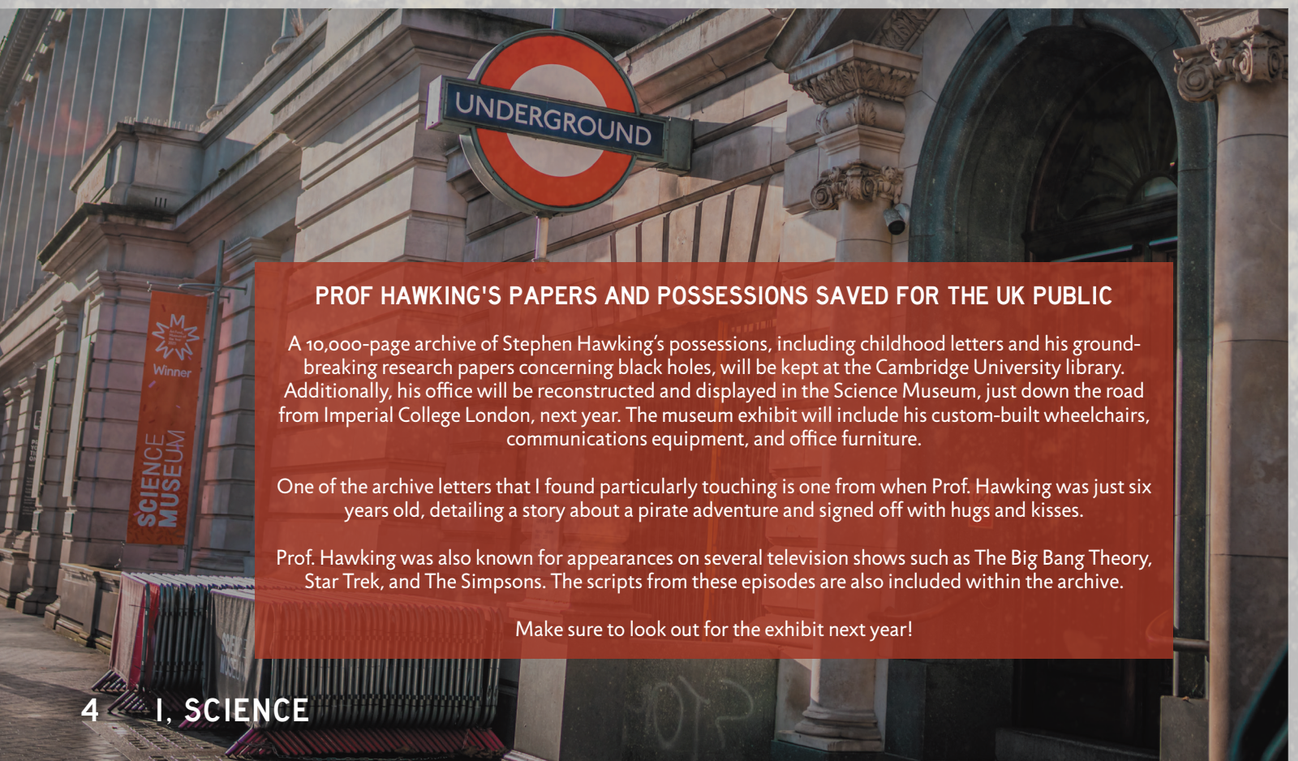


CAR COMPANIES PLEDGE FULL TRANSITION TO ELECTRIC VEHICLES

Experts in technology economics are predicting that electric cars will follow a similar boom to that seen by the internet. Technological innovations are known to follow an S-shaped (sigmoid) curve in their growth. It starts off slowly as the technology develops, followed by a period of extremely rapid growth as prices fall, and finally ending in market saturation.

It looks like electric cars are moving in a similar way, with several announcements from a variety of car manufacturers pledging a complete transition to electric vehicles. Jaguar plans to sell only electric cars from 2025, Volvo from 2030, and recently the British sportscar company Lotus said it would follow from 2028.

A big driving factor (if you'll pardon the pun) in this move is the increased cost-effectiveness of batteries. A decade ago, it cost $1,000 per kilowatt hour of battery power. Now it is closer to $100.



PROF HAWKING'S PAPERS AND POSSESSIONS SAVED FOR THE UK PUBLIC

A 10,000-page archive of Stephen Hawking's possessions, including childhood letters and his ground-breaking research papers concerning black holes, will be kept at the Cambridge University library. Additionally, his office will be reconstructed and displayed in the Science Museum, just down the road from Imperial College London, next year. The museum exhibit will include his custom-built wheelchairs, communications equipment, and office furniture.

One of the archive letters that I found particularly touching is one from when Prof. Hawking was just six years old, detailing a story about a pirate adventure and signed off with hugs and kisses.

Prof. Hawking was also known for appearances on several television shows such as The Big Bang Theory, Star Trek, and The Simpsons. The scripts from these episodes are also included within the archive.

Make sure to look out for the exhibit next year!

MARS ROVER PICTURES

You may remember reading about the landing of NASA's Perseverance rover in the last edition of I, Science. In March, another NASA rover named Curiosity captured a series of images on its 3063rd Martian day of operation that depict a new type of cloud. Mars clouds are usually formed at the planet's equator in the coldest time of year, when Mars is the farthest from the Sun. In the last Martian year, scientists noticed some clouds forming over the Curiosity rover earlier than expected.

This year, Curiosity was tasked with imaging these clouds from the moment they appeared. Previously observed clouds existed no more than 60 kilometres in the sky and were composed of ice. The clouds Curiosity has now imaged are at a higher altitude, where it's very cold, indicating that they are most likely made of frozen carbon dioxide, or dry ice. Colour images from the rover's Mast Camera, when taken just after sunset, catch the fading light, causing the clouds to appear to glow against the darkening sky.

I'd like to think that perhaps with the rapid advances in space exploration technology that are occurring all over the globe, a lucky future individual will get the chance to see these clouds with their own two eyes, an exciting prospect!

BACKGROUND ARTWORK:
JOANA VIVEIROS, ANXIETY GALAXIES IV

IMAGES, CLOCKWISE FROM LEFT:
MICHAEL FOUSERT, ELECTRIC CARS, UNSPLASH
JOHEN REDMAN, SCIENCE MUSEUM, UNSPLASH
CHRISTIAN LISCHKA SJ, ABSTRACT MARS, UNSPLASH

news & art.

Alienor Hammer draws parallels between an artwork and space exploration.

This week, Jeff Bezos announced that he will be on Blue Origin's first human flight next month on the New Shepard spacecraft, which will make him one of the first civilians to reach space. He plans to fly to the edge of space, to the boundary known as the Kármán line, which is 100km above sea level. Also aboard in the spaceship will be his brother, Mark Bezos, and the winner of the auctioned third ticket, valued at $2.8m.

New Shepard is a capsule-like spacecraft, fully autonomous, and can accommodate 6 people. It will fly to the Kármán line at a speed three times greater than the speed of sound, before falling back and deploying a parachute to reach the ground, a mere 10 minutes after its launch. The spacecraft has already safely made 15 successful test flights with no crew.

Blue Origin, a company funded by billions of dollars from Bezos, is a rival to Richard Branson's Virgin Galactic and Elon Musk's SpaceX. If the launch of New Shepard goes ahead as planned, Bezos will be well ahead in "billionaire space race".

This artwork by Shuqi Yang, titled "Spiritual Worlds" is ethereal, and reminiscent of the edge of space. What will these billionaires and their passengers participating in such suborbital flights find at the Kármán line? A dream come true, a feeling of rush and excitement, or just another outlandish experience for the rich?

ORIGINS UNKNOWN

Dave Warrell delves into what we currently know about the origins of life.

Life as we know it must have started. We have a reasonable idea of *when* it started – around 3.5 billion years ago. We have some theories about where it started – most likely geothermal vents or shallow pools on Earth. We know the ingredients that are needed: carbon, hydrogen, nitrogen, oxygen, phosphorous, and sulphur. We even know what they needed to form into: lipids, carbohydrates, nucleic acids, and proteins. And yet, despite over 100 years of research, we don't know *how* life started.

Life starting is a pretty difficult concept to get your head around. Previously, the origin of life was thought to have been an event. It was generally held that everything on prehistoric earth, before a critical point, was dictated by chemistry; elements created by nuclear fusion in stars combined to form compounds, and then, suddenly, a few of these compounds combined to form life. After this pivotal moment, there was biology. Non-living matter had given rise to life.

But this line of inquiry, how life spontaneously came into being, left us scratching our heads. Making the jump from simple chemistry to complex life is extremely difficult. A more gradual transition is less so. Scientists have moved away from the idea that there was a single event where non-living matter gave rise to a living system, viewing it instead as a process. This angle of approach required us to remove the boundaries between living and non-living, biology and chemistry. Life had to exist on a spectrum for this process to happen. The search began to identify processes that living things do, like replicating genetic information and creating amino acids, and think about how they could happen without the help of an organism.

> *Scientists have moved away from the idea that there was a* ***single event*** *where non-living matter gave rise to a living system, viewing it instead as a* ***process****.*

The processes that are necessary for life to happen are no longer inconceivable. We know the types of chemical pathways that create the molecules necessary for life. We have even shown how many of them could happen in space, without the help of Earth's hospitable environment. The issue now is agreeing on which process happened first. There is a multitude of different views, but there are two main camps. Some researchers believe that molecules which can self-replicate and store genetic information, like RNA, must have come first. Others believe that the kinds of cyclical chemical reactions which fuel our cells today must have preceded them.

'Genetics-first', or 'RNA world', refers to the belief that RNA was the first piece of the puzzle to fall into place. There are three things which make RNA an attractive candidate for the origin of life: it can store genetic information, it can speed up reactions that could have produced components of early cells, and it can replicate itself. Proponents of RNA world theory suggest that RNA was initially a jack of all trades, performing all these functions, until DNA took over the former and proteins took over the latter two. This property of self-replication is particularly crucial to the origin of life. A molecule that can replicate itself is no longer only subject to the forces governing chemistry and physics, it is also subject to natural selection. The molecules that replicate themselves most accurately, gain the most useful functions, and are the most resistant to degradation can thrive, paving the way for the evolution of life. This is seen by RNA world theorists as a smoking gun. But 'metabolism-first' theorists suggest RNA is too complex to be created from nothing; it would need to rely on an intricate series of reactions to be synthesised.

'Metabolism-first' proponents instead believe that a series of cyclical chemical reactions acted as the precursor to life. It was the energy stored and released by these reactions, like those observed in the Krebs cycle, that allowed life to begin. (That's right, the Krebs cycle – the thing that you probably tried to memorise at least once but instantly forgot – might have been fundamental to the development of life!) What is persuasive about this view is that many of the intermediate compounds of the Krebs cycle can be precursors to lipids, carbohydrates, amino acids, and nucleotides. If this cycle existed on primordial earth, it could have created all the necessary components for life. But advocates of RNA world suggest that chemical reactions are unlikely to have just set themselves up without the guiding force of natural selection, which requires a self-replicating molecule like RNA.

That's not the only rift that exists in the study of the origin of life. Different disciplines invariably bring with them different techniques, and this causes disputes. Biologists, for example, tend to approach the issue in a 'top-down' manner, beginning with the organisms we have currently, looking for possible clues and working backwards. Chemists, by contrast, tend to take a 'bottom-up' approach. They reproduce the types of reactions that we might expect to have happened on primordial earth to see whether molecules needed for life can be created. You might think that top-down and bottom-up approaches should be complimentary, but more often than not they fail to meet in the middle.

These are just two of many fractures in the scientific community studying the origin of life. Why are there so many? The problem that remains, which often goes unacknowledged, is that we have no definitive evidence of what actually happened. We have clues that exist in cells now, but that requires 3.5 billion years of working backwards, which is not an easy task. And we *can* create molecules necessary for life in experimental conditions. But many different experiments working under different assumptions have all managed to do so. We can't be certain that it was the exact conditions, or the exact reactions, which facilitated the origin of life.

The underwhelming reality is that all we can ever do is guess how life *could* have started. It's impossible for us to know how it began for sure. Unlike much of evolution, we don't have a fossil record. So, it will never be a case of *discovering* how life began, it will only ever be a case of agreeing. And it certainly seems that we have a long way to go. ■

> *The problem that remains, which often goes unacknowledged, is that* ***we have no definitive evidence*** *of what actually happened.*

BACKGROUND ARTWORK: JOANA VIVEIROS, ANXIETY GALAXIES V
OVERLAY: SHIVANI MATHUR, BRANCHING OUT

STRANGER THAN FICTION: WHAT WE KNOW (AND DON'T KNOW) ABOUT BLACK HOLES

Naomi Dinmore explains what current research can tell us about black holes and what is yet to be discovered.

Black holes – staggeringly huge, monstrously dense objects in space that devour anything and everything in their paths. Terrifying. Their existence was first predicted by Einstein in his **Theory of General Relativity** and have since been proven to exist thanks to the efforts of many scientists across the globe. Black holes have fascinated many from when they were first hypothesised. No wonder they are used so heavily in science fiction.

But how much do we actually know about black holes? And how much is just fiction?

WE KNOW...

...how they form. Black holes are formed when a dying star, many times greater than the mass of our sun, collapses under its own immense gravity, concentrating all its mass into a miniscule point. **Stellar black holes** are formed from stars over 5x the mass of our sun, **intermediate black holes** are formed from stars over 100x the mass of our sun, and **supermassive black holes** are formed when monstrous stars, millions of times the sun's mass, collapse and die. It is thought that there is a supermassive black hole at the centre of our galaxy. There are also **primordial black holes**, which are thought to have formed straight after the big bang at the beginning of the universe's formation.

WE DON'T KNOW...

...if there are other types. Stephen Hawking theorised that **mini black holes** existed, with mass much smaller than the mass of our sun. If they did exist, their existence would be extremely short-lived, and nobody has yet managed to observe or create one.

WE KNOW...

...how they die (ish). In 1971, theoretical physicist Stephen Hawking came up with the concept of **Hawking Radiation.** He predicted that black holes emit streams of energy in the form of waves and particles, gradually reducing its mass, and essentially **evaporating** the black hole. In 2019, Physicists managed to simulate the effects of a black hole and show that this radiation was emitted.

WE DON'T KNOW...

...this for sure. At the moment, Hawking Radiation is still just a prediction.

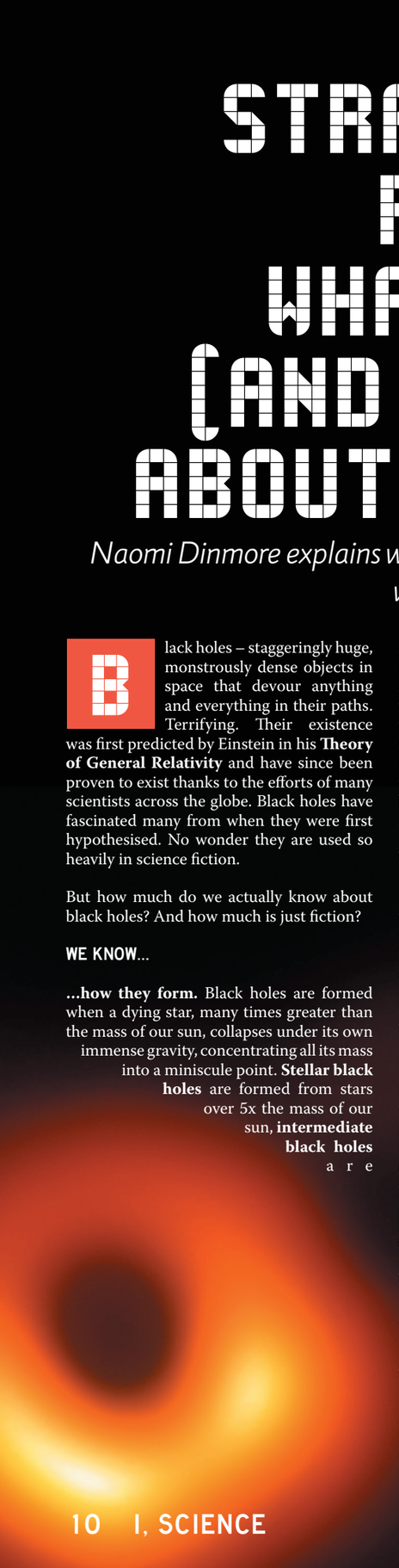
WE KNOW...

...what they look like. In 2019, with the help of computer scientist Dr. Katie Bouman and a huge international effort, scientists managed to take a photo of a black hole, using many different telescopes around the Earth to effectively make one giant telescope. They obtained a picture of the shadow of the supermassive black hole at the centre of the M87 galaxy. It is 6.5 million times the mass of our sun and over 55 million light years from Earth.

