I, SCIENCE

THE SCIENCE MAGAZINE
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GOOD vs EVIL

SPRING 2021

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I, SCIENCE

Dear Reader,

The historic battle of good vs evil, right vs wrong, dark vs light has been raging since the dawn of humanity. These concepts underpin almost every aspect of our society - including the realm of science. That's why for the second issue of the academic year, I, Science Magazine has decided to tackle all things Good & Evil.

As usual, our writers have produced some impressive pieces and have approached this relatively abstract topic both insightfully and creatively.

We start with a recap of the top news stories from this term, followed by a look into the evolution of human morality and the Baldwin Effect. Next up, we consider the good and bad in the world of pathogens, before comparing the simplicity and the complexity of theoretical modelling. Keep reading to explore the dangers of misuse of science and the spread of misinformation, ahead of reflecting on the human perception of various predators. Next, have you considered if we live in an evil universe? What about the altruism of the animal kingdom? Or, if myth-busting sparks your interest, turn over to read about some common science beliefs being debunked.

As we know, artificial intelligence is a quickly growing field of research. This issue features two articles that have tackled the morality of AI from different angles. On the subsequent pages, read about the benefits and drawbacks of peer reviewing in the scientific process, the neuroscience of morality, as well as whether sharks are really evil or just misunderstood. We also cover an incredibly popular topic at the moment; the hesitancy surrounding vaccines. Additionally, you can read about how various stakeholders in climate change are portrayed in the media as well as how scientists are presented in works of fiction. Further on, we take a look at the negatives as well as the positives of nuclear research. In this issue, we have also featured the winning submission from an undergraduate level chemistry writing contest, which is an interesting look into the process of, and difficulties in, harnessing and using solar energy. Finally, we have a thematic review of a popular TV show as well as an exploration into the scientific concepts behind two different pieces of artwork.

We've really enjoyed working on this thought-provoking theme and we hope you find it both engaging and informative!

Happy reading!

Until next time,

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

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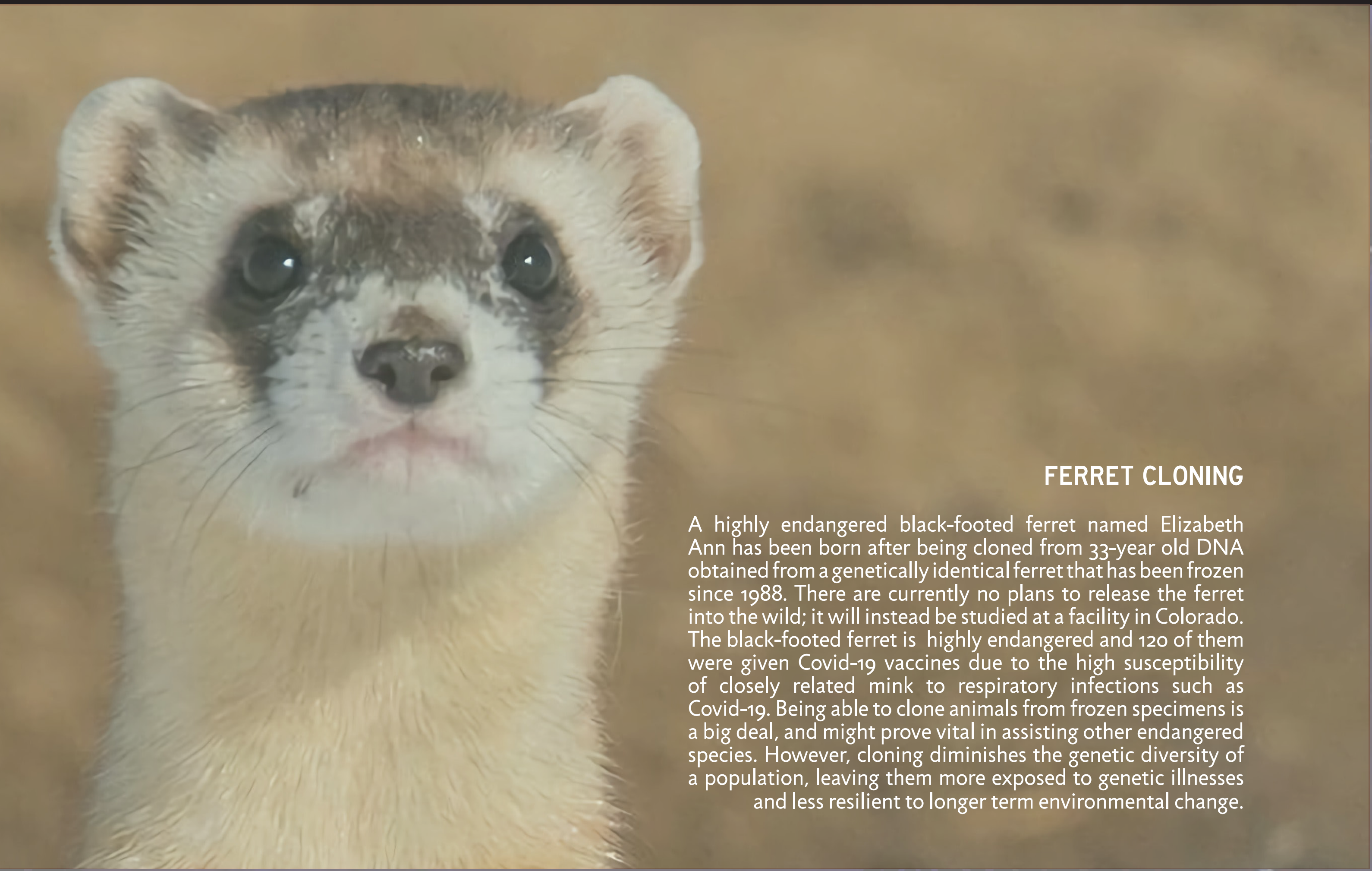
ARTWORK: SOPHIE BURLEY

news.

Keegan Schroeder covers the latest.

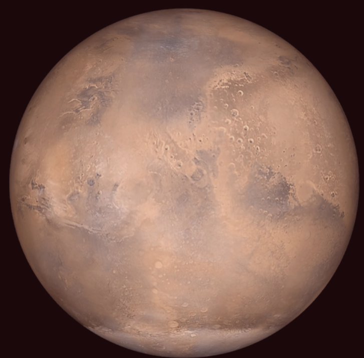


FERRET CLONING

A highly endangered black-footed ferret named Elizabeth Ann has been born after being cloned from 33-year old DNA obtained from a genetically identical ferret that has been frozen since 1988. There are currently no plans to release the ferret into the wild; it will instead be studied at a facility in Colorado. The black-footed ferret is highly endangered and 120 of them were given Covid-19 vaccines due to the high susceptibility of closely related mink to respiratory infections such as Covid-19. Being able to clone animals from frozen specimens is a big deal, and might prove vital in assisting other endangered species. However, cloning diminishes the genetic diversity of a population, leaving them more exposed to genetic illnesses and less resilient to longer term environmental change.

MARS ROVER LANDING

On the 18th February NASA's Perseverance Rover made a historic landing on the surface of Mars. The landing site is in a location known as the Jezero Crater, a site that has been considered far too treacherous to attempt until now. During the Apollo moon landings, astronauts had to resort to looking out the window during the final descent to land safely. While clearly not an option on an unmanned mission, progress has been made (no surprises there!). A new technology called Terrain Relative Navigation was deployed to ensure a smooth landing for the rover on the Jezero Crater's craggy and rugged surface. Onboard sensor data is matched to a known map of the landing area allowing for accurate targeting of specific landing points using advanced computing. At the time of writing, the rover has been on the surface of Mars for over 9 Sols (which is the Mars version of a day). A sol is slightly longer than an Earth day. Check out NASA's website to get more information at https://mars.nasa.gov/mars2020/



EVOLUTIONARY ALTRUISM IN BACTERIA

A 2020 study on E.coli has revealed a population survival adaptation that's akin to altruism. A subpopulation in a larger population of E.coli bacteria was found to be more susceptible to very low doses of antibiotic. When the bacterial population moves into an area of antibiotics, members of the subpopulation are the first to die. These bacteria were found to be releasing a necrosignal protein called AcrA. AcrA released from the dead bacteria binds to the surface of the remaining living bacteria and enhances their ability to pump out the antibiotic, giving them a higher level of resistance. In a sense, this bacterial subpopulation sacrifices itself for the good of the whole. Altruism is particularly common in species with complex social behaviour, but discoveries such as this may suggest that it is more deeply rooted in evolution. With growing levels of highly resistant bacterial strains in hospitals, exploiting these necrosignals might provide a new tool to tackle the problem as ideas are forced to become increasingly creative.

BACKGROUND ARTWORK: KIAH FISHER

IMAGES, CLOCKWISE FROM LEFT:
ROHAN CHANG, UNSPLASH
ADRIAN LANGE, UNSPLASH
NASA, UNSPLASH

> "Past our own assumptions and prejudices, and through the veils of culture and religion, we see a universal morality – an instinctual human predisposition to know right from wrong."

ARTWORK: LUCY LIPSCOMBE

THE BETTER ANGELS OF OUR NATURE

The evolution of morality is a complex concept. Will Carter investigates the Baldwin Effect, and the discovery of how altruistic learned behaviours are crucial

Kindness is one of humanity's most celebrated and redeeming qualities. Humans have a unique capacity for telling right from wrong and acting on that instinct to do good.

We all feel the urge, buried deep in our minds, to go out into the world with kindness, empathy and goodwill in our hearts. Past our own assumptions and prejudices, and through the veils of culture and religion, we see a universal morality – an instinctual human predisposition to know right from wrong. As the vast plethora of cultures have flourished across the world, countless permutations have sprung forth from our common moral seed; a universal moral sense arising from our evolutionary process and enshrined in our genome.

JUDGEMENTAL BABIES

Free from any potentially corrupting socialising influence, babies exhibit innate behaviours, providing a basis for research into human morality.

Developmental psychology for many years believed babies to be awful little brutes in desperate need of civilising; boorish brats who must be taught to tell right from wrong. Ongoing research has refuted this assumption and given us insight into infants' moral sensibilities. Ever more evidence is emerging to support the notion of an innate, rudimentary moral sense. Through careful experimentation, moral thought, moral judgment and moral feeling have all been demonstrated in infants, even within their first year.

A prime example of such research involved a puppet show where three puppets play a game with a ball. One puppet standing in the middle would pass the ball to the other two. When the first (nice) puppet received it, he would pass it back, whereas the second (mean) puppet would take the ball and run away. Having watched this drama unfold, the young participants were presented with the two puppets, both placed next to a few treats each. The infants were then asked to take a treat away from one of the puppets. In a significant majority of cases, the children took treats away from the 'mean' puppet, indicating their disapproval, with some particularly vindictive babies smacking it for extra punishment.

Many similar experiments investigating infants' moral sense have been conducted and replicated, providing significant evidence for an innate moral intuition. It follows to ask "where does this instinct come from?"

CLEVER GIRL

The Baldwin Effect explains how learned behaviours can become evolved instincts, in short: genes will be selected for if they predispose advantageous behaviours.
We usually think of evolution acting on physiological traits, but the Baldwin Effect asks us to consider genes' indirect role in predisposing behaviour and how selective pressures can promote certain behaviours.

For example, consider a species of mammals living on the forest floor with many trees bearing fruit high in the canopy. It would be hugely beneficial to nab that bounty, but it's very dangerous and climbing is a difficult skill to learn. A gene that helps an individual learn to be a better climber would be selected for and future generations will have a competitive advantage as their genes predispose them to beneficial behaviour.

> "All of life's kingdoms are rich in such mutualistic relationships."

It is through the Baldwin Effect that our innate moral intuitions are believed to have developed. We will consider two important explanations for altruistic/moral behaviour, glossing over less significant factors. First, there is the case of genetic kinship. Consider natural selection working at the level of 'selfish genes', piloting our fleshy vessels with the sole purpose of being transmitted to the next generation. As a specific gene can exist in many individuals at any one time, a gene in one individual that can benefit its exact copy in another individual will still provide an overall advantage to transmission, and so will be selected for.

For example, a gene that makes an animal more likely to share excess food with close relatives will more likely be transmitted, because of the statistical likelihood that those relatives will share copies of that same gene. In this way a gene predisposing an individual to exhibit altruistic behaviour towards their kin will be selected over many generations.

Second, there is the case of reciprocal altruism, sometimes called symbiosis, which does not depend on shared genes. Take the classic example of the honeyguide and the honey badger. The honeyguide bird is very good at finding bees' nests, and uses an enticing flight pattern to lead honey badgers to them. Working together both can reap the spoils, whereas apart neither could, aptly demonstrating reciprocal altruism.

Consider this in terms of the Baldwin Effect, how millennia ago a single pair of ancestral honeyguide bird and badger learned to cooperate and in the generations that followed, genes that expedited this process were selected for. Over time, the honeyguide and the honey badger become genetically predisposed to behave in this reciprocally altruistic and beneficial way. The case of the honeyguide and the honey badger is but one of many; all of life's kingdoms are rich in such mutualistic relationships. Natural selection will favour genes that predispose individuals to exhibit these altruistic behaviours, as they are beneficial to all parties.

Throughout human prehistory we lived under conditions strongly favouring altruistic behaviours: small, hunter-gatherer communities amongst close relatives - perfect circumstances for the evolution of kin and reciprocal altruism. These primitive instinctual inclinations exist within us today, codified in our genetics, the moral foundations for millennia of human culture and civilisation.

SICK OF PATHOGENS? ME TOO.

Dave Warrell delves into the paradox of the good and evil of pathogens.

Since the days of Louis Pasteur and Robert Koch, microbiologists have categorised microorganisms according to whether or not they cause disease. Any microorganism that does is a pathogen. Viewing microorganisms as binary, as disease-causing or not, is understandable. We see virtually everything in a similar way; in every story there are good guys and bad guys. It's how we make sense of the world. In the case of pathogens, the result is a mindset that focuses on how pathogens damage us and how we might kill them. This tends to give pathogens agency; it makes their actions appear deliberate. We think of them as *wanting* to cause disease. The result is a series of war metaphors: we are currently *battling* COVID, we *eradicated* BSE, the *fight* against polio is nearly *won*. Yet, in the last 50 years, the likelihood of a decisive human victory over infectious disease has come into question. We have seen the rise of new pathogens and we have seen attempts to kill off many others fail. There are now calls to change the emphasis, to adopt a more ecological view of pathogens to help us understand them better.

TAKING A LEAF OUT OF ECOLOGY'S BOOK

Nature depends on symbiosis: all organisms have come to depend on organisms belonging to different species for their survival. Unlike the word pathogen, symbiont, which refers to any organism taking part in a symbiotic relationship, is neutral. Sometimes symbionts can have a positive effect on one another. For example, we provide a guaranteed source of food for the bacteria that live in our gut. In exchange, many of them help us to break down certain substances and help us build up our

> "A mindset that focuses on how pathogens damage us and how we might kill them...tends to give pathogens agency; it makes their actions appear deliberate."

immune systems. Relationships like this are known as mutualism. On the other hand, there are many symbiotic relationships where one symbiont thrives to the detriment of the other. *Plasmodium* is a unicellular organism which can only reproduce inside other animals. In vertebrates, it primarily infects red blood cells, reproducing until the cells burst. In humans, this causes the group of symptoms that we call malaria. Because *Plasmodium* reproduces at our expense, it's an example of parasitism. When there is a benefit to one symbiont but no clear effect on another, it is called commensalism. For example, many bacteria happily live on our skin with no ill effects for us.

We often think of pathogens as separate entities from parasites, yet most definitions of parasites also apply to pathogens and vice versa. Think about malaria: we consider *Plasmodium* to be a parasite because it lives inside us to survive and it causes disease. How is this different to influenza viruses and the flu?

SO, IS THERE A DIFFERENCE BETWEEN A PARASITE AND A PATHOGEN?

The answer isn't clear-cut. Categorising microorganisms seems to be based on convention. Sometimes it's a case of scale. For example, tapeworms are normally visible without a microscope, and are considered parasites rather than pathogens. However, many parasites, such as *Plasmodium*, are unicellular. At the microscopic level, the differentiator seems to be cell structure. Disease-causing eukaryotes, like *Plasmodium*, have cells with a nucleus, similar to ours and are considered parasites. Disease-causing prokaryotes, like bacteria such as *E. Coli*, don't have a nucleus, and are considered pathogens. But wait, fungi, who are also eukaryotes, are generally considered pathogens?

My point is that these divisions are arbitrary, so why don't we place pathogens on the same scale as parasites? The term pathogen was coined specifically to describe an organism that causes disease. It doesn't allow for any ambivalence. By contrast, the sliding scale of symbiosis allows us to capture the good, the bad, and everything in between. This ecological approach acknowledges that, regardless of what we call these microorganisms, their only imperative is biological: to replicate. It shifts the emphasis away from the actions of the pathogen and onto the relationship with its host or other microorganisms. Importantly, it acknowledges that there are many factors which influence whether a symbiont has a positive or negative effect on its host, that a parasite in some contexts is a mutualist in others.

TAKEN OUT OF CONTEXT?

Bacteria that make up our natural gut flora typify the flexible nature of symbiosis. For instance, *Mucispirillum schaedleri* was first understood to cause colitis (inflammation of the colon) in mice with a poorly functioning immune system. However, in mice with better functioning immune systems, it was recently found that *M. schaedleri* can *prevent* colitis by stopping the secretion of harmful toxins by *Salmonella*. In this case, a pathogen in one context is a mutualist in another, depending on the state of the host's immune system. Focusing just on how microorganisms can cause disease can blinker us from discovering what symbionts normally do.

> "The term pathogen was coined specifically to describe an organism that causes disease. It doesn't allow for any ambivalence."