Black holes are formed when a dying star, many times greater than the mass of our sun, collapses under its own immense gravity, concentrating all its mass into a miniscule point.

WE DON'T KNOW...

...what they look like. Amazing as this image is, a black hole has such immense gravity that no light can escape its pull. The point after which we cannot see is known as the **Event Horizon.** The speed required to escape this boundary is greater than the speed of light, which is, as far as we know, the upper limit for the speed of any matter or energy in the universe. Because we require light to see things, what a black hole looks like beyond its Event Horizon is still a mystery.



We can measure properties of a black hole – their mass, their charge, and their angular momentum, but we don't know what happens to matter beyond the Event Horizon.

WE KNOW...

...their effects on space and time. Imagine putting a book on your mattress. It bends it slightly, right? Now imagine standing on your mattress in the same place. It bends it much more, because a larger amount of mass is concentrated in the same area. That's essentially how gravity works. The larger something's mass and density is, the more it bends space and time: **spacetime**. At the centre of some black holes, there is thought to be a **singularity**, which is an infinitely small point with infinite mass. It would bend spacetime to a point at which it could not meet itself.

Because of black holes' huge effects on spacetime, they were used to prove the existence of gravitational waves in 2016. When two black holes collided, they sent huge ripples through space that were detected by LIGO (The Laser Interferometer Gravitational-Wave Observatory, built especially for detecting gravitational waves), confirming yet another aspect of Einstein's Theory of General Relativity.

WE DON'T KNOW...

...what they're made of. We can measure properties of a black hole – their mass, their charge, and their angular momentum, but we don't know what happens to matter beyond the Event Horizon. To know that, we would need to understand **quantum gravity**, which is a branch of physics studying how gravity affects very small subatomic particles. Currently, the main branches of modern physics: quantum physics and relativity, are not quite yet compatible with each other. Quantum gravity is an area of research which tries to create a **theory of everything**, to unify these two fields. Although it is a growing area in theoretical physics, we still just don't know enough yet to know what black holes are made of.

WE KNOW...

...what happens if you get near one. The closer you are to a black hole, the greater the acceleration from its colossal gravitational field. So much so that if you were approaching feet first, your legs would be accelerated much faster than your head, stretching and stretching you out until you were just a string of atoms. This process, rather aptly named, is known as **spaghettification**. Sounds painful.

WE DON'T KNOW...

....what happens once you're past the point of no return. What is beyond a black hole? Some have postulated that black holes could actually be wormhole bridges – which is where spacetime is ripped, sort of creating a hole to another point in spacetime. This would make travel to a galaxy far far away much easier. Some theoretical physicists have hypothesised that black holes themselves contain different universes, or that our whole universe is actually inside one gigantic black hole in a series of **multiverses**. But, we still just don't know. It remains a mystery. ■

ARTWORK: FEDERICA RAGUSEO, BLACK HOLES FROM A DIFFERENT PERSPECTIVE
PHOTO: EVENT HORIZON TELESCOPE COLLABORATION

SCHRÖDINGER'S CAT: INVITATION PENDING

The science behind the fear of the unknown is complex. Ebony Gunwhy investigates.

Cold, clammy pearls of perspiration cluster above my brow. A contradictory sensation, equal parts hot and cold. My irregular breathing invites pangs of nausea, mind flitting agitatedly as I attempt to remain on the saner side of fear. The conduit for my fear? The computer monitor, where an open PowerPoint sits alongside Microsoft Teams. Awash in chit-chatter and pleasantries through staticky mics, the growing number of attendees does nothing to placate me. Yet, what good is a presentation without its audience?

I fear the unknown. A fear caused by the mystery of not knowing how people will react to my work, or whether I will blunder, embarrassing myself. Fear of the unknown (FOTU) is a common accompaniment to mystery in life. Be it the heart-thumping horror elicited by strange noises in the night, or the perhaps lighter – yet still persistent – uneasiness such as my own, caused by an inability to govern social ridicule.

Indeed, FOTU is an inherent trait of evolution. It is our own inbuilt, defence system, alerting us to possible dangers. At the centre lies the amygdala - the fear hub of our brains – which is typically activated through two distinct, parallel pathways. Upon perceiving a threat, emotional stimuli trigger the thalamus, from here travelling onward to the amygdala either directly (the 'thalamo-amygdala' pathway), or indirectly, making a pitstop at the cortex, before continuing on its journey (the 'thalamo-cortico-amygdala' pathway).
The thalamo-amygdala pathway causes that initial palm-sweaty feeling of dread, spiking our nervous systems before full circumstantial comprehension. The longer, thalamo-cortico-amygdala pathway awakens our rational thinking, helping to determine whether we have actually detected a threat. Imagine you are home alone, walking down the hall on the way to bed. Then, suddenly you see a hidden figure in the corner of your eye. Heart skipping a beat, the bunching of your muscles imposes a momentary embargo of bodily motion. The thalamo-amygdala pathway has now been activated. Upon closer inspection, you discover that the purported intruder is actually your coat, strewn haphazardly across the bannister. Slowly, your thudding heart alleviates as you place the coat in the closet, where it may never scare you again. This rationalisation of thought occurs within your cortex, during thalamo-cortico-amygdala activation.

In regulating FOTU, the cortex endures a cognitive dance with the devil: although it may help tame our irrational fears, it may also cause us to over-rationalise. What might have happened if that strange figure had been an intruder, but you did not turn around because you reasoned with yourself it was just your coat? Conversely, the cortex can also work conflictingly to exacerbate our fears. Sitting in the dark with no evidence dissuading otherwise, we may convince ourselves that that bump in the night was, most definitely, a monster.

Facing FOTU is a large part of being a scientist, but where exactly is the line between rational and irrational fear? The decisions scientists make often affect many lives besides their own. Therefore, it is particularly important to consider the degree of fear influencing those decisions. Excessive FOTU can hamper the work of many scientists. Imposter syndrome, for example, casts uncertainty over someone's place and talents within a workplace. That anxiety is common though, especially amongst graduates and early stage researchers. Learning is a never-ending process for everyone, even proclaimed experts have the ability to be mistaken.

Additionally, scientific discoveries can evoke fear from society, instigating a severity of threats against scientists, from petty criticisms to severe harassment. Charles Darwin, the father of evolution, initially excluded human evolution in his work, 'On the Origin of Species'. Natural selection prompted questions disruptive to society, regarding teleology and the continued existence of humanity – will we remain the dominant species, can we also face extinction? Through FOTU, a range of societal, cultural, and political issues are perpetually imposing boundaries on scientific progression, discouraging scientists on the basis of their research and xenophobic discrimination.

It is not always unwarranted fear, however, leading scientists astray. In reality, the mystery of Schrödinger's cat is not simply a question of 'dead' or 'alive', there are a myriad of prospects to consider. For example, if the cat is alive, what are the odds it will be viciously angry, attacking the first person it sees? Or what if it spreads a deadly disease capable of total human extinction, irrespective of being alive?

At the 1945 Trinity Test, some of the world's most reputable scientists failed to correctly predict the Atomic bomb's magnitude in explosive yield. In a betting pool, Robert Oppenheimer himself grossly underestimated an equivalent of 300 tons of TNT, with the actual yield estimated closer to 20 kilotons. General Groves stated, "The test was successful beyond the most optimistic expectations of anyone", yet surely, in both under- and over-estimation of results, failure is implicit, as opposed to success? While investigations into the complete after-effects of Hiroshima are ongoing, there exists an extensive awareness of its devastation. The radiological repercussions of the initial Trinity Test itself, remain somewhat ambiguous. With insufficient evidence, how can appropriate assurances be drawn from experiments, validating them for further use?

> *Then, suddenly you see a hidden figure in the corner of your eye. Heart skipping a beat, the bunching of your muscles imposes a momentary embargo of bodily motion.*

Albert Einstein and Leo Szilárd, petitioned for bombing deployment caution, to which Edward Teller responded, "The accident that we worked out this dreadful thing should not give us the *responsibility* of having a voice in how it is to be used." Raising the question of accountability in science: To what extent are scientists responsible for the way another uses their research? Do they not have the natural or human *right* of having a voice in how something is to be used? If your moral compass is telling you something is wrong, does it not then become your *responsibility* to voice that opinion? As part of the social contract?

A lack of FOTU or complacency contributes to being at least partly accountable for scientific consequences. Capitalising on FOTU instead in these situations might lead to improved governance in disaster prevention. Nevertheless, volatile mixtures of time pressure, funding, and worry of appearing alarmist often result in circumventing caution. Premeditating future prospects, how can we successfully navigate FOTU?

COVID-19 vaccinations are currently high on the minds of many. Amidst the harrowing pressures of time and money, critical FOTU application is crucial for ensuring optimal vaccine efficacy. Too much caution may hinder the rate of vaccine production. Too little may leave us juggling alternative problems, in addition to the virus. A scientist may reduce the quantity of unknowns through experimentation and carefully calculated risk ratios; ultimately alleviating FOTU's leverage upon decision-making abilities. Issues such as vaccine distribution require scientists and politicians to work together, providing transparency for the public. For example, scientists understand that if low- and middle-income countries are left in jeopardy, we run increased risk of new, vaccine-resistant strains developing. It is a scientist's duty to disclose this information; the onus is then on the politician to listen to that advice.

> *Constantly changing cultures and societies, alongside an exponential expansion in the unearthing of novel technology only opens up different avenues for fear.*

There is a logical assumption that the more we discover, the more we will understand life's mysteries, and thus reduce our FOTU. However, constantly changing cultures and societies, alongside an exponential expansion in the unearthing of novel technology only opens up different avenues for fear. Different unknowns to fear *and* ways to fear the unknown. All around the world, AI technology is creating a plethora of opportunistic solutions in healthcare, transport, industry, and many more sectors besides. But exactly how far down the rabbit hole is far enough?

We can support each other as scientists by remaining vigilant on these matters, constantly voicing any scientific or moral quandaries; to preserve scientific research integrity, and better protect Earth along with its many inhabitants in the process. So that if, and whenever we do decide to peer inside Schrödinger's box, we are the most prepared we possibly can be. ■

PHOTO: HOLLY MOORE, CROSSING

THE SERIAL KILLER GENE: MYTH OR TRUTH?

Ushashi Basu explores the mystery behind whether there really is a 'serial killer gene'.

In episode 21 of the third season of the American teen drama show *Riverdale*, protagonist Betty Cooper learns that she possesses the "Serial Killer Gene", which, according to her sister Polly, is perhaps the reason why she smashed the skull of their childhood cat, and also why she dons her "Dark Betty" personality. Polly also tells her that the gene has loomed over the family for generations.

As a scientist and a diligent fact checker, I promptly Googled the gene that caused so much massacre in the show – and was disappointed to learn that there is no such thing as the Serial Killer Gene.

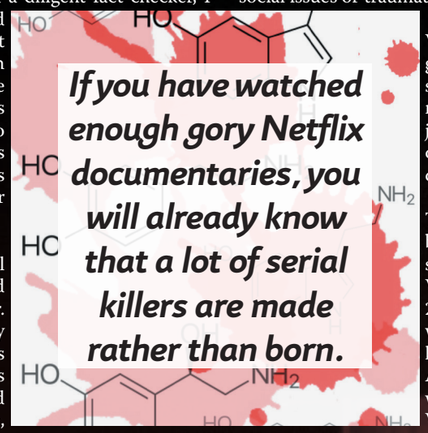
It was not all misrepresented science, however. The gene Polly Cooper was referring to is commonly called the Warrior gene, and among scientists, the MAO-A gene.

The MAO-A gene codes for the enzyme Monoamine Oxidase-A (MAOA), which is responsible for the modification of amine-based neurotransmitters such as serotonin, dopamine and noradrenaline. The enzyme replaces the amino group from the above-mentioned molecules with a different functional group. Low activity of the enzyme leads to accumulation of the neurotransmitters, causing what is known as Brunner Syndrome.

What, you may ask, does the reduced activity of this enzyme have to do with being a warrior?

Research has shown that individuals with low enzymatic activity of MAOA (due to a mutation in the gene) tend to develop antisocial behaviour. When coupled with ostracism and high amounts of provocation, this behaviour can reveal itself as aggression. Other symptoms of Brunner Syndrome include sleep disorders, lower than average IQ and frequent mood swings. Violent behaviour as a result of one or more of these symptoms is common.

This doesn't necessarily mean that anyone who carries the mutated MAOA gene will resort to murder when irked. Aggression, like all other social behaviours, is a multidimensional and complex concept, and more often than not, there are other factors that influence destructive tendencies, including external stimulation (such as maltreatment as a child) and underlying neurological issues. The MAOA gene variant, if present, tends to mostly amplify violent activities, caused by other persistent social issues or traumatic experiences.



If you have watched enough gory Netflix documentaries, you will already know that a lot of serial killers are made rather than born.

Whether this faulty genetic composition should be used, or rather misused, to justify murderous crimes, is a matter of debate.

This is highlighted by the criminal case surrounding Bradley Waldroup, who, in 2006 attacked his wife and her friend, killing the latter. Although there was evidence of Waldroup's actions being intentional and premeditated, and he admitted responsibility, when the defence showed that he possessed a particularly unusual variant of the MAOA gene, the jury was swayed, and Waldroup was given a reduced sentence of 32 years in prison. Jurors later stated that they had factored Waldroup's abusive childhood into their decision, but the neuroscientific evidence definitely played a major role.

But Waldroup had still committed homicide, and it was not in self-defence. Should he have received the sentence he did?

Theoretically, the altercation between Waldroup and his wife and her friend could have been avoided, because aggression, genetic or not, can be controlled. Those with a predilection for violence and anger can be taught to manage their emotions, and those in close proximity to angry people can be trained in identification of violent behaviour, and communication and de-escalation methods.

Reality, however, is more nuanced than that, and the above scenario is a difficult conundrum to disentangle. Not only is the science behind MAOA's phenotypic expression relatively new and untested, but in court, scientific evidence is presented in conjunction with other arguments and for outsiders, it is difficult to understand which bit of the evidence is particularly decisive.

There is also something known as the neutralising effect, which allows the verdict to go one of two ways: one wherein the defendant is shown some mercy because they are a victim to their flawed biology, and the other, where they must be restrained or their biology will continually push them towards crime. Which route the system takes depends on the particulars of the case.

The role of scientific evidence in the courtroom, the extent to which it should influence the justice system and the ramifications in society is a complicated subject, and a discussion of this belongs in a different exposition, for another time.

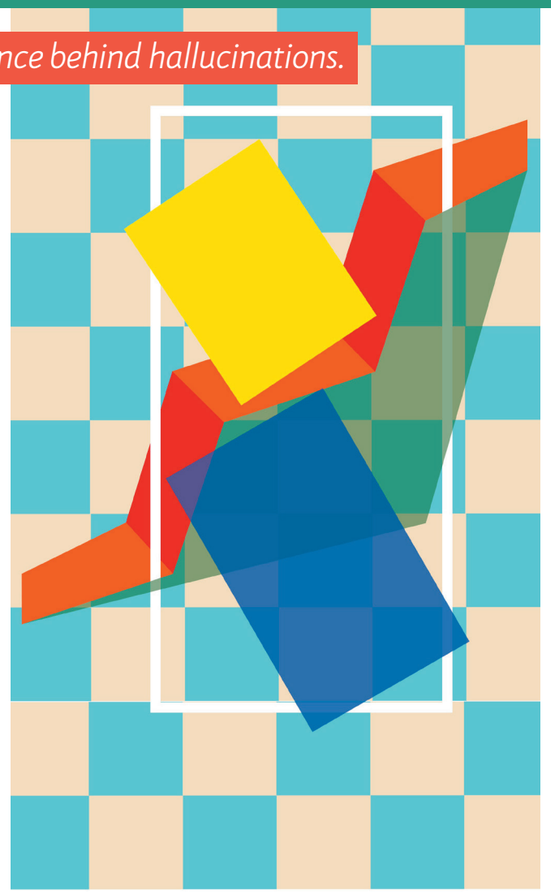
In conclusion, although there might be aggressive people in the world who possess a mutated MAOA variant, there are many more who don't and yet, are inclined to anger and violence. The "Warrior Gene" is just one of many explanations for why someone might have murderous tendencies. Moreover, there are some people who, despite being carriers of the MAOA mutation, do not resort to aggression. And if you have watched enough gory Netflix documentaries, you will already know that a lot of serial killers are made rather than born.

And as for the genetic accuracy of the *Riverdale's* storyline, I'd suggest not taking any of it too seriously. After all, there are now Moth Men on the show. ■

PULL QUOTE ART: USHASHI BASU, UNTITLED
PHOTO: DEBRA POLLARINI, MEANWHILE I'M BREEZING OUT OF FORBIDDEN GARDEN MEMORIES

MYSTERIES OF THE MIND

Julia Borowicz investigates the science behind hallucinations.