HIV is a good example of why it might be important to understand what a symbiont does in its normal ecosystem. HIV originates from SIV (simian immunodeficiency virus), which infects monkeys and apes. The majority of SIV infections in monkeys and apes don't cause any disease in their simian hosts; the virus and its hosts have adapted to live together. HIV infects our T-cells, an important part of our immune systems. Similar to malaria, it reproduces in those cells until they break open. However, much of the damage done in HIV infections is actually done by our own immune system. It kills its own cells in which HIV is hiding. Together with HIV this wipes out the immune system. Yet, most of HIV research focuses on how HIV causes disease and what drugs can stop it replicating, not how SIV and monkeys have adapted to live with one another.

JUST A MATTER OF TIME?

Pathogens can even become beneficial to us over time. Given the current pandemic, this idea might sound far-fetched, but we know that this has happened in the past. My favourite example of this is syncytin, a protein that is crucial for the formation of the placenta. The gene encoding syncytin is not mammalian in origin: it came from a virus. In the process of evolution, one of our long-lost ancestors was infected by what we would likely have considered a pathogen. Over time, that pathogen became a mutualist. That mutualist then became integrated into their genome and in so doing helped them to stop laying eggs. If that isn't a demonstration that 'pathogen' is a narrow view of a microorganism, I don't know what is.

Imagine my surprise, then, when I discovered that some microbiologists have started to use the word 'pathobiont' to describe symbiotic microorganisms that have the potential to be pathogenic. That's just a symbiont! To describe a microorganism as a pathobiont is the equivalent of describing all people as proto-criminals. Yes, virtually every human has the potential to commit a crime, but only when a whole host of environmental factors push them that way. If you're always looking out for what crimes someone is committing, that's all you'll see.

I am not about to say that pathology should be abandoned, its role in understanding diseases is crucial to how we develop drugs to treat them. But I think it's worth reflecting on this: a pathogen is not always a pathogen. Pathogens are just a type of symbiont, and more often than not, the nastiest pathogens are the most out of their depth. They have adapted to co-exist with a host, and much of the time disease is a result of the host changing, rather than the pathogen. Over time, they could even come to work to our advantage. Thinking of them as symbionts instead of pathogens and understanding their place in their normal ecosystems might just open more lines of inquiry, which could even help to develop treatments that circumvent issues like antibiotic resistance. So, I'm declaring war on the word pathogen, to help us win our battle against them. ■

> "To describe a microorganism as a pathobiont is the equivalent of describing all people as proto-criminals."

PULL QUOTE ARTWORK: HERMINE DE CLAUZADE DE MAZIEUX

ARTWORK: LUCY DUKES

SIMPLICITY AS GOOD, COMPLEXITY AS EVIL?

Calvin Nesbitt examines why as scientists, we think that simplicity underlies good models in theoretical science, whilst complexity is something considered to be 'evil' and something to be removed from our theories.

That's another thing we've learned from your Nation," said Mein Herr, "map-making. But we've carried it much further than you. What do you consider the largest map that would be really useful?"

"About six inches to the mile."

"Only six inches!" exclaimed Mein Herr. "We very soon got to six yards to the mile. Then we tried a hundred yards to the mile. And then came the grandest idea of all! We actually made a map of the country, on the scale of a mile to the mile!"

In Lewis Carroll's final novel Sylvie and Bruno, the Germanic oddball known only as 'Mein Herr' speaks with great pride of his cartography skills. One can imagine the glow in his eyes, the tremor in his voice as he boasts of the largest maps he has made. One of these maps is so large that it is 1:1 with the country it represents. At first, this absurdist vision appears as obviously silly and irrelevant to our day to day scientific lives as grinning Cheshire cats. But it is worth pausing to think about this bizarre vision. A vision of lines drawn on an unimaginably large canvas, drawn over the country the lines themselves represent. Not just because it's funny, or a bit odd, but also since it's instructive in helping us understand what we consider 'good' about a scientific theory. Taken as a parable, it helps us understand how we, in science, respond to the missing or evil little details (the devil's in the detail!). How we respond to the complexity of the world we're trying to describe. How we respond to the unrepresented features on the map.

> "That if there is potential for **good** in science, which I think there is, then it probably lies in its ability to materially **improve lives**."

I should set out my stall early and say that if there is potential for good in science, which I think there is, then it probably lies in its ability to materially improve lives. Think: stopping children dying from disease, preventing world hunger or preparing ourselves for the worst aspects of climate change. Of course, here there are many questions about who is given access to the benefits, and who controls what we want to 'improve'. Questions that are important to consider, especially given the colonial context in which many of our disciplines were developed.

A second avenue for good in science is one that is often described with softer language. Words such as 'clarity', 'beauty' or 'understanding' will be used. Roughly speaking, it's something like the ability of science to help us comprehend the natural world around us. Its ability to make sense, to create feelings of joy within us as it explains something that previously was hidden from our day to day experience.

As a graduate student in the 'Mathematics of Planet Earth', I find myself standing with one foot in each of these camps. Often, when a mathematician is considering what it would mean to describe the curvature of a seven-dimensional surface or whether a symmetry can be represented as a matrix, it is not because she thinks that it is necessarily useful but because there is joy. The good in the theory comes from it creating understanding or aesthetic appeal. In contrast, many climate scientists can more naturally be placed in the first camp. In a world that is relentlessly heating up, where extreme weather events are soon to become the norm and where ecosystems are being pushed to their limits, a focus on solving problems that have material benefit seems a priority.

At this point, it's important to clarify a particular aspect of the climate sciences that make Mein Herr's map all the more relevant. In climate science we can't perform experiments as freely as in other sciences. We have only one earth and there are limits to what we could or should change about it. In response to this, we often work with models or computer simulations that represent the earth in varying amounts of detail. In essence, these models are computers calculating algorithmic solutions to mathematical equations that describe the earth. There'll be an equation describing the winds, one for the oceans, one for ice and so on. By altering the equations the computer solves, for example, we may add a term representing human pollution; we can perform experiments on the computer to predict how different scenarios may play out in the future.

Much like Mein Herr's map, these models are often as complicated as the earth itself. To give an idea of the scale involved, I should mention that the European Union is currently finalising the details on their planned 'digital twin' of the earth. It constitutes an €8 billion investment and hopes to perform one billion billion calculations per second. As with climate models before, it will simulate a huge number of climatic processes: vegetation, ice, aerosols, the winds, the ocean and more. As mentioned above, the thinking is that once such a model is built we can use it as a virtual laboratory to help understand the increased risks posed by climate change.

To me, this approach we have in the climate sciences points to a tension between the two 'goods' we mentioned previously; a tension implicit in Mein Herr's map. The material benefit of these models is only really delivered if we make them impossibly complex; if, like Mein Herr, we represent every detail, accounting for all the processes we're missing. Then, in the same way that one could never practically use Mein Herr's map, we're left with a model that is so complex it becomes devilishly tricky to understand, it's comparable to understanding the original earth itself.

To be clear, this isn't an attempt to undermine these models, they're some of the biggest achievements of modern science. Rather I'm trying to show how these notions of good I set out at the top of the piece are often, in practice, somewhat opposed or unattainable. What is making one valued, its complexity, its correspondence to reality, is precisely the evil in the other. On the other hand, it's the simplicity entwined with understanding that we want to drive out in the first good. There is a tension within climate science. A tension implicit in the map of Mein Herr.

This tension has been (and still is) widely discussed within climate science To finish, I would like to introduce the response of American meteorologist Isaac Held to it. In his influential 2005 essay "The gap between simulation and understanding in climate modeling" Held outlines the issues I've alluded to above. His response? The modelling hierarchy. The 'modelling hierarchy' is a conceptual ladder or tower of models. It encompasses simple toy models of climatic processes at its foot and the complex realistic models at its top. The idea is that one has a complete grip on the models at the base and traces ideas up the hierarchy. For example, on the bottom of one's hierarchy there may just be a model of ocean temperature that ignores the waves for now. Layers of complexity are slowly added as you
climb the hierarchy (maybe some waves, ice, wind, plankton!), hoping that you can trace your understanding up the hierarchy until you finally arrive at the Promethean models lying at the top.

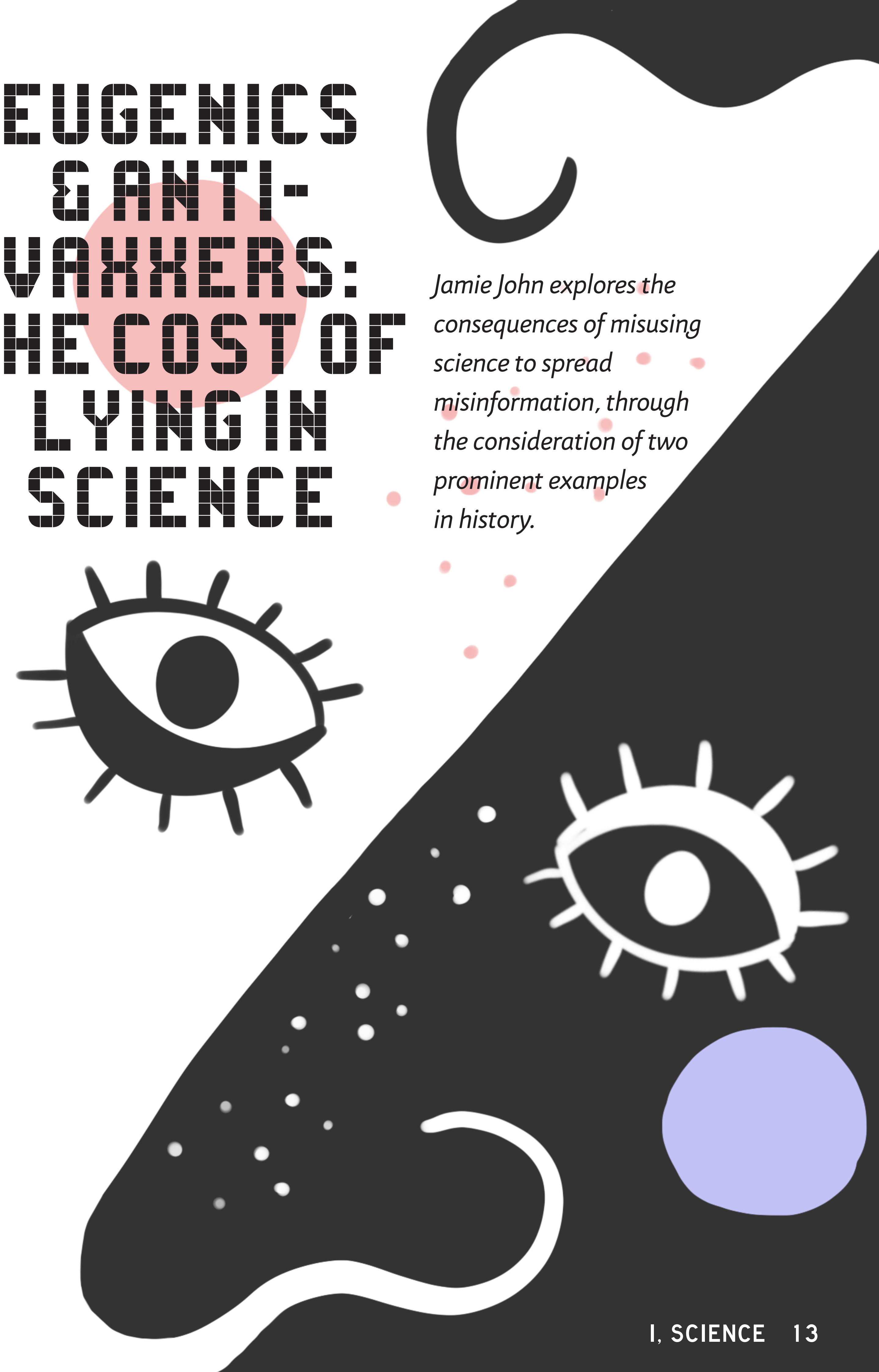
It's an attempt to have your cake and eat it. Our confidence, or trust of the top is based on our understanding of the base. Our justification for caring about the bottom is based on the usefulness of the models at the top. The complexity/the good/the evil on the top slowly replaces the evil/the good/the understanding as we climb. The good, the evil, the understood, the complexes are entwined and feeding on one another the whole way. ■

> "In the same way that one could never practically use Mein Herr's map, we're left with a model that is so complex it becomes **devilishly** tricky to understand, it's comparable to understanding the original earth itself."

ARTWORK: MERVE SAFA ERGUNER
PULL QUOTE BACKGROUND: BRIDGET SWANN-CLARK

EUGENICS & ANTI-VAXXERS: THE COST OF LYING IN SCIENCE

Jamie John explores the consequences of misusing science to spread misinformation, through the consideration of two prominent examples in history.



ARTWORK: KAROLINA WILGUS

In *Foundation*, the seminal science fiction novel, Isaac Asimov presents a world where psychohistory, a science which allows the future to be predicted using probability theory, has been invented. Psychohistory is so effective that its creator predicts the fall of a vast empire which stretches to the furthest reaches of the Milky Way. Contemporary science has not quite reached this stage, but it certainly exerts a similar hold over public imagination. It is often seen as providing concrete truths, much like psychohistory provided in *Foundation*. Unfortunately, modern science does not give us all the answers we ask of it. It is prone to manipulation and can be used to spread misinformation – people can, and do, use science to support their own agendas. This has become increasingly apparent in the past decade or so with the growth of social media, but it is by no means a recent phenomenon. Misinformation in science has a dark history, stretching back into the past and serving as the justification for mass atrocities.

> "Misinformation in science has a dark history, stretching back into the past and serving as the justification for mass atrocities."

A good place to begin when considering misinformation in modern science is in the fields of statistics and biology, with Sir Francis Galton. Galton was a scientist in the 1800s and a pioneering statistician, coming up with the idea of correlation and laying the foundations for fingerprint identification. However, what he is best known for is for being a eugenicist – a term that he coined. Galton was fascinated by the work of his half cousin, Charles Darwin, and his book, On *The Origin of Species*. He seized upon the ideas of natural selection, which Darwin had proposed as the mechanism for evolution, and applied them to groups of people. In his book, *Hereditary Genius*, Galton investigated the link between the success of parents and their offspring. He found, unsurprisingly, that there was a positive correlation between the two – successful parents had successful children. Galton neglected the social inequalities which contributed to this and attributed the correlation solely to biological inheritance – those who were from wealthy upper-class families had better genes.

But he went further than this. In *On The Origin of Species*, Darwin described artificial selection as being the method by which farmers selectively bred livestock to produce generations of animals with desirable traits. Francis Galton applied this idea to humans – he believed that mankind could be improved by similar means and encouraged the 'cultivation of race.'

During the course of his investigations into biological inheritance and eugenics, Galton made advances in statistics, developing ideas such as correlation and standard deviation to quantify observations from his samples. But he strode outside of the realm of statistics, breaking one of its cardinal rules: he implied causation from the correlation between race and societal standing. Galton was not the only prominent figure to embrace eugenics; his ideas were also espoused by British political figures. Neville Chamberlain and Winston Churchill, the two Prime Ministers during the Second World War, were both members of the British Eugenics Society and Churchill was even the Honorary Vice President.

Galton's ideas would be adopted by various groups in the 20th Century. In what would prove to be a running theme in misinformative pseudoscience, his falsities would be extended and reshaped into political ideas which would fuel xenophobia and cause a great deal of harm.

One place where Galton's theories were particularly well-received was the United States. One of the earliest and most influential proponents was Charles Davenport, an American biologist. Davenport had met Galton in London and became fascinated with the idea of eugenics. In 1910, with funding from the Carnegie Institution, he created the Eugenics Record Office, which gathered data on the American population and disseminated eugenics propaganda.

The eugenics movement in America gained momentum and its followers – influential academics and policymakers – advocated for compulsory sterilisation and immigration restrictions on those deemed to be inferior. Unsurprisingly, the groups affected were the poor, the 'immoral,' ethnic minorities, and disabled people. The restrictions were aimed at improving America's genetic makeup by systematically eliminating these groups.

These ideas started coming to fruition from 1907 onwards and by 1931, 30 out of 48 states had enacted forced sterilisation laws. Minority women were disproportionately affected and were sterilised without a full understanding of the implications of the surgery, if not forcibly. Although nationwide support for eugenics waned following the 1940s, forced sterilisations continued behind closed doors well into the 1970s – it is estimated that over 64,000 people in the US were sterilised between 1907 and 1963.

Even more sinister is the impact of the American eugenics movement in Nazi Germany. If American eugenics appears strikingly similar to Nazi ideology, that is because it is. Hitler was influenced greatly by the movement in the US, remarking in *Mein Kampf*, 'There is today one state in which at least weak beginnings toward a better conception [of immigration] are noticeable. Of course, it is not our model German Republic, but the United States.'

But the links between Nazism and American eugenicists stretch beyond mutual admiration – the Rockefeller Foundation funded German eugenics programmes, keeping them afloat through the Great Depression. One Josef Mendel (known for his sickening experiments on twins in Auschwitz) was a recipient of this funding. The Nuremberg Laws of 1935, which targeted Jews in Nazi Germany, were partly inspired by American eugenics and the existing segregation laws in the US.

Whilst public support for eugenics faded in the wake of the awful atrocities committed in Nazi Germany, misinformation has only become more present in modern science. We have failed to learn from the mistakes of the past – misinformation continues to circulate, bolstered by social media. In 1998, Andrew Wakefield published his now infamous paper on the MMR vaccine, falsely claiming that there was a link between it and autism.

Although not ideologically related to the racism of the eugenics movement, Wakefield's fraudulent paper has fuelled vaccine mistrust, and inspired an entire movement which uses pseudoscience to discredit vaccination schemes. There are clear parallels between Galton's misappropriation of Darwin's theory of evolution and the anti-vaccination movement. In both, science, held up as a shining beacon of objective truth, was misused to spread and lend credibility to lies about our world. In both, prominent figures adopted the lies, gave them a mouthpiece and used them to further their own political gains. And in both cases, there was a tragic cost to human life.