Have you ever seen, heard, or felt something that you weren't completely sure existed? You probably couldn't figure out if it was real. You probably couldn't believe your own senses. The root of the problem is hallucinations - perceptions of nonexistent objects or events accompanied by the sensory realness of the experience. Despite the common stigma that only people suffering from mental diseases or psychedelic drug users experience hallucinations, it has now been proven that they can also happen episodically in everyone's life.

Around 15% of healthy people experience so-called 'low-level' hallucinations, which can vary from an imaginary notification beep on your phone to someone saying your name in the street. That has probably happened at least once to all of us. Surprisingly, despite such events being so common, scientists are still not completely sure about the mechanisms behind them. Some ideas about these strange affairs arise from the medications used in their treatment – antipsychotics. This group of drugs works by blocking excess dopamine – a potent neurotransmitter responsible for numerous brain functions including reward, pleasure, and motivation. Due to the efficiency of antipsychotics in treating diseases such as schizophrenia, scientists have concluded that there is a strong link between hallucinations and excess dopamine.

Personally, I don't think I've ever experienced anything like a hallucination. What I fear the most is that, when it comes, I won't realize that what I'm experiencing is not true.

Excess dopamine might not be the only reason why our brains are prone to hallucinations. What else is contributing? Well, our brain is lazy. It makes shortcuts to make sense of the vast amounts of information we are bombarded with every day. The brain comes to conclusions about the world around us based on probabilities of what is likely to occur and on what it's used to. This is the basis of the Bayesian theory of how we perceive the world. Most of the time the shortcuts that our brain takes are true to reality, however, the probability is never 100%. Mistakes happen.

Personally, I don't think I've ever experienced anything like a hallucination. What I fear the most is that, when it comes, I won't realize that what I'm experiencing is not true. It's scary to think we can't always be certain of our senses, of our perception. When the ideas and the definition of hallucination came around, an important issue arose in the field of philosophy called 'The Problem of Perception'. If such errors can occur in our perception of reality, can we really consider it to be an openness to and an awareness of the world? Not entirely.

The problem of perception tries to solve the uncertainties behind the relationship of sense-experience to material objects. Traditionally, it's been viewed as logical, and it inferred that beliefs about objects can be made from immediate experience. However, this is not the exact knowledge about the object. These are just the assumptions that have been created through the experience. For our beliefs to have any secure foundation, they need to be derived from the pure knowledge of reality, not solely from the process of experiencing it. It's right here where we encounter the crossroads about the process of relaying information to our brain through perception. Some philosophers think it's all based on fallacy and illusion while others are much less skeptical, finding reassurance in scientific transcendental hypotheses, and even proving the existence of electrons and chromosomes invisible to the naked eye. Nevertheless, the occurrence of hallucinations hasn't helped to put this discussion to an end.

Mistakes of our brain, errors in our perception, a sudden excessive release of dopamine. Hallucinations can be explained in different ways, but no matter the definition, they still lead to disturbing

questions – can we always trust our senses? Can we believe what we see, hear, or feel is real? We don't have any other option, nevertheless, we need to be aware of the uncertainty that lingers in everything we experience. Our perception can be based on one great illusion which expands to each one of our senses. Our brains can make shortcuts out of sheer laziness showing us only snippets of the true reality. Even despite all these facts, I still choose to form my knowledge of the world based on what I experience. Maybe one day the world will surprise me. ■

ARTWORK: CHAOYU TANG, UNTITLED

CRYPTOZOOLOGY, I HARDLY KNEW YE

Jay Balamurugan considers whether there is science in cryptozoology, and what this means for the discovery of new species.

There are creatures that science refuses to recognise.

That was the tagline of Animal Planet's oddball found-footage horror mockumentary series *Lost Tapes*, which aired on the channel from 2008 to 2010. A remarkably bizarre foray for the wildlife-focused channel, which until then had not ventured particularly far into the realm of fiction programming. The premise of each episode was this: an individual or group of people encounter a cryptid – an animal of indeterminate origin and unsubstantiated existence – and happen to film it, with said encounter often ending in tragedy, the creatures caught in glimpses between blurry shots of people running through the woods. Interspersed between these fictional narrative segments were interviews with scientists and folklore experts, describing the history and, uh, science behind these creatures. The cryptids featured ranged from the more plausible, such as oversized anacondas, to the more outlandish, such as the Yeti, to the absolutely bonkers, such as vampires and lizard-men.

Now, all cards on the table, I was a huge fan of *Lost Tapes* when I was in my early teens. What kid would shy away from a spooky little adrenaline-fueled endeavour into the unknown? The fact that it aired on the same network which, at the time, also presented some of the most prestigious documentaries out there, such as BBC's *Planet Earth* and *Life*, lent an odd credence to the viewing experience. It felt *real*. Despite that, it was not particularly… great. The writing was all over the place, the acting was about as dynamic as a stale baguette, and most relevant to this article, the science of cryptozoology, as depicted in the show, was not conveyed in the best way. It was popular however, and that led to Animal Planet greenlighting a whole host of cryptozoological programming across the early 2010s – which were of, well, declining quality. This topic could fuel a whole selection of articles, but instead of going in depth into that bizarre time a major *documentary* broadcasting station decided to produce a fictional film about *mermaids* (for some reason?), I am going to talk about that initial fascination with cryptids and how cryptozoology straddles the line between coherence and ridicule.

Science does not refuse to recognise anything, because it is not an institutional body or an individual with motivations and convictions.

"There are creatures that science refuses to recognise."

That tagline was played at the start of each episode of Lost Tapes, and anyone who has had any experience with science would likely roll their eyes at it. Of course, that is simply not how science works. Science does not refuse to recognise anything, because it is not an institutional body or an individual with motivations and convictions. It lacks an agenda – which is often something the more vitriolic cryptozoologists tend to use as a scapegoat to facilitate their notions of the existence of creatures beyond our current understanding. 'Bigfoot isn't real? *Of course* you'd think that, the scientists are covering it up.'

That all being said, I would like to clarify: I am not just writing this article to roast cryptozoology in a thousand words or so, as entertaining as that might be. I am quite a fan of the concept of the study of undiscovered creatures. There is merit to the idea. After all, just because the most high-profile cryptids out there have little backing does not mean all of them are purely myth. Sure, it is pretty much certain that Loch Ness is not the home of a behemoth remnant plesiosaur. Absolutely, there is very little chance that 10-foot-tall humanoid primates roam the Himalayas. There are, however, cryptids which have a reasonable chance of being discovered – and some already have been in the past.

Right up until the late 20th century, evidence of the giant squid was scarce enough that many thought it to be little more than the fable of the Kraken, passed on from sailor to sailor. The okapi, or forest giraffe, was only recognised as a genus of its own when European scientists found parts of one on sale in a market – despite the locals having told them for a good long while that, yes, these were real animals that they had experience with. Gorillas were once only known as 'tribes of monstrous hairy men' and were nothing more than myths, except to native peoples who had long been familiar with the species. Green anacondas and reticulated pythons were both thought implausible to exist by Western researchers, despite communities in the Amazon and Southeast Asia respectively having strong environmental and cultural relationships with them. The same can be said for the Komodo dragon, the platypus, the Nile crocodile, and the spider monkey, among others. A proportion of the public still refuses to believe that narwhals exist.

Notice a pattern? You may think that these are all animals that live in deep, isolated parts of the world. While true to an extent, I would argue that is not why they were once cryptids. Distance and isolation here are somewhat relative. Relative to what? I thought about how to phrase my answer to that question for a good while, but really, there is no point in beating about the bush. It is relative to Europe.

These are all animals that were already well known by local people – save for a couple exceptions, like the giant squid (unless you subscribe to the notion that there are local people 1000 metres down in the North Atlantic). Beyond that, many were known to local *science*. These were not just animals found in mythological tapestries, like dragons, but had been studied and interacted with by native people. While aboriginal Australians may have had their own share of cultural cryptids, like the abstract Bunyip, there was a clear distinction between those legendary beings and those creatures which were more tangible, like the echidna and platypus. So why did Western scientists find it so hard to distinguish between the two? That is a question with a less straightforward answer, and one with a lot of nuance and even more baggage. The nature of science as being quite Euro-centric and colonial, especially over the course of the last few centuries, has resulted in this nearly subconscious bias arising in any form of scientific endeavour which involves the rest of the world. There were really not an awful lot of European cryptids-turned-real-animals over the 20th and 21st centuries, unless you count the odd big cat sighting in the UK that turned out to be a particularly chunky tabby. Western scientists tended to only value their own colonial brand of science, and it led to some failings within zoology as they ignored well-documented research in favour of their own preconceptions. The only real animals were the ones they decided to recognise, and of course, animals at home were those that were familiar and so were not cryptids. There is nuance here, and there are examples of explorers and scientists taking the opposite approach, but the bias towards Western confirmation may have altered the global perception towards cryptozoology.

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So, what does this say about Mothman? Or Nessie? Or the Yeti? Or the Chupacabra? Or the Yowie? Or the-

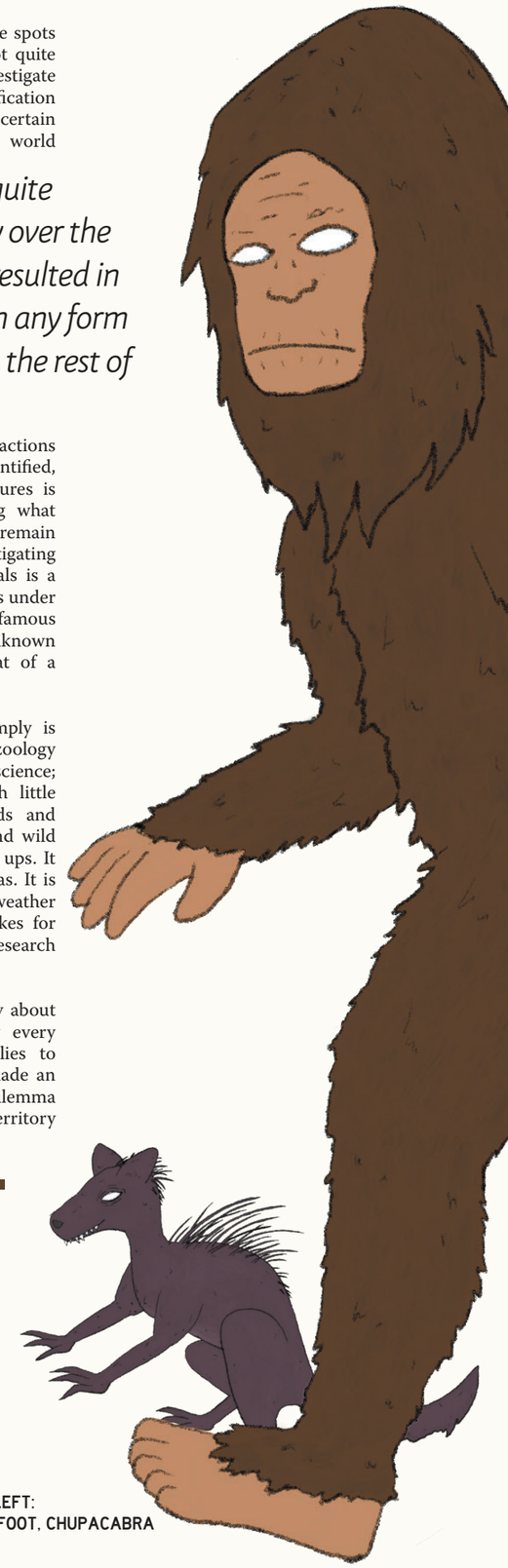
You get the point. There are hundreds of 21st century cryptids. At least 50 of them have feature-length horror films dedicated to their spook-tacular nature. Am I saying that there are real anomalous animals here that have been kept hidden due to scientific negligence or cultural biases? Well, no. Mothman? Probably a large sandhill crane misidentified by drunk teenagers. Nessie? Likely a conglomerate collection of decent hoaxes and some occasional sightings of sturgeon or Greenland sharks. A lot of these cryptids start off innocently enough as the odd unidentified fish or bird and snowball rapidly for a few key reasons. The historical distrust of Western scientists towards native peoples and their experiences with local fauna has led to a climate where cryptozoology has been given more credibility than is necessarily due. The notion of incredible animals having been hidden for so long without discovery has been perpetuated when it simply is not always true: gorillas were never *hidden*. Local tribesmen knew about them for as long as they existed in that environment. Neither were okapi, or Komodo dragons, or any of these other animals. They were only cryptids to the West.

Cryptozoology has merit. If someone spots a beetle or a lizard that they do not quite recognise, it is more than valid to investigate further to determine their classification within the wider tree of life. If certain cultures in different parts of the world have documented evidence of interactions with species that have not been identified, talking with people from said cultures is a clear first step in understanding what those animals might be and if they remain in the local ecosystem. Even investigating old photographs of unknown animals is a perfectly scientific process which falls under cryptozoology – this is how the infamous De Loys ape photograph of an unknown primate was determined to be that of a spider monkey.

There is *some* science here. It simply is not enough to rebrand cryptozoology as anything more than pseudoscience; too much of it is individuals with little understanding of research methods and heavy biases making exaggerated and wild claims about conspiracies and cover ups. It is movie monsters and shaky cameras. It is thin thread and chicken wire. It is weather balloons and blurry coyotes. It makes for exciting television and destitute research articles.

Now, that wraps up all I have to say about that. Notice, however, that nearly every argument I have made here applies to *terrestrial* creatures, and I barely made an attempt to explore that giant squid dilemma any further. Life on land is familiar territory – it is more explicable.

The ocean holds *far* stranger things. ■



ARTWORK, CLOCKWISE FROM LEFT: JACOB GABLE; MERMAID, BIG FOOT, CHUPACABRA

THINGS THAT GO ZZZ IN THE NIGHT: THE MYSTERY OF SLEEP

Ever wondered the reasons why we need to sleep?

Stephanie Greed investigates.

We spend around a third of our lives asleep, but scientists are still unsure why. However, in the last decade there has been a push to get a better understanding of the importance of a decent night's sleep, and the consequences when we don't.

Since the industrial revolution, sleep has been considered a waste of time, with adages such as 'money never sleeps' and Margaret Thatcher's 'sleep is for wimps' after reportedly getting by on four hours a night. While we intuitively understand the effects of not eating, feeling hunger as an evolutionary protection mechanism, the effects of not sleeping, other than feeling tired, are less well known and can be equally as serious.

We are all familiar with feeling tired, groggy and irritable after a night of poor sleep. However, the consequences may be even more serious than just those side effects: a tired person will have a significantly poorer memory, creativity and judgement, a worse ability to problem solve, and increased impulsiveness. Pulling an all-nighter leads to a decrease of around 40% in the ability to learn and make new memories, the difference between acing an exam and barely scraping a pass. Things get even more worrying with prolonged periods of poor sleep, with an increased risk of obesity, cardiovascular disease, cancer and mental health imbalances. The effect of sleep on our physical health is beginning to be noticed by global public health agencies, with shift work now being considered a carcinogen by the World Health Organisation.

There are many theories as to why we sleep, which go in and out of fashion as more evidence is unearthed about the physiological effects of sleeping poorly. Three of the main theories being discussed at present are:

ENERGY CONSERVATION

In historic times, when food was scarce, shutting down the body for the hours where it is least efficient to search for food would save valuable calories. However, research shows only around 100 kcals are actually saved in comparison with staying sedentary for these hours, the equivalent of one piece of toast.

RESTORATION

This is one of the oldest explanations, whereby all that is used or lost in the body during the wear and tear of the day can be restored, rebuilt and replaced overnight. Recent evidence supports this theory, as many genes associated with muscle growth, tissue repair, protein synthesis and the immune system are switched on mostly, or in some cases only, when asleep at night.

BRAIN PLASTICITY

This theory proposes that the brain is developing, processing and consolidating ideas and memories overnight, by refreshing and reorganising its contents without interfering with our waking thoughts. Sleep is known to aid the learning process, by both preparing your brain to make new memories before learning takes place and cementing those memories in long-term storage afterwards.

The effect of sleep on our physical health is beginning to be noticed by global public health agencies, with shift work now being considered a carcinogen by the World Health Organisation.

The theories of why we sleep tend to converge on the idea that the main organ that reaps the benefits of a good night's sleep is the brain. In fact, studies have shown that some areas of the brain are more active when we are asleep than awake. Brainwaves in deep sleep peak in pulses of electrical activity which are used to shift memories from short term to long term memory banks. Connections within the brain also appear to undergo a reorganisation, with important memories being strengthened and connected together to create a vast network of knowledge and memories, whereas the less important connections are pruned. This network can then be drawn on to more effectively tackle any problems that arise in daily life. Also, the brain is a high consumer of energy during the day and so produces a lot of metabolic waste, sleep sets aside a time for all this potentially harmful waste to be flushed out.

The implications of a disrupted sleep pattern on mental health are considerable. The mutation of genes associated with sleep have been shown to predispose a person to mental illness. The significance of the overlap within the brain between systems associated with sleep and mental health is still a significant area of research. Studies suggest a feedback loop is present between the two: sleep disruption precedes and exacerbates certain types of mental illnesses which in turn can result in further difficulty in getting a good night's sleep. Dreaming, one of the great mysteries of sleep, only happens in deep sleep and can help a person process memories, trauma and emotions from their waking life. This can have significant benefits to a person's mental health.

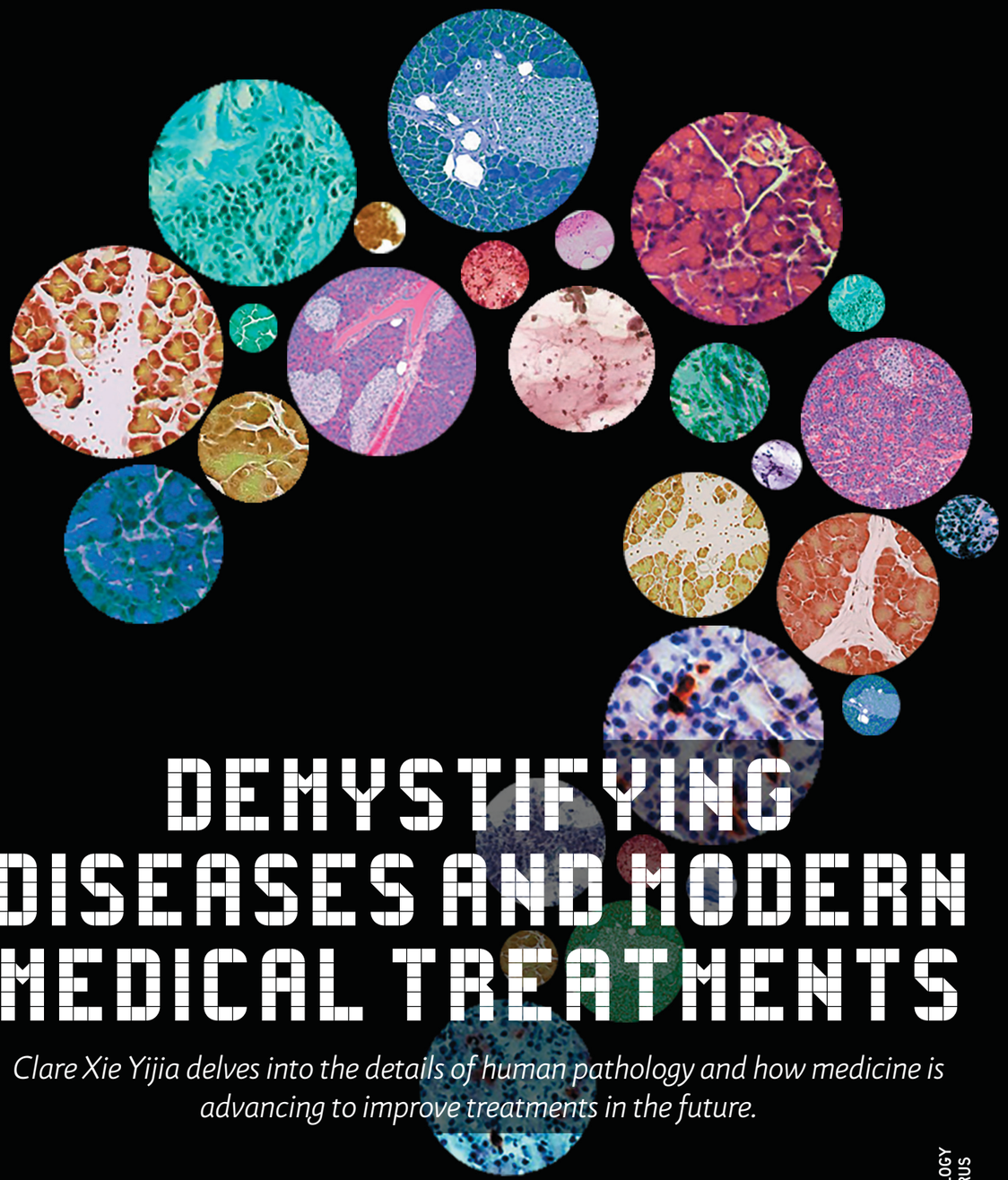
It is important to note, however, that as with many health and wellbeing-related scientific discoveries, the implications of poor sleep can be sensationalised. The popular science book 'Why We Sleep: The New Science of Sleep and Dreams' by Matthew Walker is a comprehensive and compelling analysis of the scientific research on the effects of sleep on a person's mind and body. This #1 Sunday Times and New York times bestseller is eye opening for those who read it in the belief that sleep is a luxury or a nuisance that would ideally be avoided. However, scientists have suggested the manipulation of the data on sleep in the book may not be entirely fair, favouring scaremongering tactics about how not getting 8 hours a night dooms a person to a shorter lifespan full of failure and mediocrity.

Despite variation in how harmful a lack of sleep can be on a person's physical and mental wellbeing, it is undoubtedly important. Therefore, it is crucial to know the ways in which we can improve the length and quality of our sleep. Some we may already know, for example avoiding caffeine, alcohol, and bright screens, and ensuring your bedroom is cool and dark. Physical activity is an excellent way to maintain your physical and mental wellbeing but should be avoided in the hours just before going to sleep. Added to this, it is beneficial to establish a regular sleep pattern which includes waking at the same time on weekdays and weekends. Finally, if you struggle with sleeping, it is better to avoid naps in the afternoon or evening, remove any visible clocks from the bedroom and avoid lying awake for a long time in bed but instead leave and do a mindless task elsewhere until you feel tired.

Getting a good night's sleep may be the secret weapon to a happy, healthier life; to quote the fantasy novelist Jim Butcher, 'Sleep is God. Go Worship.' ■

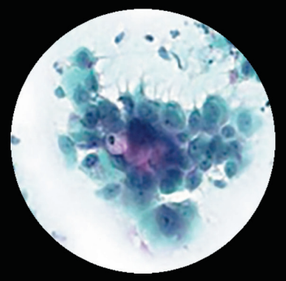
Brainwaves in deep sleep peak in pulses of electrical activity which are used to shift memories from short term to long term memory banks.

ARTWORK: SHIVANI MATHUR, DREAMS



DEMYSTIFYING DISEASES AND MODERN MEDICAL TREATMENTS

Clare Xie Yijia delves into the details of human pathology and how medicine is advancing to improve treatments in the future.



ARTWORK, LEFT: MOLLY MACLEOD, HISTOLOGY
ARTWORK, RIGHT: FEDERICA RAGUSEO, VIRUS

Since the beginning of human existence, we have been in a constant war against sickness. From primitive society to present day, mankind has always been perplexed by the emergence of diseases and has sought to understand, treat and prevent illnesses. In the early days, healers largely relied on superstition and witchcraft. Now, the rapid advances in science have given us a much clearer understanding of our physiology and the causes of illnesses.

From a biochemical perspective, the human body is an intricate system consisting of a collection of molecules, each playing indispensable roles in maintaining the body's structure and functions. These molecules include macromolecules such as proteins and lipids, as well as inorganic molecules such as water and metal salts. A range of physical and chemical processes involving these molecules are what makes life possible, and disruptions to these processes can cause problems to normal body functions.

The body is constantly exchanging substances and energy with the outside environment. A healthy body is able to regulate and maintain a stable internal state. This ability is called homeostasis. Significant disruptions to the homeostatic balance is often the main factor triggering diseases. These disruptions can happen in many ways, such as through contact of harmful bacteria and viruses, exposure to excessive radiation, or consumption of poisonous compounds. Internal disruptions can be genetic in origin, where DNA mutations or protein misfolding can lead to malfunctioning of the body's normal metabolism.

Perhaps one of the most surprising (and alarming) triggers is oxygen. Oxygen arguably plays the most important role in sustaining life, acting as the fuel to respiration that produces energy for various metabolic activities. However, oxygen is also the culprit of a wide range of chronic or degenerative conditions such as inflammation and cancer by inflicting oxidative stress.

Oxidative stress is caused by the imbalance of reactive oxygen species (free radicals) and the molecules that can stabilise them (antioxidants). When there are more free radicals in our body that can be balanced by antioxidants, the excessive radicals can induce large numbers of rogue chain reactions which damage body tissue, DNA or proteins. Oxidative stress can accumulate naturally as part of the ageing process, but it can also be induced by exposure to harmful environmental factors such as pollution or radiation.

Some scientists have proposed that the link between oxidative stress and diseases originated from the gradual changes in the earth's atmosphere. The earth's primitive atmosphere was thought to be reducing and contain very little oxygen. However, the emergence of cyanobacteria (blue-green algae) that produced oxygen as waste about 2.4 billion years ago gradually increased the atmosphere's oxygen level, causing organisms used to a more reducing atmosphere to constantly adapt to increasing oxygen levels or risk sickness and death. Although existing organisms have successfully evolved to inhabit the oxidating atmosphere, it appears the evolution process is not perfect and that oxidative processes can still pose health threats.

Other disease triggers in the environment originate from human activities, such as industrial and agricultural processes releasing dangerous substances that can disrupt the body's natural functions. For example, the burning of fossil fuel releases large quantities of harmful gases that can cause many respiratory health problems when inhaled.

From a biochemical perspective, the human body is an intricate system consisting of a collection of molecules, each playing indispensable roles in maintaining the body's structure and functions.

Under normal circumstances, transient exposures to pathogenic factors through diet or contact will not lead to severe diseases, as the body's self-healing mechanisms are constantly working to maintain the homeostatic state. However, when the concentration of the pathogenic factor is high or the exposure duration is long, our bodies may need medical intervention to recover.

Medical intervention is also needed when the triggered immune response is causing more harm than good. For instance, although normal fever is a protective mechanism for the body to fight off diseases, very high temperatures (>40°C) are dangerous and can cause brain damage or seizure without intervention. Another prominent example is the 'cytokine storms syndrome' seen in patients suffering from severe COVID-19. Cytokine storm is a serious immune disorder caused by excessive secretion of cytokines, causing the body to start attacking its own cells and tissues instead of just attacking the virus. As a result of this indiscriminate attack, vital tissues such as arteries and veins can be damaged, while massive release of nitric oxide further thins the blood. This can bring patients' blood pressure down to a dangerously low level, causing them to die from septic shock.

Fortunately, the greater understanding of disease causes and rapid advancements in science have enabled doctors and scientists to develop many effective interventions to identify and tackle complex health problems.

Tenacious research in medicinal chemistry has continuously expanded the armoury of medicine available to combat various diseases. From antibiotics such as penicillin to the AIDS-fighting antiviral AZT, these marvellous medicinal advances have enabled humanity to enter a new era, with an unprecedented ability to treat communicable diseases. Innovations in medical technology have enabled the development of many life-saving medical innovations, such as the dialysis machine or artificial heart valve. Currently, scientists are developing artificial organs grown from cell tissues, which might one day provide a much-needed solution to the scarcity of donor organs for transplant.

Moreover, we are now blessed with a suite of diagnostics tools and preventative treatments. Advancements in imaging and sensing technology have greatly expanded the accessibility of health screening, allowing potentially dangerous health conditions to be identified early - even before any signs or symptoms are shown.

In recent years, research into genetics and biomolecular engineering has unveiled many promising medical technologies, such as gene screening and gene therapy. Through screening genetic samples, we can now diagnose inheritable diseases from as early as the foetal stage. It is hoped that in the future doctors will be able to treat and prevent diseases by gene modification instead of using drugs or surgery.

Despite the advances in modern medicine, there remain many medical conditions which cannot be cured yet, such as cancer, AIDS, and Alzheimer's. In humanity's continuous fight against diseases, we still have a long way to go. Nevertheless, looking back at the great strides we have made in medical diagnostics and treatments, and witnessing how the global community have come together in the face of adversity in the current pandemic, I believe we will have many more medical breakthroughs to come in the future. ■

This artwork by Kelly Briggs explores patterns of growth on different scales, spanning micro to macro. The artist describes how she has been observing samples from an ancient forest near her home and studying its microscopic landscapes. She says: "Looking so deeply into these new lands and their inhabitants feels like space travel – except instead of looking out I'm looking in."

Ancient woodlands are extremely complex ecosystems which have evolved over centuries and harbour very specific communities of native wildlife that can be found nowhere else. In the UK, they only cover 2.5% of the countryside, despite being the richest and most intricate ecosystem, providing shelter to the most threatened species.

It is vital to protect such ecosystems, because you can't consider centenary trees and young saplings to be the same. They are both trees, but ancient oaks, for example, have created their own unique ecosystems and become home to species that have taken a long time to accumulate and thrive. If these oaks are gone, there is absolutely no guarantee such species will come back and live on younger trees.

You can recognise ancient forests by looking at specific species known as "indicator species". In the UK, these include wildflowers such as bluebells, wood anemones, and lily-of-the-valley. They also include slugs like the lemon slug.

KELLY BRIGGS, THE LANGUAGE OF THE SPHERES, A3 INK ON PAPER

The artist, Steffi Smith, was inspired by the mystery behind the deep-sea exploration that is being conducted as part of the UN Decade of Ocean Science.

Very little is known of deep-sea ecosystems and, in fact, space has been explored more than the deep-sea. Part of the reason why is because of pressure: when you start at sea level and journey out to space, you only have the atmospheric pressure in between. But when you start at sea level and dive into the sea, at just ten metres of depth, you have already added the equivalent of atmospheric pressure. In other words, every ten metres of oceanic depth is equal to the pressure of our atmosphere. So, if you try to reach the deep-sea floor at 2 kilometres of depth, you will have 200 times the atmosphere's pressure on top of you.

If you've ever seen submersibles designed to explore the ocean depths, you can now understand why they look so thick and clunky! They are made to withstand huge amounts of pressure for long hours at a time.

Because of the issues we face in exploring the deep-sea, it remains a mysterious and fascinating ecosystem, and one of our last frontiers of discovery.

STEFFI SMITH, PORTHOLE, MIXED MEDIA

SCIENCE BEHIND THE ART

Alienor Hammer reveals the scientific concepts influencing two pieces of artwork.

FAST RADIO BURSTS: THE BAFFLING LIGHTHOUSES OF THE SKY

ARTWORK: MOLLY MACLEOD, FREQUENCY

Anirudh Kulkarni examines what fast radio bursts are and how they occur.

Fast radio bursts have had their causes shrouded in mystery ever since their discovery, and astrophysicists are racing towards figuring out what triggers them. Once thought of as a rare phenomenon, they are now known to be ubiquitous with about an estimated 1,000 coming towards us each day from all over the sky.

In 2007, the Parkes telescope in Australia received a strong burst of radio signal that had never been detected before. Now known as the Lorimer burst, this discovery was a special case of Fast Radio Bursts (FRBs), which have fuelled scientific curiosity and public imagination ever since. Metaphorically, they seem to be like lighthouses distributed across the universe beaming away radio waves into space.

*Metaphorically, they seem to be like **lighthouses distributed across the universe** beaming away radio waves into space.*

Radio waves are the same waves you use when you tune into your cherished evening radio show. They sit on the electromagnetic spectrum just like visible light – the colours that we see. However, radio waves have very long wavelengths: measuring from about tens of centimetres to metres, unlike visible light which is on the order of hundreds of nanometres (a tenth of the thickness of a hair). Radio frequencies also range from MHz (like your favourite FM station) to GHz. However, the radio that you listen to has been transmitted by human sources, whereas the radio waves detected by telescopes come from outer space.

Radio telescopes have antennas which detect these radio waves. The Lorimer burst, named after the first author of the paper reporting the event, lasted 5ms and had a frequency of 1.2–1.5 GHz. To know how far the signal travelled, scientists looked at the dispersion of the signal through intergalactic space before arriving at the telescope.

Dispersion is the hallmark of refraction, a feature of light. When visible white light passes through a prism, it gets separated into different frequencies, which we see as colours. Rainbows are caused when light gets dispersed by rain drops. Furthermore, these different frequencies travel at different speeds in the refractive medium.

Intergalactic space is not empty; rather it is filled with free electrons which disperse light waves passing through it. As a result, the higher frequencies of radio waves reach us first and lower frequencies reach us later. By studying the amount of dispersion, one can estimate the distance travelled by the radio signal. The FRB detected in 2007 seemed to originate from a very distant place in our universe.

Pinpointing the precise source of the FRB, however, was not easy. Radio telescopes have a good time resolution (in the order of milliseconds) but do not have a good angular resolution. The Parkes telescope can only pinpoint the source to an area of 1000 galaxies but cannot be any more precise. We needed more events like the Lorimer burst to find out the location.