It has been over 20 years since the publication of the fraudulent Lancet paper, and yet, despite the best efforts of governments and scientists, the belief still persists that vaccines cause harm. When the COVID-19 pandemic eventually ceases, in whatever form that may be, we will reflect upon the cost of this misinformation.

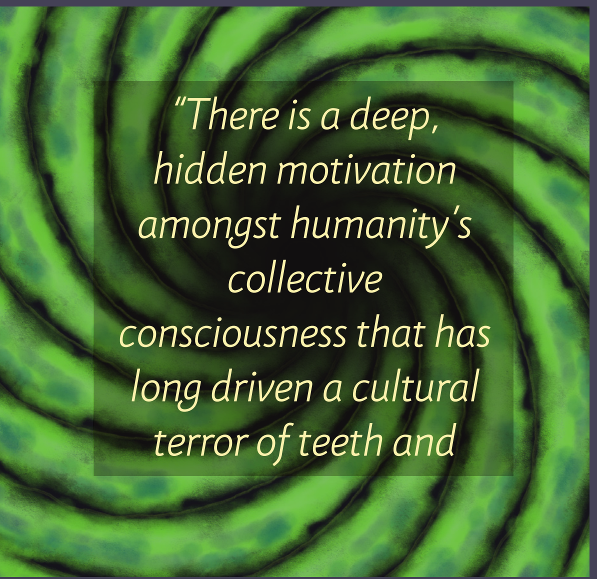
Science is an incredible tool which enables us to understand the physical world. It can tell us why an apple falls to the ground rather than remaining at rest, or how a small zygote develops into a fully formed human being. But we must be careful not to draw hasty conclusions, to infer causation from correlation, or to let our political beliefs influence our science. If we do so, we run the risk of repeating the devastating mistakes of the past. ■

> "There are clear parallels between Galton's misappropriation of Darwin's theory of evolution and the anti-vaccination movement. In both, science, held up as a shining beacon of objective truth, was misused to spread and lend credibility to lies about our world."

FUR, FEATHERS, SCALES

Jay Balamurugan reflects on the human perception of various types of predators in the animal kingdom.

Dragons have always lurked at the periphery of human civilisation. From the majestic *Quetzalcoatl* of ancient Mesoamerica to the terrible *Nidhogg* of old Scandinavia, from the chaotic *Apophis* of early Egypt to the royal *Zhulong* of imperial China. Creatures equally worshipped as gods as they were feared as monsters. Rarely do they overlap in any sense beyond their base ideals: tremendous, powerful, and fearsome. And yet, they invoke entirely varying emotions from their respective cultures. Terror and reverence, horror and veneration.



There is a deep, hidden motivation amongst humanity's collective consciousness that has long driven a cultural terror of teeth and claws. Reasonable, one might think. No one would claim to be unfazed by the nature of a predator. The image of a tiger erupting from the shrubbery with lips curled and claws out would surely frighten any human as much as that of an alligator bursting forth from its underwater recluse, jaws open unyieldingly wide. Humans were not always the apex species on this planet, and the remnants of primeval fear remain embedded in our psyche. Reminders of an ancient dogma that has long since faded. Monsters in our cultural tapestries.

Not all are treated the same, however. While lions have had their time in the shadows as maneaters, so also have they been cast under the sun as kings and gods. Wolves are vicious pack hunters, but also loving family units. Eagles are raptorial killers, and somehow remain symbols of strength and freedom. Not all predators have the luxury of redemption. Snakes are rarely depicted as anything but slithering, sinister creatures intent on causing harm. Crocodilians are ominous, dark shapes beneath the water's surface, lurking just out of sight, ready to strike. Sharks are almost mechanically efficient at killing, tracking down their quarry from miles away.

They *are* all animals, though. None of them are truly good or truly evil. They simply *are*. So why is it that we find some of these predators not only worth fearing, but worth worshipping? Why do some feel irredeemable, while others can rise above an imagined inherent malevolence? There may be a simpler answer to this than one might expect.

Warmth.

Let us return to the dragons of old. Which ones are worshipped, and which ones are feared? Be it a matter of correlation or causation, a glance over the vast number of religious and cultural depictions of the beasts provides an answer to this question: the ones with warm-blooded traits. Fur and feathers.

The feathered serpent *Quetzalcoatl* brought brightness, vitality, and fertility with it as it flew over Teotihuacan, while the dark, scaly form of *Nidhogg* gnawed on the corpses of the sailors it dragged into the ocean. *Zhulong* illuminated the world with its thick mane and mammalian crown, while the giant snake *Apophis* brought chaos and darkness as it swallowed the Sun. Our comfort in warmth and our fear of its absence has painted our stories and myths with an endothermic-centric brush.

And of course, we *are* endotherms. We are *warm*-blooded. We generate heat through our very simplest act of living, our bodies operating millions of cellular furnaces, burning through our consumed fuel in an effort to keep us going. We find comfort in that which behaves like us – and we find ways to envelop our fear of predation by way of assimilation. We domesticated wolves and wildcats. We idolised lions and bears. We sing praise to hawks and owls.

But those unlike us? Creatures cold-blooded in physiology? Ectotherms are othered. Shunned from the light of human veneration. Their cold scales, unblinking eyes, and primordial appearances feel too distant, too alien. There are the rare instances of true adoration for these animals in specific cultures, but rarely without an element of fear.

Understanding why humanity has an innate fear of these specific features amongst the animal kingdom is a vital step to take in learning how to not only coexist, but thrive alongside all our planet's creatures, whether they are adorned with scales, feathers, or fur. In reality, these species are all individually different from each other, and imposing human qualities onto them is rarely productive or valuable, especially when those qualities imply moral value. A predator is not evil because it takes life – it is fulfilling a role in an ecosystem, nothing more, nothing less. The predators that exist closer to humanity on the vast taxonomic tree of life are not any more worthy of moral high-standing than those further away. The world we live in is vast and complex, and every species on it is worthy of our respect. ■

ARTWORK: PATRYK STARZYKOWSKI
PULL QUOTE ARTWORK: SOPHIE BURLEY

DO WE LIVE IN AN EVIL UNIVERSE?

Sophie Burley explores the cosmological axis of evil, and questions whether the Universe we live in can really be considered evil.

Why are we here? How do we exist? How did the universe come into being?

Some of life's greatest questions are shared by philosophers and cosmologists alike. Physicists act as detectives, piecing together astronomical 'evidence', turning back time, uncovering how things began. For now, the leading theory is the 'Big Bang' which suggests the Universe exploded out from a single point, expanding and stretching in all directions. There are two strong pieces of evidence in support of this theory. The first is that even after all this time, the universe is still expanding. The second is the existence of the Cosmic Microwave Background.

"Physicists act as detectives, piecing together astronomical 'evidence', turning back time, uncovering how things began."

The Cosmic Microwave Background (CMB) is the afterglow of electromagnetic radiation left over from the Big Bang itself. Since its accidental discovery in 1965, astronomers have been dedicated to mapping it out. However, the results of both NASA's Wilkinson Microwave Anisotropy Probe (WMAP) and the European Space Agency's (ESA) Planck mission have since revealed something unexpected. That is, the maps of temperature fluctuation across the sky show a long stretch of radiation with above average temperature perfectly aligned with the plane in which the planets orbit our Sun. This alignment has earned the title "Axis of Evil".

"We have two different sky surveys showing the exact same patterns, even when the galaxies are completely different. There is no error that can lead to that. This is the universe that we live in. This is our home."

You are more than likely thinking that this name is a little dramatic. So what?

Well, if everything did start with a Big Bang, one thing we generally expect is that no matter where you are or where you look, all the properties of the Universe will be the same. No obvious mappable features, no 'landmarks', nothing that would let you know your whereabouts. There certainly shouldn't be anything special about our little corner of the cosmos, and yet that is exactly what has been observed. This irregularity acts like a beacon, a 'google maps pin', or a comedically big cartoon arrow pointing out our location. In short, it's a big problem for physicists. It threatens our most promising theory on the origin of the universe, which is why they named it the "Axis of Evil". The Universe and its inhabitants (you and me) aren't villains, but this real-life space oddity has the power to destroy everything we thought we knew.

This is far from the first time we've been forced to re-evaluate our position in the universe. Early astronomical observations and a strong sense of human significance led to placing Earth at its centre. Ptolemy's geocentric view This thinking did not last, and the Copernican Revolution saw the Earth's position downgraded for the first time, in favour of a heliocentric universe surrounding our Sun. Following further demotion, we now finally accept our place on an average planet, orbiting an average star, in just one part of a potentially infinite Universe. With each paradigm shift, we have been forced to cast aside our importance and acknowledge that the Universe simply does not revolve around us. At least, we were fairly confident it didn't, but the Axis of Evil is raising questions, with physicists even describing it as "the ghost of Copernicus". An astronomical haunting is rather unlikely, but definitely goes some way towards communicating the mystery surrounding this anomalous observation.