Unfortunately, some of the subsequently detected FRBs turned out to be anomalies caused by the activity of nearby microwave ovens or lightning rods which bogged some research down. Dubbed as "perytons", after the mythical winged stag that casts a human shadow, these anomalies did not, however, deter scientists from pursuing their study.

In 2012, an FRB that repeated every 6 seconds was discovered. This was the key to trying to find out more about the source. To improve the localisation, scientists used an interferometer, a combination of many radio telescopes that are spread apart. In this specific case, they used the very large array (VLA) telescopes in New Mexico, with its striking Y-like spatial arrangement, to localise the FRB to a galaxy. Subsequently using an Optical telescope in Hawaii, they found out, to everyone's surprise, that it was a dwarf galaxy. This event motivated scientists to find out more about these mysterious bursts.

*However, the **observation of several repeating FRBs** has narrowed down the speculations to magnetars, even though it is not yet clear how magnetars produce FRBs at these intervals.*

Thanks chiefly to the Canadian hydrogen intensity mapping experiment (CHIME), many more FRBs have been detected since then. The CHIME, which was set up to study hydrogen in the sky and measure the acceleration of the expanding universe, has also been deployed to detect FRBs. It is situated in Canadian mountains to get rid of radio interference. It is equivalent to 1,000 Parkes telescopes and captures the full Northern sky each day. With its peculiar cylindrical telescopes rather than the parabolic telescopes, it has detected over 100 of FRBs. Among these, at least 18 different repeaters have been detected.

The cause and origins of these FRBs had a better chance of being understood after the CHIME was deployed. Previously, several theories had been put forward. Supernovae, or the explosions of dying stars, was one of them. Some others have speculated it to be the collision of two massive objects from the list of: a neutron star (a star so heavy that under the gravitational force, all the atomic constituents have been stripped apart resulting in a huge ball of neutrons), a black hole (another star so heavy that it is completely pulled into itself by the gravitational force thereby leaving a singularity in spacetime), comets, and asteroids. However, the observation of several repeating FRBs has narrowed down the speculations to magnetars, even though it is not yet clear how magnetars produce FRBs at these intervals.

Magnetars are neutron stars which carry enormous magnetic fields on the order of a petaGauss (that's at least 1010 times more powerful than an ordinary household magnet). Magnetars are known to produce bursts in the X-ray and gamma-ray frequency range. This is thought to happen when they have "starquakes", much like earthquakes, which crack its surface releasing energy.

Recently, telescopes have detected an FRB in our very own Milky Way galaxy. Dubbed the FRB 200428, it came from the star SGR 1935+2154, which turned out to be a magnetar. X-ray bursts from the magnetar at around the same time as the radio emission were also recorded. This was possible only because the magnetar is so close to Earth. But surprisingly, this burst was about 1,000 times less energetic than the FRBs seen in distant galaxies. So, several questions still remain.

New telescopes which can localise FRBs with arc-second precision in real time are on their way. This means that they can pinpoint the source to a very small portion of the sky. At the same time, other predictions are being made about the gravitational waves or neutrino bursts that would accompany FRBs. It is hoped that studying all these signals in parallel might help shed a better light on the underlying puzzle of the perplexing FRBs. ■

THE NATURE OF MYSTERY

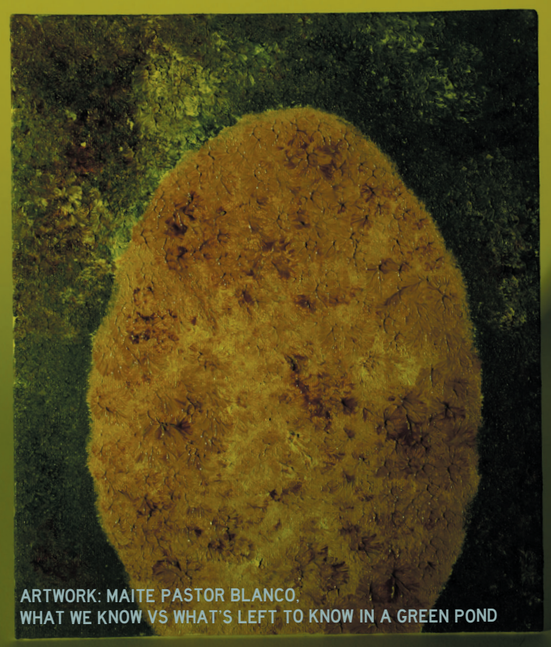
Isobel Chandler explores why humans are drawn to the mysterious.

There has been a murder. A person has been found dead in a locked room in Birmingham, surrounded by a puddle of sea water, a circle of mysterious powder thought to be turmeric, and a carefully arranged pattern of energy drink cans. Who could have done this? And how?! What a … mystery.

Okay, so this might not be the start of an Agatha Christie novel, but we all know roughly how the rest of the story will go. A clever protagonist and their helpful sidekick will follow the clues to the correct answer. They'll be thrown off once or twice, but then a chance encounter or phrase will shed light on a key piece of information and thus the mystery will be solved. The red herrings have to be challenging enough to stay interesting, and not so obvious that you stop reading. (If you're wondering, the Birmingham man was murdered by his butler's identical twin.)

Even if murder is not your thing, mystery is ubiquitous. Thousands of hours of media across all genres are dedicated to following the story of something strange as it is solved, or not. Nowadays, *mystery* generally means something that is inexplicable or not understood. The word itself originated in the 14th century and was used in a theological sense – 'religious truth via divine revelation' or 'mystical truth' – before it was used in the relatively more mundane sense we have today. There is still an element of the extraordinary in the modern word. It is this notion of something that is secret or beyond our understanding *but that maybe we could understand* that we find so compelling. We generally expect to arrive at a solution to a mystery we come across in the media, and we know that this will be satisfying. However, the mystery itself is also enthralling. It is difficult to leave something alone once you have been made aware of what you don't know.

So, we are fascinated by mysteries, but there is something dangerous about them too. Mysteries stand out - they don't quite fit into normal life or categorisation. It can be difficult to live with a mystery in real life if it means you never find out exactly why or how something happened. It is easier to like mysteries we have some control over, like those in a book or a film, rather than having to live with the unknown. Too many undetermined things can feel threatening and then any rationalisation starts to seem better than nothing. This has caused trouble throughout human history: The strange old woman who lives alone on the edge of the town and picks odd plants by moonlight *might* be responsible for the crops failing and the baker's daughter running off with the wandering bard, or maybe she's just Mabel, who makes excellent herbal teas, and who talks to herself because everyone needs a decent conversation once in a while. Cell towers *might* be responsible for a global pandemic, *or*….



ARTWORK: MAITE PASTOR BLANCO, WHAT WE KNOW VS WHAT'S LEFT TO KNOW IN A GREEN POND

In general, we respond to threats by freezing, attacking, running away, or forming complex social structures that allow us to band together and overcome them.

'Science' comes from the Latin word for knowledge. It is an entire discipline, a way of looking at the world, that allows us to stare mysteries in the face and wonder about their molecular composition and what they eat for breakfast. Faced with the infinite confusion of the world, science is a way of breaking big things down into smaller sections and solving them one research paper at a time.

Ironically, the very system created for solving the mysteries of the universe can be difficult to explain to outsiders. Science has its own language and culture. Unless you are part of it, it can seem opaque, hidden, and inexplicable. Society has a chequered history with science and the possession of specialised knowledge – is it helpful or a threat? Perhaps this reflects the relationship we have with anything a bit mysterious. Are they sources of excitement or fear? Do we hate them or love them, or do we just think we can fix them? If nothing else, they arouse our curiosity. And to be curious is to be human. In the words of Terry Pratchett:

"Some humans would do anything to see if it was possible to do it. If you put a large switch in some cave somewhere, with a sign on it saying 'End-of-the-World Switch. PLEASE DO NOT TOUCH', the paint wouldn't even have time to dry." (Thief of Time)

We start to ask 'why' as children, and never stop. Even if the answer is that there is no answer, at least we find out where the boundaries are. At least we know a bit more about what we don't know. And even though I hope many of the problems facing modern science will someday be answered, it is difficult to imagine a world in which there isn't still some mystery. 'Mystery' should be added to the list of universal constants. Science is our tool for solving many of them, but it is an impossible task. There will always be mysteries. They will always be an intriguing and uncomfortable reminder of what we don't know. How could we be human without them? ■

It is this notion of something that is secret or beyond our understanding but that maybe we could understand that we find so compelling.

WHY DON'T BANANA SWEETS TASTE LIKE BANANAS?

Alice Hirst delves into the differences between the bananas we eat today and their past counterparts.

Have you ever wondered why banana sweets never actually taste like a real banana? Well, that's because artificial banana flavour is based on a type of banana that is no longer grown commercially.

If you were to have bought a banana before the mid-20th century, you would have most likely bought a Gros Michel. Also known as "Big Mike", these bananas are fatter and more flavourful than the variety currently sold in shops, which is called the Cavendish. The Gros Michel contains a much higher concentration of a chemical compound, or ester, called isoamyl acetate. If you were to smell this ester on its own you would immediately recognise it as banana. Being cheap to produce and highly versatile makes this ester very popular as banana flavouring. In contrast, the Cavendish has more subtle and complex flavours that cannot be effectively replicated by isoamyl acetate. So, it is not so much that banana flavouring does not taste like bananas, it is more that bananas do not taste the way they used to.

In addition to their richer flavour, Gros Michels also have a thicker peel which makes them much less likely to bruise and easier to transport. This then begs the question, why are they no longer available in the supermarket? The answer is simple: *Fasarium oxysporum f.sp. cubense*. This is a fungus which causes Panama disease, a condition that prevents banana plants from drawing water, causing them to wilt and die. In the 1950's a mass outbreak of Panama disease almost wiped-out Gros Michel bananas, to the point that they could no longer be commercially grown. Enter the Cavendish, which proved to be naturally more resistant to *F. oxysporum*, and thus succeeded in becoming the most common kind of commercially grown banana.

This might have been the end of the story about bananas, if it was not for one other feature. If you have ever eaten a banana you may have noticed that it did not contain any seeds. While wild bananas have large hard seeds, edible bananas are seedless. This means that store-bought bananas are sterile, and that they must be propagated asexually from offshoots. In other words, new banana plants are cloned from the fragments of a parent plant, meaning that all the bananas you find in the supermarket are genetically identical.

So why does this matter? Although the Cavendish was originally cultivated due to its resilience towards Panama disease, in the late 90s a new strain arose called TR4. Unfortunately, the Cavendish is susceptible to this new strain, which has been working its way through banana plantations. Now, because all banana plants are essentially clones they lack the genetic diversity required to develop resistance to the disease, meaning TR4 could very well kill them all. Despite best efforts to prevent its spread, Panama disease has been working its way into all the major banana growing areas, including Asia, Africa, Australia, and South America. Unlike the last time, however, we do not have a new variety that could replace the Cavendish.

Not only are bananas an $11 billion industry, they are also the planet's favourite fruit. While in the Western world they might be missed as a delicious and convenient snack, for millions in Latin America, the Caribbean, Africa, and Asia they are a fundamental source of nutrition. So, what can be done to save them? Some scientists are trying to grow new experimental and hybrid breeds in the hope of finding one that is both resistant to Panama disease and that also tastes similar enough to the Cavendish so consumers will not notice a difference. Others are trying to use genetic engineering to manipulate banana chromosomes with the aim of making the Cavendish tougher and more resistant to all disease. These solutions, however, are both difficult and time consuming. At the moment there is yet to be a new banana with fruit that tastes good, ripens at a predictable time, can travel without being bruised, and that's easy to grow in large quantities. The race is on to find one before it is too late. ■

If you have ever eaten a banana you may have noticed that it did not contain any seeds. While wild bananas have large hard seeds, edible bananas are seedless.

ARTWORK: JACOB GABLE, BANANAS

THE CONUNDRUM OF CONSCIOUSNESS

Akila Raghavan explores the yet unsolved scientific mystery of human consciousness.

You've stubbed your toe on the corner of your coffee table. You feel pain.

Your partner sends you a romantic text message. You feel loved.

You shovel a heaped spoonful of chocolate pudding into your mouth. You taste sweetness.

You trip over seemingly flat ground in front of a large group of people. You feel embarrassed.

We are all capable of feeling all these emotions and sensations. This is because we are all sentient beings – we have a *consciousness*.

Simply put, consciousness embodies everything that we experience. However, attempting to understand consciousness has proved to be anything but simple for scientists.

Our brain, an unassuming lump of grey jelly, is an incredibly complex organ consisting of around 100 billion cells called neurons, which are each connected to 10,000 others. This results in an intricate network of over ten trillion nerve connections. Despite our vast understanding of the brain and how it works to produce human behaviour, scientists are no closer to figuring out how this mass of tissue that sits nestled comfortably within our skull can give rise to what we know to be our consciousness.

How does the feeling of loneliness stem from the constant firing of chemical and electrical signals between neurons in our brain? How does this mass of neural tissue function in order to allow us to experience the sensation of itchiness?

The short answer is – we don't know yet.

The conundrum of consciousness appears to sit right on the boundary of philosophy and science leading researchers to question whether conventional scientific methods will ever be able to solve this mystery.

Taking the philosophical approach, we can trace the problem of comprehending the nature of consciousness and its properties all the way back to the initial work of 17th century French philosopher, René Descartes. In an attempt to make sense of this, Descartes came up with Cartesian dualism. This concept states that consciousness resides within an immaterial domain he termed res cognitans, or the realm of thought, as opposed to the domain of material things, which he termed res extensa, or the realm of extension. Descartes believed that the interaction between the two domains occurred within the brain. Effectively, this theory assumed that the physical body is separate from the mind. Aside from this first answer to the problem of consciousness, Descartes is also credited with giving us the most famous summary of human consciousness: "I think, therefore I am."

Other philosophers, such as Karl Marx and John Locke, rejected this mind-body dichotomy put forth by Descartes and claimed that consciousness, and therefore personal identity, is not tied to any substance. Psychologist William James has likened consciousness to a stream, in that it is constantly flowing and unwavering despite the changes and shifts around it.

Today, researchers studying human consciousness are primarily focused on what consciousness means in both a biological and a psychological sense. The majority of the experiments done in this field rely heavily on assessment of verbal responses given by test subjects, which brings in the risk of subjectivity. In order to determine the accuracy and significance of such studies, scientists must compare these verbal reports to any corresponding activity simultaneously occurring in the brain. That is, they are looking for neural correlates of consciousness (NCC).

NCC is defined as the minimal amount of observable neural mechanism that is required for any sort of conscious experience to occur. For example, what must happen in your brain when you experience a sense of calm after yoga? Do your neurones need to be firing impulses in a certain pattern or at a certain frequency? Do specific neurones need to be involved? Or do they have to be located in specific regions of the brain?

Research into defining the NCC has observed that the seat of consciousness is much narrower than previously thought. In cases of extreme trauma, such as the severing of the spinal cord from the rest of the nervous system in victims of car crashes, it has been seen that such individuals still retain their consciousness. Additionally, in situations of accidental surgical mishaps involving misplaced scalpels in specific regions of the brain, patients have recorded that they are unaffected in their ability to feel and experience things.

Data from cases such as these all point to the heavily celebrated cerebral cortex of the brain being the region in which consciousness appears to generate. Through the study of patients who have had specific areas of their brain removed and experiments involving the electrical simulations of certain regions, scientists have been able to conclude that the posterior cortex specifically has a definite role to play. This region appears to be responsible for processing not only sights and sounds, but also all the other sensations of life.

The study of the brain is not the only area that researchers are exploring when it comes to the science behind consciousness. Scientists are also looking into the intrinsic properties of each individual experience itself. A theory termed the integrated information theory (IIT) postulates that each experience triggers a specific response which is unique to the individual having the experience. Thus, IIT states that there is a cause-and-effect relationship between the properties of such experiences and the complex mechanisms our brains undertake.

IIT also predicts that the complexities of human consciousness cannot be replicated digitally. This means that any attempts of programming a computer with consciousness will only result in a simulation of inputted conscious experiences, not a conscious computer itself. Thus, consciousness must be organically integrated into the structure of the system. Should IIT prove to be true, this bodes well for the future of AI – we can rest easy knowing we don't have a Terminator-esque future ahead of us!

Ultimately, the science behind consciousness currently lies in a state of uncertainties and yet to be proven theories. Perhaps the continued advance of technology will allow this research to progress and, one day, solve one of life's biggest conundrums: how an unassuming lump of grey jelly can emanate the feeling of life. ■

BACKGROUND : CHAOYU TANG, UNTITLED
ILLUSTRATION: ARIANA LOEHR, OUT OF MY MIND

The conundrum of consciousness appears to sit right on the boundary of philosophy and science leading researchers to question whether conventional scientific methods will ever be able to solve this mystery.

IS DEDUCTION EVEN SCIENCE, MR. HOLMES?

Naomi Dinmore compares the process of detective work to the scientific method.

Think about the plot of every whodunnit story. It usually starts off with something like: *"Shock horror! There's a dead body! How do we solve this?"*. Cue suspicion, suspense, and drama. Then, the detective appointed to the case will tirelessly piece together clues[BA1] to get the full picture of that fateful, stormy night. The detective will usually follow a "top-down" approach – which means they apply general rules to specific cases. (*For example, it is a general rule that humans cannot teleport, so a guest who was enjoying their time in the dining room could not have murdered poor Mr. Boddy in the library.*) The aim, for any detective, is to eventually approach the truth and find the culprit.

This process, known and used in the areas of philosophy, mathematics, and computer science, is called **deductive reasoning**. It involves taking what truths you already know and applying them to specific situations. A classic example of this is taking these statements: 1. *All men are mortal*; and 2. *John is a man*; and coming to a logical conclusion: Therefore, *John is mortal.*

Sherlock Holmes, arguably fiction's most famous detective, prided himself on using deductive reasoning. He favoured its logic, rationality, lack of uncertainty, way of approaching truth – and its "scientific" nature. One of his most famous quotes aptly describes this philosophy: "*when you have eliminated all which is impossible, then whatever remains, however improbable, must be the truth*" (The Blanched Soldier).

The opposite is also the case: scientists often liken themselves to Holmes. Many people believe scientific research to be "nature's detective story" – scientists try to piece together the clues from the world around us.[BA2] Some say that the ultimate goal of science is to uncover the truth about the universe.

But – in practice – this isn't how science works.

The philosopher Francis Bacon was the first person to introduce the idea of a method to "do" science. He suggested that ideas should be tested using experiments, and this has developed into the method most scientists use today: 1) *Coming up with a hypothesis or idea that needs testing*; 2) *gathering evidence and collecting data*; 3) *Analysing this data, observing trends and what that means*; and 4) *comparing your data to your hypothesis.*

In other words - historically, science has always followed a "bottom up" approach, opposite to the detectives' "top down" way of solving mysteries. In science, we build upon each other's work, testing smaller, measurable effects and extrapolate them into wider contexts.

In philosophy, this is known as **inductive reasoning**. Bacon wanted to introduce this idea to push the boundaries of human knowledge, leading to a historical era known as "*The Age of Enlightenment*". But, while Holmes claims to know more than anyone else around him, his goal is not to push the limits of human knowledge – just, simply learn the facts and come to a conclusion for a singular, specific case. He uses his knowledge of biology and chemistry as a tool - the same way an engineer uses physics.

> *In other words - historically, science has always followed a "bottom up" approach, opposite to the detectives' "top down" way of solving mysteries.*

In science, by taki ng samples of data, and trying to apply that to some sort of conclusion about the world, we introduce other factors that mean we can never reach an absolute truth. Lab conditions, while making experiments repeatable – are not real-world conditions. Correlation does not always equal causation. In other words, science has uncertainty. It[BA3] [DN4] cannot tell you what the "truth" is.

Plus, science is conducted by humans with their own sets of biases and worldviews, so it might not actually be so logical and rational, after all. Sorry, Sherlock.

The only certainty we have in science is if you can prove something is *not* true. For example, you can disprove the hypothesis that the earth is flat by going to a tall cliffside and measuring the curvature of the sea against a ruler.

This concept, known as **falsifiability**, was brought to light by another philosopher: Karl Popper.

I suppose, in some way, only being able to prove falseness is similar to Holmes' approach: "*once you have eliminated the impossible…*", but in reality, we still don't know the limits of what is possible in science. For many years, scientists believed the atom to be the smallest elementary particle, until we managed to split it, and to quote Phoebe from *Friends*: "*A whole bunch of crap came out*".

So why does detective work use one type of thinking, and science use another?

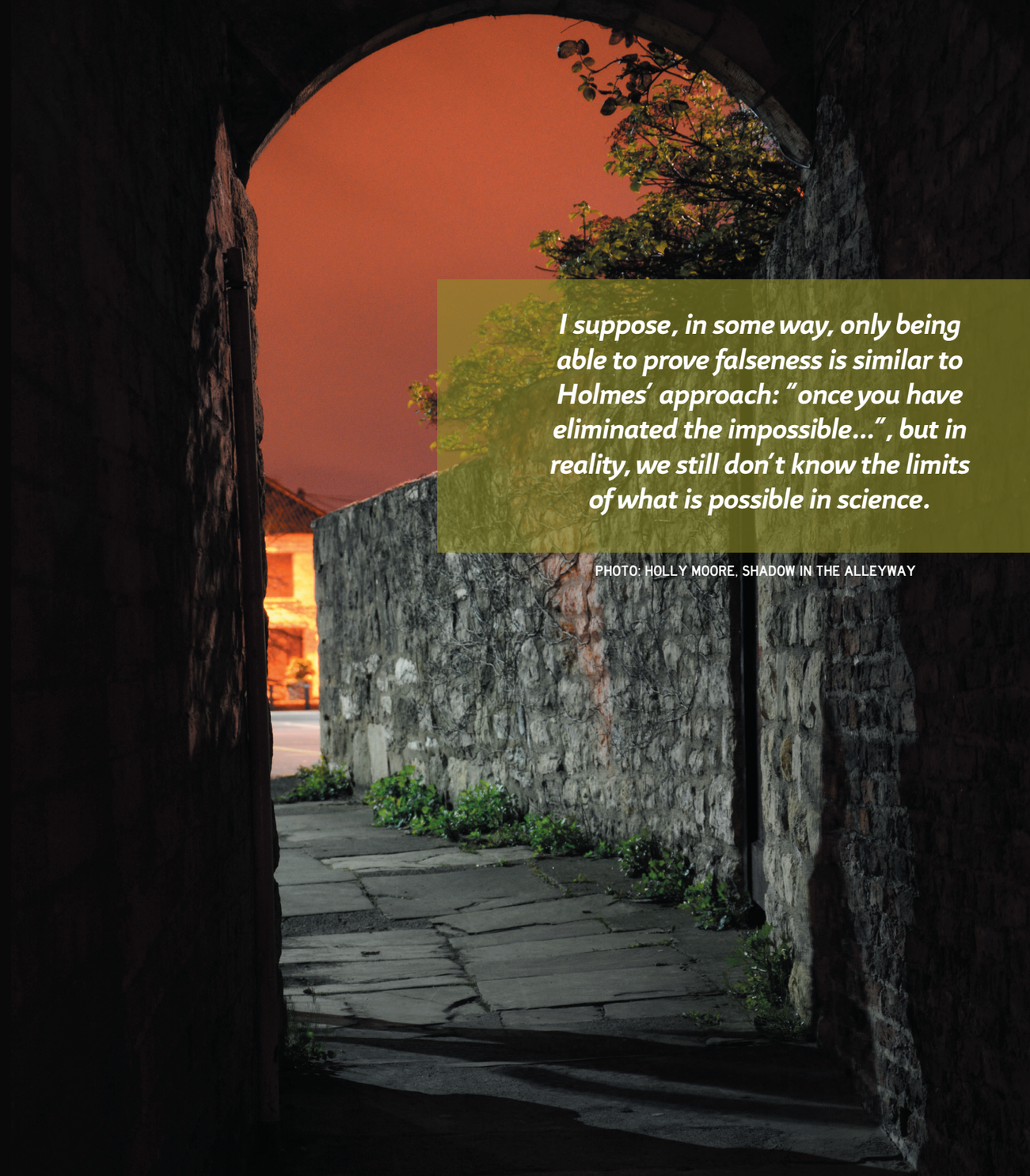
Let's use a case study to see why. The story of *A Study in Scarlet*, the first Sherlock Holmes story, follows the titular character using the clues around the dead body: the German word for revenge written on the wall, footprints, a woman's wedding ring, and a note to the dead body's secretary.

How would a scientist resolve this using induction?

1. They would make a hypothesis.
2. They would find data that either supports or disproves that hypothesis.
3. They would then spot trends in the clues and infer what that means for the case.
4. This might introduce bias into the situation. It would also take much longer.

Let's do the opposite. How would Sherlock try to approach the theory of evolution, for example, using deduction?

1. He wouldn't. He doesn't believe in theorising until you can be absolutely sure of what is and isn't true: "*It is a capital mistake to theorize before you have all the evidence. It biases the judgement*" (A Study in Scarlet). [BA5]



> *I suppose, in some way, only being able to prove falseness is similar to Holmes' approach: "once you have eliminated the impossible…", but in reality, we still don't know the limits of what is possible in science.*

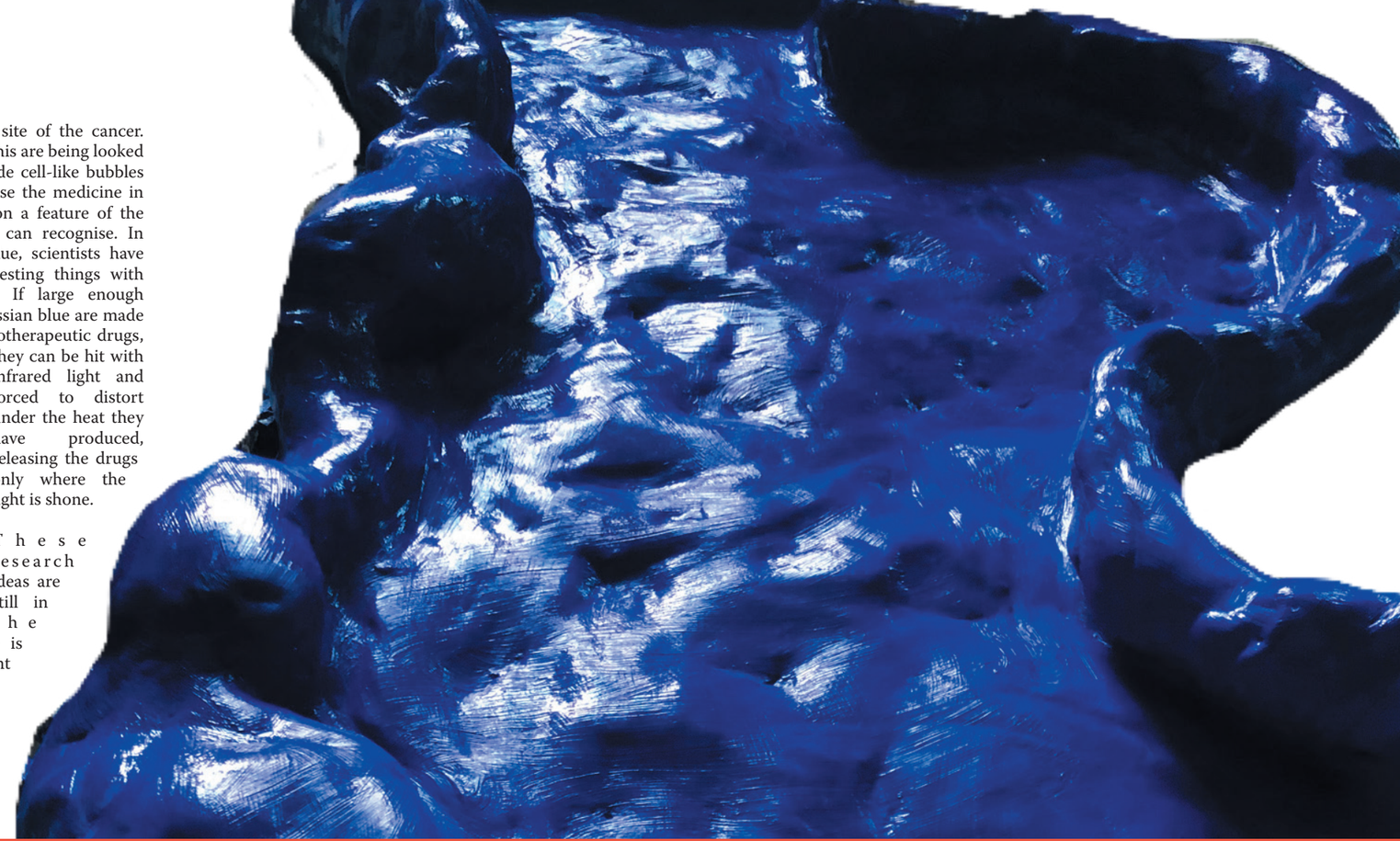
PHOTO: HOLLY MOORE, SHADOW IN THE ALLEYWAY

Many modern philosophers of science have criticised the Baconian scientific method, saying it introduces bias, and that, because it is conducted by humans, science can never be wholly impartial and logical. This is why it is vital for scientists to collaborate, compare results across different worldviews, and critically review each other's work. Mr "I Work Best Alone" Holmes, no matter how much he says he is, is not actually impartial. If he were to use inductive reasoning, working with possibilities rather than truths, he would be bringing his own Victorian Englishman's worldview to the table.

Some philosophers of science would agree with Holmes' view that theorizing before collecting evidence biases judgement. But in science, where else would you start? It's not like we have a dead body to go off, after all. ■

POISON, PAINT AND PILLS: THE LEGACY OF CYANIDE

Daisy Rogers-Simmonds explores cyanide's mysterious history.



Easy to disguise in food but resulting in rapid, dramatic, death, cyanide has become synonymous with the murder mystery. A favourite of pharmacist-turned-novelist, Agatha Christie, cyanide was her poison of choice, using it to kill her fictional victims in four of her books. Thanks to her extensive training in chemistry, Christie was often praised for her accurate portrayal of poisonings, cyanide being no exception.

Cyanide poisoning is so successful because of its effect on respiration. Preventing oxygen from being used up, it rapidly halts the production of energy. Symptoms of cyanide poisoning include low blood pressure, respiratory failure, slow heart rate, convulsions and coma, making it a toxin of choice for those with a dramatic flair.

At the time of Christie's writing, cyanide was hardly difficult to obtain. It was in common use, including in photography, where potassium ferricyanide was used as a toner. While not toxic itself, when heated, exposed to UV light, or acid, it releases the highly toxic hydrogen cyanide. It is this hydrogen cyanide which has the characteristic smell of bitter almonds. It was even easier to obtain by simply buying pesticides from the local shop.

A simple substance consisting of just one carbon and one nitrogen atom bound together by three bonds and holding a single negative charge, cyanide is just as toxic today as it was when Christie was plotting her characters' demise. But does this miniscule molecule get a bad rap? An important ingredient for chemists, perhaps cyanide can be good for more than a murder most foul?

One substance containing cyanide which has garnered much interest over the years is Prussian blue, a striking, vibrant blue pigment that may be familiar to fans of the late, great Bob Ross. Prussian blue can claim the title of the first man-made 'coordination' compound, which is composed of a central metal (in this case, iron) surrounded by other molecules (cyanide). Prussian blue was initially made by accident, by a German dye-maker called Heinrich Diesbach. On a quest to make a crimson colour, one of the necessary ingredients, 'potash' (now known as potassium carbonate), was contaminated with cyanide-containing substances, and it was the inclusion of the cyanide that yielded a surprising deep, rich blue.

Over the course of the twentieth century, it became increasingly obvious that Prussian blue was useful for more than just painting. The structure of Prussian blue is akin to a cage, with a space in the middle that turned out to be just the right size for imprisoning the heavy elements thallium and caesium. Just like hydrogen cyanide, thallium is a nasty poison. However, thallium is more insipid, taking its time to claim its victims. Since Prussian blue itself, even though it contains 6 cyanides, is not toxic, it can be used as an antidote to thallium poisoning by trapping it and safely taking it out of the body. Similarly, radioactive caesium is not something you really want to be putting into your body, which posed a massive problem after the nuclear fallout at Chernobyl in 1986. Luckily, Prussian blue can mop caesium up too, and is a key component of the oral radioactive caesium removal drug, Radiogardase.

A simple substance consisting of just one carbon and one nitrogen atom bound together by three bonds and holding a single negative charge, cyanide is just as toxic today as it was when Christie was plotting her characters' demise.

Modified versions of Prussian blue are also being looked into for making MRI scans clearer. Some versions of Prussian blue with added manganese or gadolinium have properties which improve the contrast on MRI scans, and initial research shows promising results for how well it clears out of the body afterwards.

Finally, variations on Prussian blue are being used to combat certain cancers. Large cages of Prussian blue holding some gold inside heat up a lot when infrared light hits them. For this reason, these particles are being researched to see if they can heat up cancer cells in a targeted manner. This theory has been tested on mice with tumours. The Prussian blue and gold particles were injected into the mice and infrared light was directed at the tumour. Cells are very sensitive to changes in temperature, and as the particles heated up, it was found that the cancer cells died and did not return over a period of 18 days.