Initially, a large percentage of physicists assumed its existence was merely a mechanical error or fluke, but with repeated study and improved instrumentation, it is an 'error' that has yet to vanish. In fact, last summer a new and innovative sky survey was published. Rather than mapping the temperature of the CMB, this study mapped the spin direction of rotating galaxies and like its predecessors confirmed the 'evil' observation. It is reasonable to assume that errors can propagate through a CMB study, as the radiation itself is so faint and easily contaminated by light within our universe. However, Lior Shamir who conducted the galactic rotation survey, points out:

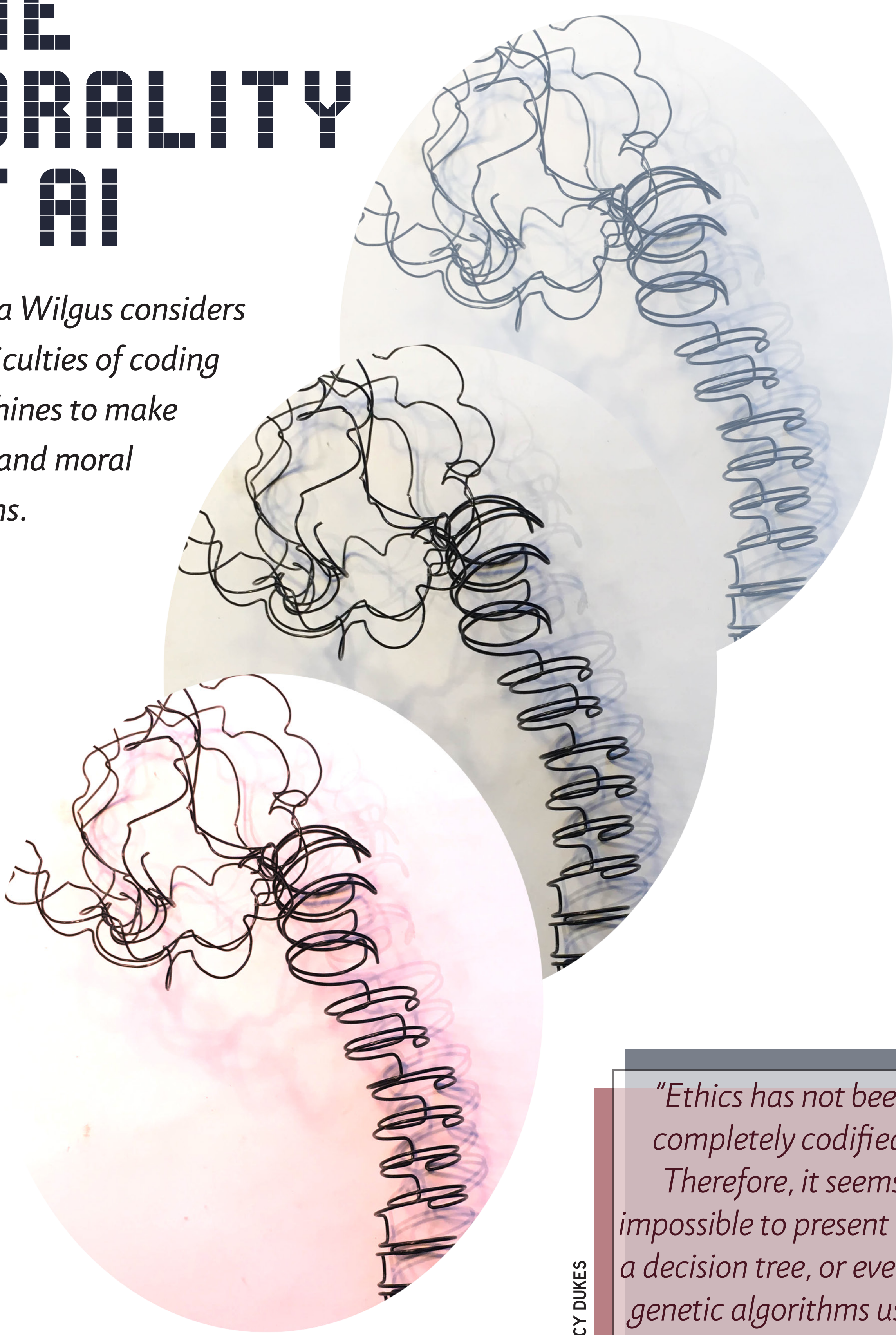
"We have two different sky surveys showing the exact same patterns, even when the galaxies are completely different. There is no error that can lead to that. This is the universe that we live in. This is our home."

So, there we have it. It looks like we may officially live in an 'evil' universe, but then I suppose the next step is to determine what that actually means... ■

ARTWORK: PATRYK STARZYKOWSKI
BACKGROUND ARTWORK: KIAH FISHER

THE MORALITY OF AI

Karolina Wilgus considers the difficulties of coding AI machines to make ethical and moral decisions.



ARTWORK: LUCY DUKES

"Ethics has not been completely codified. Therefore, it seems impossible to present it as a decision tree, or even as genetic algorithms used to program intelligent agents."

In the year 2090, an AI machine called Robin was purchased by the Rogers family from Bristol, to help them with chores at home. The code written for Robin allows the user to customize ethical, emotional, and political settings of their new 'family member.' The Rogers voted Labour and believe all actions should be judged by their consequences, hence their choice of settings: left winged and utilitarian. They also made Robin quite emotional – "He'll be better with the kids," said Miss Rogers. At home, Robin was great, he helped with all the cooking and cleaning, and was also very good with the kids.

One weekend, the family decided to go on a trip to London and took their intelligent machine with them. After a long walk from Whitechapel all the way to the City, the emotional robot couldn't bear one thing. How come on one of the streets homeless people are begging for food, while round around the corner there are people dressed in suits with their pockets full of money? Robin, therefore, decided that stealing some cash from a businessman in a fancy cafe and handing it out to the people inhabiting Whitechapel road was perfectly reasonable, and of course, perfectly moral. Unfortunately, the omnipresent CCTV caught our friend red-handed. The case is taken to court.

Now, let us stop here and analyse some problems emerging from this story.

As defined by Moor, we can classify future AI systems as either: (1) implicit ethical agents that blindly follow a set of moral rules and actions programmed by their designer; or (2) explicit ethical agents that calculate the most moral action based on a set of moral rules. Here, we will focus on implicit ethical agents, as the second option seems to be achievable only far into the future (if ever).

In her article on the morality of AI, Silviya Serafimova posed this question: whose morality and which rationality? Since people often argue about moral claims, who should decide on the morality of intelligent machines? The Rogers decided for themselves and showed that, even when considering solely the three main types of normative ethics: consequentialism, virtue, and deontological ethics, the choice is not easy. Robin is a consequentialist; the consequences of his actions are generally good as the people in need got some money. If he was programmed into virtue or deontological ethics this probably wouldn't be the case.

When the Rogers saw all the homeless people in Aldgate East, they did feel sorry for them and they knew it was good to help those in need. Yet, they did not stop to give them money or even talk to them. This is called the moral lag. Whenever you know it is good to do something but you do not do it. Well, Robin did, and now he is being punished for it. So, how do we even tell a machine that whilst helping others is good, sometimes you don't because, well, you just don't. That's another thing to think about.

But back to the basics: how do you code for all this? Ethics has not been completely codified. Therefore, it seems impossible to present it as a decision tree, or even as genetic algorithms used to program intelligent agents. As humans, we think about things,

"Since people often argue about moral claims, who should decide on the morality of intelligent machines?"

especially moral dilemmas, not as a set of inputs leading to a set of outputs. Rather, it is a detailed picture of a situation with multiple nuances that often contradict each other, usually leading to no exact 'output' at all. There are a bunch of possible plans of actions one could undertake, all with their individual consequences. This is the closest to 'output' we can achieve. Hence the concerns on how to put all of this into code, starting with how to explain all this using logic.

Classical monotonic reasoning does not seem suitable for this purpose. The scope for drawing conclusions defensibly, with the right of invalidation of some claims after more knowledge is gained, as offered by non-monotonic logic seems more in place. An example of this could be 'telling the truth is good by *default*. The common sense we use as a background for working out moral dilemmas is basically a set of default rules. We have all had a discussion with ourselves about how being honest can be bad in some situations, but *by default* it is indeed good. Non-monotonicity, however, does not offer enough 'flexibility' required for writing such code on its own. We need semi-decidability as well.

A semi-decidable logic system will always tell correctly if a formula - a plan of action - is a part of a theory – a system of moral rules. However, unlike a decidable system, if the formula is not a part of the theory it will either reject it or loop to analyse it again. Non-monotonic logic fails this requirement. If we categorize telling the truth as being good *by default* (thus a part of the system of moral rules), and then we add semi-decidability into this, the algorithm will loop itself on the very problem of the relation between telling the truth and *'being good by default.'*

As pointed out by Serafimova, the failure to satisfy the semi-decidability requirement, makes it impossible for the intelligent agents to look for *'new ethical knowledge and its alternative ways of computation.'* It intuitively makes sense: if a plan of action is not a part of the system of moral rules it will be rejected rather than looped, leaving no opportunity for self-update.