Prussian blue particles are also being used to combat cancer as drug delivery vehicles. Many chemotherapeutics attack cells in a largely indiscriminate fashion, whether they're cancerous or not, leading to distressing side-effects. The idea behind drug delivery vehicles is to trap the chemotherapeutic drug in a cage which will only be opened at the site of the cancer. Multiple ways of doing this are being looked into, including man-made cell-like bubbles that will 'pop' and release the medicine in the right place, based on a feature of the illness that the bubble can recognise. In the case of Prussian blue, scientists have been doing some interesting things with its heating properties. If large enough particles containing Prussian blue are made into cages to trap chemotherapeutic drugs, they can be hit with infrared light and forced to distort under the heat they have produced, releasing the drugs only where the light is shone.

These research ideas are still in the early stages and there is still much development and testing to be done. Multiple issues need to be addressed, such as where do the big drug-carrying cages go once they have been opened? Cancer is a collection of varying diseases requiring a multi-pronged approach and a great many tools to defeat. Who would have thought that one day a particle splashed on the canvasses of artists everywhere could potentially form a valuable weapon in our arsenal? ■

"Was there something in the whiskey? ... Everything points to one of the cyanides."
– And Then There Were None, Agatha Christie

ARTWORK: DOVILE ANTUSAITE, DETACHED 3

THE MYSTERY OF MISOPHONIA

Alexia Yiannouli discusses the condition of misophonia and contrasts this with ASMR.

ARTWORK: SHIVANI MATHUR, ABOUT TIME

Misophonia has been a mystery to medicine for some time. Taken from the ancient Greek meaning 'hatred of sound', what was once thought of as simply a pet peeve has now been correctly identified as a medical disorder. Sufferers of the condition are left feeling emotions of anxiety, fear, and even disproportionate anger as a result of being exposed to certain types of noises. But the name of the condition is not quite accurate. People with misophonia don't have an intense hatred of all noise, only some forms of it. And their response to those types of noise can't really be defined as hatred, but as extreme and involuntary reactions to specific auditory stimuli.

Ferocious tapping on a keyboard in a quiet room. Heavy breathing. Mechanical mastication of food by overworked molars. The impatient clicking of a pen. It is estimated that one in six people have misophonia, with everyday noises that might have otherwise gone unnoticed result in a heightened emotional response which sufferers struggle to control.

Misophonia can be considered as a type of synaesthesia; a condition when particular sensory stimuli can evoke additional sensations as a result of increased neural connections. The condition was only given a name in 2000 and has the potential to drive wedges in relationships and have a considerable impact on people's day-to-day lives. It is often still not considered a proper [RA1] condition, resulting in the stigma of it being considered only a pet peeve.

Ferocious tapping on a keyboard in a quiet room. Heavy breathing. Mechanical mastication of food by overworked molars. The impatient clicking of a pen.

THE PHYSIOLOGY BEHIND THE MYSTERY

Since acknowledgement of the condition started to surface in the 1990s, scientists have been trying to work out exactly what causes the condition. In 2017, researchers discovered that, when those suffering from misophonia experienced a sound that would trigger them, they would have a sudden and increased activation of their anterior insular cortex, the area of the brain comprising the salience network responsible for processing emotions. Studies also discovered overactive involvement of the hippocampus and amygdala, which led to it finally being recognised as a condition that caused physiological changes to brain activity.

Delving deeper into the physiology behind the disease, sound vibrations are transmitted via electrical energy into the inner ear, before travelling via the eighth cranial nerve to the brain. The unconscious mind then works to unscramble the sounds collected by the ear in order to make sense of what they mean. This process, known as auditory gating, allows your brain to differentiate between stimuli and identify those that are potentially harmful. In the case of misophonia, the auditory gating [RA2] doesn't quite work in the way that it should, evoking an exaggerated response to a non-threatening stimulus and triggering the fight or flight system, sending it into overdrive.

A proposed explanation for what happens is that after a trigger is detected, and a stimulus is perceived as harmful - whether it is actually dangerous or not - it elicits a physical response which then leads to an extreme emotional response. Attempts to explain the process are still somewhat hypothetical, with a lot about the misophonic response chain still not known. This leads to consideration of an important question - why are we so quick to label something as having psychological or emotional origins just because we don't know exactly what causes it?

Despite the discovery of what causes misophonia, like many other mystery conditions, knowledge of successful treatment remains limited. Some options for treatment involve tinnitus retraining therapy, cognitive behavioural therapy, and other forms of counselling, which can be used to decondition emotional responses to specific noises.

ASMR: IS IT REALLY THE ANTITHESIS TO MISOPHONIA?

A relatively new phenomenon, ASMR, or Autonomous Sensory Meridian Response as it is more formally known, has been considered the antithesis to misophonia. Instead of triggering negative emotions, it instead evokes feelings of extreme relaxation. A concept which is loved by some and repulsed by others, you could almost consider it to be the marmite of the synesthetic world. But instead of ASMR and misophonia being thought of as paradoxical phenomena, are they actually more similar than we once thought?

ASMR is a term coined by cybersecurity professional Jennifer Allen, used to describe the strange body tingling created as a result of certain sounds. Recent studies have found that when trying to identify responses to ASMR, a high prevalence of synaesthesia was noted in participants, suggesting that the physiology behind ASMR and misophonia might not be as juxtaposing as once thought.

One survey found that when evaluating 300 people suffering with misophonia, half of them also experienced ASMR, suggesting a plausible synergy between the two synesthetic concepts.

A recurring theme is that there still isn't enough research into the world of synaesthesia to explain the two concepts. Both misophonia and ASMR involve auditory stimuli resulting in emotional and physiological reactions, however the link between the two still needs further research, with many questions remaining unanswered. For example: how is the link between auditory stimuli and the parts of our brain controlling and processing our emotions established? Is it psychological or physiological? Or is it both? How can someone feel anger from certain noises and complete relaxation from others?

So, the next time you catch yourself contemplating the untimely demise of someone for their gum chewing or finger tapping, or as the feeling of relaxation spreads across your body while a stranger on the internet whispers into your headphones, marvel at the mystery of your brain and consider how much there is that we still don't know about the inner workings of our mind. ■

Recent studies have found that when trying to identify responses to ASMR, a high prevalence of synaesthesia was noted in participants, suggesting that the physiology behind ASMR and misophonia might not be as juxtaposing as once thought.

HOW DO YOU SOLVE A PROBLEM LIKE UNCERTAINTY?

Dave Warrell discusses the Great Barrington Declaration and the role of uncertainty in science.

The Great Barrington Declaration was an uncomfortable moment for science. The statement, authored by three eminent public health experts and signed by several hundred researchers, went against the grain by positing that lockdowns were blunt instruments which may be causing more harm than good.

Bhattacharya, Kulldorff, and Gupta instead suggested that those vulnerable to COVID-19 (the elderly and those with relevant pre-existing health conditions) be kept separate from society while the virus spreads through it, allowing the majority of the population to build up a natural herd immunity. In their view, this would stop the virus in its tracks while buoying the economy and maintaining civil liberties.

Some of their science was rightly criticised, namely the idea that naturally acquired herd immunity was a viable public health strategy (look at how Sweden is faring compared to its Scandinavian neighbours), as was their sponsorship (the declaration was sponsored by American Institute for Economic Research: a libertarian, free market think tank).

However, it wasn't just because three of the most well-respected public health experts on the planet were making some questionable suggestions that it was an uncomfortable moment. It was also that they raised some valid points. These are (or perhaps were) well-respected scientists, after all. In the Declaration, the authors highlighted that lockdowns come at the expense of the economy, mental health and cancer screening and treatment, to name a few issues. While herd immunity was easy to dismiss, it is much more difficult to sweep these points aside.

Now, I should be clear that I don't agree with the Declaration. I trust the significant body of experts who see the solutions it offers as unworkable and the notion of naturally acquired herd immunity as tenuous at best. But it is nonetheless an important lesson in the role of uncertainty and values in science.

Towards the start of the pandemic, there was a generally agreed upon approach: to lock countries down in order to save lives and prevent healthcare systems from being overwhelmed. Although most countries had regrettably been unable to stop community transmission, modelling predicted that locking down would still save thousands of lives, seemingly making it a no-brainer.

But from the very start of the pandemic there was a significant degree of uncertainty regarding the correct course of action to take. With lockdown imminent in the UK, the Government hesitated based on insights from behavioural psychology. They were concerned that calling for a lockdown before it was completely necessary may lead to people tiring of the rules en masse, making the problem worse in future.

As the pandemic wore on, the level of uncertainty only increased. Evidence from different fields of research suggested that the economy had suffered, social inequality had been exacerbated, and domestic violence had become worse. More and more research was amassed that highlighted the significant issues with lockdown, creating more uncertainty around whether it was the right thing to do or not.

There were many different disciplines of science telling us about different problems at any one time. There always are.

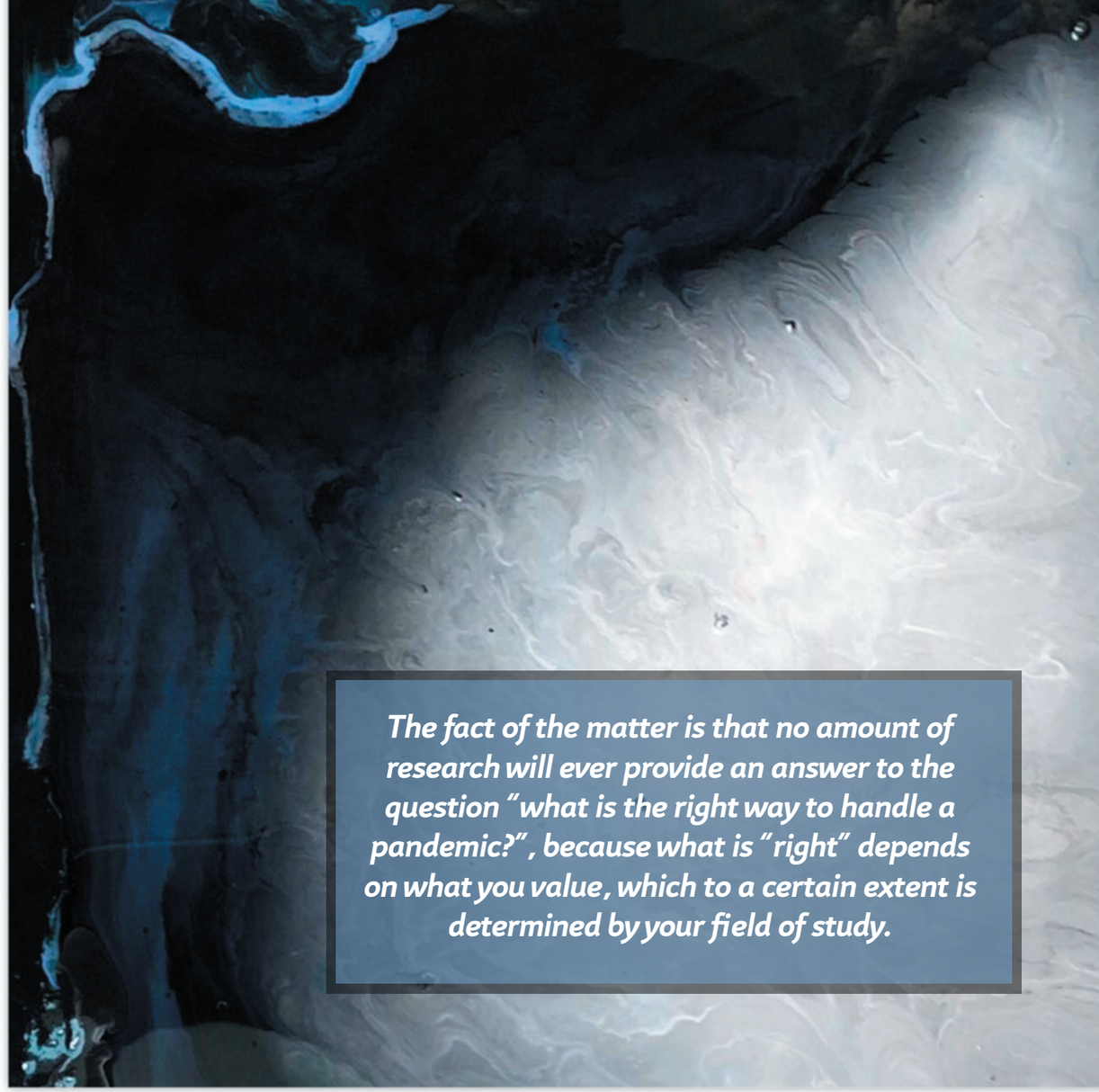
After some delay, the UK government had decided to place human lives above all else, a decision that most of us agreed with. The Declaration, which was released as the UK was poised to enter a second lockdown, tapped into something that was becoming increasingly clear: this had to be balanced with other priorities.

Herein lies the issue with proclaiming to follow 'the science'. There were many different disciplines of science telling us about different problems at any one time. There always are. Although the authors of the Declaration have been reviled, what they are chiefly guilty of is bringing a different perspective to the table, one that suggested a different course of action to the one to which we had collectively committed. They made suggestions that aimed to restrike the balance between preservation of life and preservation of liberties and the economy. While the science underlying their suggestions might have been a little iffy, their ideology cannot simply be dismissed.

Ultimately, then, what is at the heart of the Great Barrington Declaration is a disagreement about what matters most. Do we try to prevent deaths caused by COVID, or do we support the economy? Is the availability of respirators more important than small businesses having to close?

These conundrums cannot be answered by 'the science' because science is not one thing.

ARTWORK: DEBRA POLLARINI, OMINIA



The fact of the matter is that no amount of research will ever provide an answer to the question "what is the right way to handle a pandemic?", because what is "right" depends on what you value, which to a certain extent is determined by your field of study.

Science is a huge number of disciplines, all with a slightly different worldview. People with conflicting views on a topic can both have arguments backed by science. The Great Barrington Declaration is a prime example: what happens when three economically minded epidemiologists and an army of healthcare professionals approach the same issue? They frame the problem differently, have a different body of literature to fall back on, and so set about solving it differently. Is it any surprise, then, that they come up with different answers?

The problem is not just that their answers are different, but that they are irreconcilable. They are each legitimate in their own right but cannot be compared. And this phenomenon is nothing new. The same is true of the climate crisis. For years different fields of research have come up with evidence that highlights different problems and suggests different solutions, not all of which are compatible. This kind of conflict is what climate change deniers pounce on and manipulate.

The fact of the matter is that no amount of research will ever provide an answer to the question "what is the right way to handle a pandemic?", because what is "right" depends on what you value, which to a certain extent is determined by your field of study. Science can, however, provide answers to questions like "how do we preserve most lives?" or "how do we protect the economy?". It is then up to our governments to decide what to prioritise. What they decide to do or not do cannot be led by 'the science', because there is no single science.

Policymakers are informed about what is happening or could happen; this information can be provided by science. It is up to them to decide what should happen. And when deciding what should happen, there will always be conflicting, irreconcilable issues that come up. There are always value judgements involved. And there will always be uncertainty. ■

THE ROOT OF ALL ASTHMA

Ioana Esanu investigates if the hygiene hypothesis plays a role in developing asthma.

The human body is a wondrous thing. From organelles to cells to tissues and organs, you are a magical machine running mostly on oxygen and sugar.

1989. The Berlin Wall falls. Two sides of the same nation reunite, and just like that, the perfect opportunity arises for scientists across Germany. They could finally compare the effects of an Eastern versus a Western lifestyle on a large control group of genetically similar individuals.

It was thus that Erika von Mutius discovered a rather strange occurrence. Children who had grown up in heavily polluted East Germany were much less likely to suffer from asthma or atopy compared to children growing up in well-developed West Germany. And this was not just some anomaly. 8,750km away, in Hong Kong, asthma rates are up to 15%. Little more than an hour away, in much more polluted Guangzhou, only about 3% of citizens suffer from the disease.

THE HYGIENE HYPOTHESIS

Coincidence? Not really. Rather, a widespread theory known as the "hygiene hypothesis". The origin of the theory lies in the London School of Hygiene and Tropical Medicine, where epidemiologist David Strachan concluded that the sanitary Western lifestyle might come with its disadvantages. People in the Western world are much less exposed to germs and other pathogens than those in low-land middle-income countries. Cleanliness and sanitation, key aspects of a developed nation, seem to have made our bodies more prone to allergies (and indeed asthma). The reduced exposure to infectious agents in childhood is believed to increase the likelihood of developing such diseases in adulthood.