And this rather complicated problem, is just the tip of the iceberg.

I'll leave you with that one last point. The entire Rogers family is taken to the police station and then to court. But who's at fault here? Is it:

a. Robin
b. The family owning Robin
c. Someone who wrote Robin's code

A New York Times article claims that, together with the development of neuroscience there is a general trend for freeing people of any blame for their actions. "My brain made me do it," reads the article. Should Robin argue "my code made me do it"?

Robin only stole a bit of money but intermingling computational errors with moral mistakes can lead to much graver consequences. That's something we should keep in mind for the future and its exciting technological advancements. ■

ARTWORK: SHIVANI MATHUR

PEER REVIEWING: THE GOOD, THE BAD, & THE UGLY

Anirudh Kulkarni discusses the importance, benefits, and drawbacks of peer reviewing.

ARTWORK: SHIVANI MATHUR

Peer reviewing, the quality assurance process that defines scientific research, has been increasingly called into question over the last 20 years. How do we know that peer reviewing is itself a scientific method? What are its alternatives and what is its future?

Have you ever wondered how the research done in labs eventually becomes science? For any research to be deemed scientific it needs to be validated by peer-reviewing (PR) before being published in a scientific journal, the method that distinguishes scientific articles from blog posts.

The oldest known case of PR dates back to the Royal Society of Edinburgh in 1731. Today, with more than a million articles being published annually, it has become essential to sift through scientific research. It has also become a matter of pride for the authors to have articles published in prestigious journals, like Nature, which publishes only about 7% of the 10,000 papers it receives annually.

WHAT DOES PR EXACTLY INVOLVE?

Each journal has its own nuances in the way it wants to conduct PR. Typically, when an article, say of a geologist, is sent out to a journal, it is first filtered by the editors based on different factors including the relevance for the journal. It is then passed out to volunteer third parties, usually geology researchers, who assess the scientific validity, methodology, significance, and novelty of the results. In traditional single blind PR, the authors are unaware of the identity of the reviewers. This is to avoid them being disgruntled with the reviewers in case of rejection. The authors then decide to either make any changes suggested by the reviewers or retract their paper or publish it if all the reviewers give a green signal.

> "For any research to be deemed scientific it needs to be validated by peer-reviewing (PR) before being published in a scientific journal, the method that distinguishes scientific articles from blog posts."

To highlight the importance of PR, consider this example of open access journals, where articles are published without rigorous PR. In 2013, a Science editor fabricated articles with the main result being variations of: Molecule X from lichen species Y inhibits the growth of cancer cell Z, where X, Y and Z took random scientific names, much like a Mad Libs game. Some results were deliberately flawed and contradictory. Of the 304 open access journals that it was submitted to, most of them either had no PR or only focused on the superficial formatting details before accepting the article for publishing. Most of these "predatory journals" accept anything as long as you pay the publication fee.

The rigorous PR system therefore offers benefits to the scientific community by screening high quality research. In the post-truth era of today where fake news and misinformation are riding political news, PR seems like the golden standard to be achieved.

OR IS IT?

Well, not exactly. In spite of these benefits, PR is still a human endeavour and mistakes are inevitable. Firstly, it can be very slow (taking about a year to complete), impeding progress to scientific advances. It is also very expensive: the unpaid annual costs of PR have been estimated to be about 2 billion pounds. There is also low level of inter-rater reliability among reviewers although some argue that having a diversity of opinion is crucial to the review process. The process usually involves only three reviewers from the big pool of researchers. They are also rarely paid for it, which disincentivises the process.

Given the "publish or perish" maxim in academia, it is not surprising to see fraud creep in because in some cases repeating the whole experiment is impractical. Pharmaceutical companies such as Amgen have reported that up to 89% of biomedical papers are not reproducible. Moreover, the data of published articles is not always openly available. The 1998 study falsely linking the MMR vaccine with autism by Wakefield sees its effects on vaccine mistrust even today. In a case in 2005, Dr Hwang Woo Suk admitted to have fabricated the data used in stem cell research which was unnoticed by PR. In another study, the BMJ journal deliberately inserted eight errors in an article and sent it off to 420 reviewers. None of the 221 that responded spotted more than five errors.

Since the reviewers are anonymous, they might also reject any valid science that goes against their own research findings or if they are not cited enough. This is referred to as the "reviewer #2 phenomenon". A notorious example of this is Vijay Soman, who critically reviewed Drummond's paper and later published some of its paragraphs to another journal.

Some have even compared PR to censorship, such as when journals made political decisions not to publish data that had been collected on commercial Norwegian whaling. The system may also be biased towards the institutions of the authors and it has been shown to be biased against women and minorities. A 2017 analysis for the journals of American Geophysical Union revealed that women were used as reviewers only 20% of the time while they comprised 28% of the members.

Journals have also been retracting articles after it has been brought to light that these articles had either fabricated data or favourable reviews, or committed ethical violations including using unproven surgical treatments on patients. A blog called Retraction Watch has been set up which assembles a publicly available list of these retractions. It now includes more than 18000 papers and even includes a 1756 paper from Benjamin Franklin.

HOW CAN THE PR BE IMPROVED?

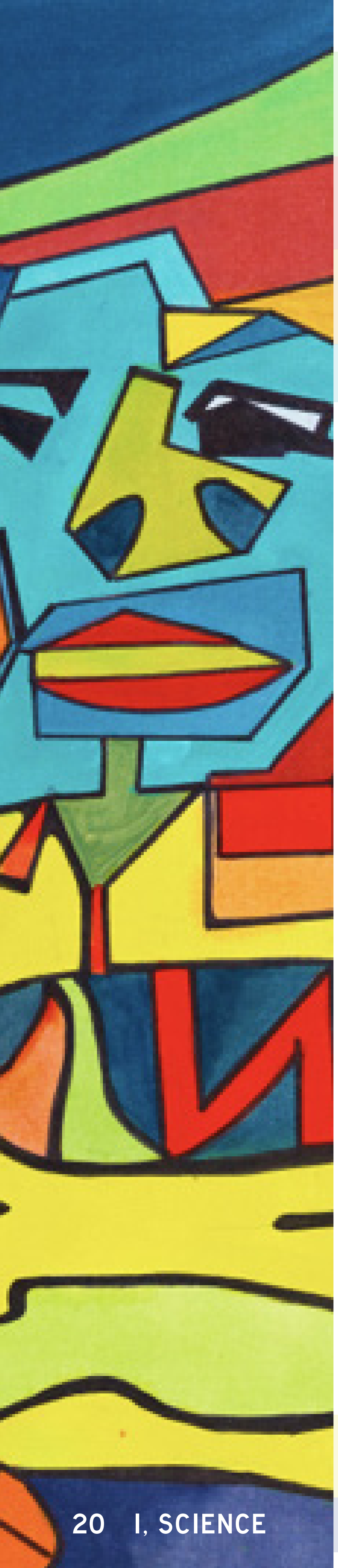
Suggestions have ranged from opening up the entire process i.e. open review (where authors and reviewers know each others' identities so that the reviewers are held more accountable for their reviews) to double blinding, where the identities of the authors and the reviewers are both concealed (where there is no preconceived bias).

Some have suggested crowdsourcing - anyone can comment on the article before its publication to post-peer review, which involves opening up commentary even after publishing. Others have proposed making it obligatory to submit data behind the papers and a call for more transparency (have the reviews published as well).

All of these changes have begun to be tested in one way or another. However, so far, it seems like the PR that we have today is the most reliable and efficient system. In July 2011, the House of Commons Science and Technology Committee in the UK concluded that, despite its flaws, PR is vital and cannot be done away with. Surveys show that 9 in 10 authors believe that PR improved the quality of paper they publish and regarded it as the cornerstone of academic research.

> "In spite of these benefits, PR is still a human endeavour and mistakes are inevitable."

PR has been compared sometimes with democracy. It is not perfect, but it is the best system we have so far.■



MYTH - BUSTING BS... BAD SCIENCE

Alexia Yiannouli debunks some commonly believed myths.

The world we live in is filled with misconceptions. Old wives' tales. Things we were told by our parents that we believed to be true. We might expect a child to believe something as being true without any evidence, but why is it we still believe many of the things we heard growing up?

As a species we thrive on the unusual, the weird, and the wonderful. The idea that dropping a penny from a tall building will kill someone standing below (no, it won't kill them, but still not something that is encouraged). The notion that if you go outside with wet hair, you'll catch a cold (while you will be *physically* cold, it's another no - wet hair is not a particular aphrodisiac for viruses). And one of the favourites: microwaves cause cancer (they don't). There are, of course, more serious misconceptions in science, for example, the research suggesting a link between vaccines and autism has not aged well. Myths are constantly being debunked in science, but there are several that people still remain convinced by.

I therefore call BS - Bad Science.