Once popular in the 1990s, the hygiene hypothesis is now standing on its last leg, as more and more statistics disprove it. In 2004, the Global Initiative for Asthma reported the prevalence of clinical asthma around the world, and a few surprises arose. South American countries like Brazil, Peru and Costa Rica recorded some of the highest numbers, even though pollution was high and sanitation was poor – their exposure to pathogens had not protected them against asthma. On the other end of the spectrum, hyper-hygienic Japan and Scandinavia had a moderate incidence of the disease, meaning that the cleanliness had not impacted their chance of atopy. All in all, scientists agree that there is more at work than just germs and dirty playgrounds.

BREATHING MATTER

What is the difference between children today and 70 years ago? TikTok. Or more generally, technology. When you think back to your afternoon schedule in primary school, you likely picture yourself sitting cross-legged on the floor in front of the TV. Your grandparents remember something else entirely: playing outside with their friends and running around until they had to be dragged back into the house. Thomas Platts-Mills, of the University of Virginia, claims there is a direct correlation between sedentarism and asthma rates. The USA saw a rise in cases after children's TV shows became widespread – such as the Mickey Mouse Club in the mid-1950s.

Platts-Mills' research shows that the human body experiences a wholly different breathing pattern when watching TV compared to when reading, or more obviously, when exercising. A TV-watching child will sigh less and take shorter breaths, which in time will damage the smooth muscle in the bronchioles. This underactivity of the lungs is believed to increase the risk of asthma. What's more, if a patient develops asthma as a result of their sedentary lifestyle, changing their habits will likely not improve their condition, but rather aggravate it. Exercising is one of the main triggers of an asthma attack, resulting in wheezing and shortness of breath.

HAVE YOU GOT THE GUTS?

The human body is a wondrous thing. From organelles to cells to tissues and organs, you are a magical machine running mostly on oxygen and sugar. And it just so happens that most of you is not you, but rather bacteria. A few dozen trillion of them – good and bad – play a part in your life in many subtle ways.

A recent human study from the University of British Columbia reveals that the first 100 days of life of an infant may be crucial to their likelihood of developing asthma. There are 4 gut microbes whose absence in infancy may cause the disease in later childhood: *Lachnospira, Veillonella, Faecalibacterium,* and *Rothia*. It is interesting to note how babies actually acquire these microbes. Most of the time, they gather them from the surrounding environment. Others are unable to do so, due to circumstances of their birth, antibiotic exposure, and even lack of breastfeeding.

THE PANDEMIC

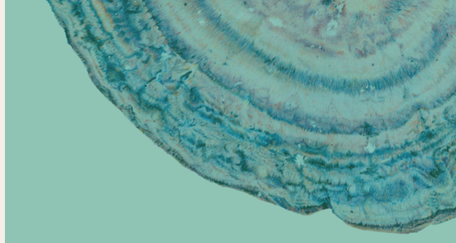
Now this is all very interesting, but why should we care? After all, doctors understand the disease mechanism and are proficient at treating asthma. While researching this article, something quite scary struck me. In the past 14 months when we have been locked up inside, we may have all but invited asthma to make itself comfortable in our lungs. The COVID-19 pandemic has forced us, for better or worse, to adopt new habits that might prove to be double-edged.

Wearing masks to protect people around us and sanitizing our hands and surfaces now seem like common sense – and they should be! The common cold and flu have been at an all-time low this past year because we have improved our societal and individual hygiene. It has been proven repeatedly that "Hands. Face. Space." is an effective strategy against COVID-19 transmission. However, only time will tell if there are repercussions to this. If the hygiene hypothesis is right, we might notice asthma and atopy rates skyrocketing in the next decade.

Moreover, there is no disputing that sedentarism has become the norm now. From watching lectures in bed to only taking 10 steps between the couch and the fridge, people are exercising a lot less than before. This is even more worrying for the children who are not playing outdoors with their friends anymore, but rather spending most of their time in front of electronic devices. It is still much too early to research the long-term effects of our new lives, but it is safe to assume our health will be impacted significantly.

Soon enough, we will find ourselves in the same situation as Erika, back in 1989. A whole generation raised indoors, in a clean environment, will be an excellent candidate to review the hygiene hypothesis. Whatever the answer may be, there are myriad facets of the asthma issue that are yet to be investigated. Even though science is far from cracking this mystery, it is wonderful to revel in the intricacies of immunology and infectious diseases. ■

ARTWORK: LAURANE LE GOFF, MANTIS
LAURANE LE GOFF, TRAMETES VERSICOLOR



DEFINITIONS

Asthma
A chronic disease wherein patients' airways become inflamed, making it difficult to inhale and, especially, exhale

Atopy
The genetic tendency to develop allergic diseases (such as asthma)

FACTS & FIGURES

300 million people world-wide suffer from asthma.

The highest rate of asthma is in the UK, followed by Australia and the USA.

The lowest rates of asthma are in China, Georgia, Greece, Romania and Russia.

UNVEILING THE DARKEST MYSTERIES OF SPACE

Only 5% of the universe is visible to the naked eye. Gemma Ralton unveils one of the secrets behind the other 95%: dark matter.

The night sky has long been a subject of mystery, awe and wonder. And one of the greatest mysteries in the universe is the concept of dark matter.

Scientists realised in the early 20th century that when you add up all the things that emit light; stars, planets and interstellar gas, it only accounts for about 15% of the matter in the Universe. The rest is known as dark matter and scientists can be certain of its presence due to its gravitational attraction rather than its luminosity.

Despite 50 years of research, scientists still have no direct evidence for dark matter, but could this be about to change with the help of some repurposed table top sensors?

DISCOVERING THE "MISSING MASS"

The idea of mysterious invisible things in the universe has a long history dating back to the 18th century. Ahead of his time, French scholar Pierre Laplace speculated that the universe contains massive stars whose gravity is so great that even light cannot escape – a phenomenon later defined as black holes.

However, the concept of dark matter itself was first inferred by astronomer Fritz Zwicky who, in 1933, discovered that the mass of all the stars in the Coma cluster of galaxies provided only about 1% of the mass needed to keep the galaxies from escaping the cluster's gravitational pull. Originally named the "missing mass", Zwicky's observations were initially met with much scepticism but were later confirmed by other astronomers.

Thirty years later, astronomer Vera Rubin provided a huge piece of evidence to support the existence of dark matter, discovering that the centres of galaxies rotate at the same speed as their extremities, contrary to popular logic.

HOT VS COLD DARK MATTER

Dark matter is invisible; it doesn't emit, reflect or absorb light or any other type of electromagnetic radiation such as x-rays or radio waves. However, dark matter interacts with the ordinary matter that we can see, exhibiting measurable gravitational effects on large structures in the universe such as galaxies. Therefore, astrophysicists can identify the distribution of dark matter in the universe without directly seeing it.

Two varieties of dark matter have been found. The first is made of the familiar baryons which include protons, neutrons and atomic nuclei. These cover about 4.5% of the universe and make up the luminous stars and galaxies. The second type is in an unfamiliar non-baryonic form, subdivided into Hot Dark Matter and Cold Dark Matter. The difference between the two refers not to the temperature of the matter itself, but the size of the particles, which in turn determines how fast they can travel.

UNLOCKING THE MYSTERY

Among the researchers dedicated to unlocking some of the biggest mysteries in the universe, a team from the University of Delaware have proposed a new way to look for the particles that might make up dark matter by repurposing existing tabletop sensor technology.

Their research, published in February 2021 in the journal *Physical Review Letters*, focuses on the possibility that dark matter is made up of dark photons, a type of dark matter that would exert a weak oscillating force on normal matter.

Measuring this force is difficult, but assistant professor Swati Singh and her collaborators think they can overcome this obstacle by using optomechanical accelerometers as sensors to detect and amplify the oscillation.

Their study builds on previously published research which demonstrated that several existing and near-term laboratory-scale devices are sensitive enough to detect, or rule out, possible particles that could be dark matter. The team is part of a growing community, actively working to develop additional tabletop sensors to look for dark matter and other weak astrophysical signals.

We are now a small step closer to finding out what is really out there in the mysterious dark void of space. ■

*Dark matter is **invisible**; it **doesn't emit, reflect or absorb light** or any other type of electromagnetic radiation such as x-rays or radio waves.*

ARTWORK: KIAH FISHER, LUCENT
JOANA VIVEIROS, ANXIETY GALAXIES IV

REVIEW

Fatima Sheriff reviews Annihilation by Jeff VanderMeer

Annihilation tells of a scientific mission into Area X, an amorphous place on the coast of America that was subjected to a cosmic event which shifted the landscape into something alien. Previous missions either haven't returned or, in one case, the crew have returned separately with complete amnesia. Having been put under hypnosis by their leader to survive the journey in, four new scientists begin their investigation.

From the offset, this intricate tale is shrouded in mystery. We know little about our characters and what has driven them to undertake this hellish expedition. Everything they discover only brings a wealth of more questions, with only glimmering specks of clarity amid the fog of confusion. We only learn about the voyage through the diary of our protagonist, The Biologist, piecing together fragments of her stream-of-consciousness narration from the moment she steps foot into Area X. Her biased storytelling is gripping and self-aware, as her rational mind points out every incongruent pattern in her thought process. In the build-up of tiny, odd details, like her insistence on calling an underground tunnel they find "the Tower", everything turns topsy-turvy rapidly.

Companionship serves only as a distraction from the goal, as anonymity is paramount between the central characters, who are known only as the Psychologist, the Surveyor, and the Anthropologist. While they must work as a team, their expedition is highly individualistic and self-centred. Each has their own missions and diaries to record findings, and conferring could bias their reports. They have also been told to monitor each other's mental states for any lapse that would suggest that Area X has infiltrated their minds, creating suspicion and caution in every interaction. Panic sets in at regular intervals and, without truly knowing the other characters, it is a roll of the dice how they react in every bizarre situation. One intriguing aspect is the casual way in which the Psychologist uses hypnosis on her team, described in the narration as a normalised aspect of their survival plan for Area X.

What transpires is a fantastical yet terrifying journey into both the mind of the Biologist and the Area itself. It is a brilliant combination of a Shirley-Jackson-esque narrator, observing her own downfall and that of the others, with the best creative aspects of space fiction that describes a sense of adventure alongside the impact of isolation. The difference is that it is all the more unnerving to imagine Area X on Earth, gradually engulfing its continent with its mutated creatures and strange alien atmosphere that drives people to insanity.

As we only observe it through the Biologist's lens, we can also appreciate the beauty of Area X, and her scientific curiosity leads to an almost zen-like acquiescence. It seems that by embracing it, she begins to encompass a complex duality of being both entranced and immune to its madness, and we are privy to these intriguing contradictions first-hand. VanderMeer creates a terrifying mental space to inhabit with monstrosities emerging from outside and within, but even at its most disturbing, it is utterly transfixing, and one of my absolute favourite novels.

It is perhaps not for the faint-of-heart, but equally, for those like me not well equipped to read an overly complex Science Fiction novel with Capitalised New Words for every concept, it is remarkably easy to follow and, at around the 250-page mark, doesn't overstay its welcome or overexplain. Whether you choose to read the next two books in the Southern Reach trilogy to discover more about Area X's history is up to you, but as a standalone piece, *Annihilation* is incredibly compelling because of its mystery and the scope for scary hypothetical spirals that this gives rise to. ■

ARTWORK: KIAH FISHER, AFTER GLOW
JOANA VIVEIROS, ANXIETY GALAXIES IV

A DAY WITHOUT QUANTUM PHYSICS

The winner of the first I, Write competition is Havana Ide from Howell's School, Llandaff, GDST (Girls Day School Trust) in Cardiff. Havana explores how the world around us is governed by quantum physics.

I, WRITE COMPETITION WINNER

I, Write is a new science writing competition created by by Science Communication masters students at Imperial College London. The project was organised by members of the I, Science team, Gabriella Linning and Sophie Burley. The theme of the competition was *Science in My Life*, with the aim of challenging secondary school students to think critically about how science can be found in the world around them. We had many great entries and would like to thank our finalists for their outstanding articles!

The team at I, Science would also like to congratulate our two runners up - Aishah Daiyun from The Brooklyn Latin School in New York and Yu Hang Hui from Island School in Hong Kong.

Quantum physics is perhaps the most alienating subject area in the scientific world, puzzling an elite group of thinkers for decades. It is the fundamental theory in physics that provides a description of the physical properties of nature at atomic and subatomic scales.

Understandably, most people tend to shy away from this area; if even the most renowned scientists like Einstein can't fully crack the quantum code, why should the average person even bother with quantum physics?

This disconnect is perhaps less common in other areas of physics. For example, most people are to some extent aware of the impacts of Newton's Laws; drivers apply their breaks to slow down their car (an application of Newton's first law) and footballers kick balls with a greater force to enable a greater acceleration (an application of Newton's second law).

But what most people aren't aware of is their intrinsic connection to the quantum realm, thinking the theory is very remote and unconnected to their everyday lives. You might well ask yourself, what does a particle accelerator have to do with my existence? Why does it matter that Schrodinger's cat is both dead and alive? As a result, many of us realise very little about the applications and tend not to think where quantum mechanics has taken us beyond the physics lab.

Let's imagine a day in your life where the rules of quantum mechanics go awry. This will illustrate that quantum physics isn't remote and unconnected to your everyday life after all; it is your everyday life.

Maybe you use an alarm clock to wake up in the morning. Normally, you could snooze this clock with a tap of a button, wake up to the sound of birds or even the morning news (if the alarm clock is a particularly fancy one). But, despite setting your alarm before you went to bed, you wake up to light pouring into your room, indicating that you have overslept.

'Why didn't my alarm go off?'

Your alarm clock plugs into your wall socket, which gives off an electric current that oscillates exactly 60 times per second, normally keeping time well and waking you up. 'The plug is faulty' you assume, getting out of bed to make your way downstairs.

Habitually, you switch on your flat screen TV and sit down to watch your favourite breakfast TV programme. As expected, the screen flashes on and you sit back, ready to start your slightly delayed morning. A headline catches your eye:

'Early data suggests break down of quantum realm, experts in disarray'

The image flickers away suddenly and you are left staring at a black screen. You check the power, try to switch the TV on and off again, and even hit the remote on the table. No luck.

'First the alarm clock... now the TV'

The image on your TV screen is formed by thousands of illuminated LEDs, a semiconductor material that functions due to the basic principles of energy levels within an atom.

'Well, I'll have to catch up on the news tonight. It didn't seem that important.'

With that thought, you get up to make your breakfast. As usual, you pop two slices of bread into your toaster and let it toast for about 3 minutes. Inside the toaster, the heating filament turns from black, to orange and finally to a glowing red colour, nicely heating up your breakfast. You check to see how toasted the bread is...

'The heating filament has stopped glowing. Hm.'

The glowing of a hot object is a universal phenomenon: you heat something up, and it will first glow red, then yellow, then white at hotter temperatures. The heating filament in a toaster produces infrared radiation, a form of light on the electromagnetic spectrum, to heat this slice of bread.

You push the handle up and down again.

'It was working just a moment ago, the bread has started to toast. Why did it stop?'

Fed up, you decide to head out. Your mind is made up that today just isn't your day. It's ghostly quiet outside, not a soul to be seen.

'Strange...'

You get into your car and turn on the built-in GPS, where you type in the postcode of where you need to get to.

'No location found? Why isn't it picking up my location?'

GPS or Global Positioning System is a network of satellites that normally makes finding locations and directions quite easy. 24 satellites orbit the Earth, with four being used for each location needing to be found. Every satellite in the GPS constellation includes an ensemble of atomic clocks, an amazing invention that keeps time to such precision that they only lose about a second over 108 million years! An error as small as a millisecond could leave you 300km from where you want to be.

You try once more.

'No location found'

Frustrated, you sit back, confused as to what is going on today. Racking your brain, you try to work out what is happening.

'But nothing has happened... apart from the quantum thing on the news this morning.'

You pause for a moment, thinking about everything that has gone wrong today.

'The alarm clock, the TV, the toaster, the GPS... are they all related to quantum physics?'

Everything that you have tried to do today has failed, due the disappearance of the phenomenon that is quantum physics. Power stations couldn't produce rhythmic oscillations to keep time in your alarm clock, nor can LEDs shine brightly. The heating filament in your toaster was unable to radiate enough heat to toast your bread, and atomic clocks were unfit for purpose.

'So will we just be living tech-free until the quantum realm fixes itself?'

Actually, you won't be living at all. Without quantum physics, a necessity for life on Earth is unable to exist: water. The odd properties of water that make life possible are facilitated by hydrogen bonding, a type of bonding between water molecules, holding them together. Quantum water is a relatively new theory which suggests that without the quantum uncertainties in these bonds, water, as we know it, couldn't exist.

'No water...no life?'

You glance into your wing mirror.

No one is staring back at you. You aren't there. Nothing is there. ■

Without quantum physics, a necessity for life on Earth is unable to exist: water.

Quantum physics isn't remote and unconnected to your everyday life after all; it is your everyday life.

ARTWORK: KIAH FISHER, LUMINOUS

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