Here is a roundup of some of the most common scientific myths.

BS #1: CHEWING GUM TAKES SEVEN YEARS TO DIGEST

Wrong! Consider what chewing gum is actually made of - the nutritional ingredients of resin, wax, and elastomer, whatever that is. Your GI tract is clever, but struggles to digest anything with little to no nutritional value. Your body does not want that stuff sticking around, if you'll pardon the unintended pun, and so it gets excreted with the rest of your waste products. Lovely. While it won't spend seven years in your intestines, it's still not a good idea to swallow it just for the sake of convenience. So yes, I am saying that it's better to spit it out than to swallow it. Make of that what you will.

BS #2: CAMELS' HUMPS STORE WATER

Wrong again! Camels' humps actually store fat. The hump acts as a fat reserve, helping camels adapt to their harsh desert environment and allowing them to go up to five months without food and water. The anatomical design of camels is clever - they can drink lots of water in one go and then their body does the rest to preserve it for as long as possible. They excrete dry faeces and their kidneys work to filter toxins and minimise loss through urine. They can even retain moisture in their nostrils from breathing. So, although it does seem plausible for camels to be storing water in their humps, it's another myth debunked. It does lend itself to what else they could be storing in there. A baby camel? Smuggled goods? Trade secrets? Disappointedly, although perhaps not for the camel, it's actually just fat.

> *"Myths are constantly being debunked in science, but there are several that people still remain convinced by."*

BS #3 HUMANS ONLY USE 10% OF THEIR BRAINS

Another myth! At the time of writing, I would believe this fact to be true. My brain feels as though it's functioning at much less than a tenth of its capacity. However, although we don't use every part of our brain every minute of the day, we do in fact use all parts of it throughout the course of the day. Different parts of the brain are used for different tasks, so it makes sense that we use far more than just 10% (whether it feels like we do or not). Yes, this is true even during a global pandemic, when our brains feel like a metaphorical sieve - but maybe one made out of one massive hole instead of many small ones.

BS #4 HOUSE FLIES ONLY LIVE FOR ONE DAY

Once again, not true! House flies seem to be in an identity crisis and are abundantly mistaken for the mayfly, which of course looks completely dissimilar. House flies can actually live for up to a month. Whether they reach their intended lifespan - or meet their untimely end with the bottom of your slipper, or the cover of your rolled up I, Science copy (should it ever be printed again) - is negligible.

BS #6: HUMANS ONLY HAVE FIVE SENSES

Another fallacious statement! We actually have nine senses, and no, common sense is not considered to be one of them. That's probably just as well, since most people don't seem to be able to utilise it on a daily basis. Alongside the well-known five; touch, taste, smell, sight, and hearing, there are other more subtle senses. We also have proprioception - which helps us understand where our body is in space. We also have an awareness of where our limbs are and the actions we use them for. Additionally, we have thermoception, meaning we can detect the difference between hot and cold. We can enter a room and immediately impart a comment on it being hotter than the seventh circle of hell, or colder than a witch's...never mind. We also have equilibrioception - a fun tongue twister of a word for being able to balance and generally remain upright the majority of the time.

> *"House flies can actually live for up to a month. Whether they reach their intended lifespan - or meet their untimely end with the bottom of your slipper, or the cover of your rolled up I, Science copy (should it ever be printed again) - is negligible."*

BS #7: SHARKS HAVE TO KEEP SWIMMING OR THEY'LL DIE

Dramatic, and drawing on some interesting themes from Finding Nemo, but it's another resounding no. What is becoming a common theme with these myths is that there is a small, if not microscopic, element of truth to them. In this case, it is true that some sharks - Great White and Mako sharks, for example - do have to swim constantly to ensure that water enriched in oxygen continuously flows over their gills. They are known as obligate ram ventilators, which means that they have to ventilate their gills by swimming really fast with their mouths open - sexy, right? Other sharks use the niftier method of buccal pumping, meaning they can draw water into their mouths and then through their gills, so they can catch a bit more of a break. So, it is true that some sharks do have to keep swimming to survive, but many don't need to, proving another myth to be BS.

BS #8: GOLDFISH HAVE A MEMORY OF ONLY 3-7 SECONDS

This one is relatable, but it's another false myth. Goldfish have been found to learn basic things and remember them for up to three months - they can even tell the time! From doing some research into the brain of a goldfish, I've concluded that they have a higher attention span than some people... myself included.

BS #9: DOGS' MOUTHS ARE CLEANER THAN OURS

Whoever came up with this was clearly trying to justify their food-sharing habits with their dogs. I could make an extensive list of all the bacteria you'd find in a dog's mouth - pasteurella, bartonella, giardia, cryptosporidium, just to name a few. While you probably won't get ill from your dog licking your face or sharing your ice cream (not recommended), it's still undoubtedly not worth it.

BS #10: LIGHTNING DOESN'T STRIKE THE SAME PLACE TWICE

Surprisingly, lightning doesn't have the capacity to remember what, or where, it has hit before. Whether it strikes the same tree once, twice, or five hundred times (however unlikely) is irrelevant. Lightning is the electrical discharge caused by an imbalance between storm clouds. They don't confer before deciding where to strike. One cloud doesn't say to the other, "you know what, don't worry, we got that tree last week, let's mix it up and go for the one over there," however anthropomorphically funny the notion might be.

So, there you have it - complete BS.
(Bad science, that is.)■

ARTWORK: CHAOYU TANG

MY MORAL COMPASS ISN'T WORKING!

Julia Borowicz explores the neuroscience of morality and its complexities.

Have you ever done something you felt guilty about? Have you ever felt not entirely sure if it was the right thing to do? I bet you answered yes to both of those questions. Everyone has a bit of a guilty conscience. Despite a defined set of laws that we try to obey, we often disagree on what is right and what is wrong, and sometimes, we feel insecure about following the rules in real life. These emotions and principles that arise within us can be called morality, which is different and inherent to every individual. In psychology it's called 'moral sense' – the capacity for forming judgments about what is morally right or wrong, good or bad - and it originates as every thought process does – within the brain.

HOW, WHERE AND WHAT?

In order to have a grasp on what morality is and how it is formed we need to look at the place it originates – the brain. In the case of neuromorality, which is a field of neuroscience that studies the connection between neural activity and morality, scientists use different methods, including MRI (magnetic resonance imaging) scans, electrophysiology (EEG) and studying behavioural change in people with brain lesions acquired in an accident or removed during surgery. Finally, they also look at the pharmacology of the brain to look for chemicals and neuromodulators that can play a vital role in the process of using moral judgement in undertaking decisions.

MRI MAP OF MORALITY

As a highly complex process, morality involves an engagement of both the 'emotional' and 'cognitive' parts of the brain. Thanks to multiple MRI studies conducted all over the world we can now map out some of the areas within the brain responsible for the control of different behavioural processes. Some of the areas are recurrently found to be crucial to emitting a moral judgment, but none of them are uniquely attributed to morality. Altogether they form a complex map of neuromoral circuits which contribute to our decision making and sense of fairness. For instance, empathy resides in the insular cortex, whereas the ventromedial prefrontal cortex (VMPFC) is responsible for emotionally driven moral decisions. On the other hand, the dorsolateral prefrontal cortex appears to moderate the VMPFC's response. The whole process may be mediated by the anterior cingulate cortex. This already sounds complicated, but it's only the tip of the iceberg when trying to understand the intricacy of moral judgement.

> *"Such cases raise a disconcerting question – are we fully responsible for our poor choices or are they a result of something going wrong in our brain?"*

SOMETHING WENT WRONG

Another way to understand morality is to look at individuals who suddenly lose it. Brain lesions often lead to extreme changes in personality which help us understand which parts of this organ account for modulating our behaviour. Overall, lesions in the right hemisphere's frontal lobe are associated with antisocial states and left frontal lesions are associated with increased violent behaviour. One of the most famous brain lesion-induced personality changes is the case of Phineas Cage. After suffering damage to the VMPFC due to an accident, he started to express socially inappropriate statements and lie to his friends and family. Another interesting case is the story of Donta Page who was trialled for the rape and murder of a young woman. Imaging of his brain showed damage to one of the neuromoral circuits which reduced his sentence from death sentence to imprisonment for life. Such cases raise a disconcerting question – are we fully responsible for our poor choices or are they a result of something going wrong in our brain?

THE CHEMICAL OF VIOLENCE

There are several chemicals in the brain that contribute to the formation of morality. One of them is the hormone oxytocin produced in the pituitary gland. In humans, this is the substance responsible for the formation of a strong relationship between a mother and a child by reducing fear and anxiety and increasing bonding. In several studies, it was shown to increase trust and generosity in some situations, however, in others, it can increase envy and bias. Another neuromodulator involved in morality is serotonin. It's particularly involved in aggression and it enhances the negative feeling we have in response to seeing others suffering. It seems that our moral judgement can be easily influenced by changing the levels of chemicals in our brain. It's a dangerous thought since a lot of different medications, especially antipsychotics, do that exact thing. Perhaps the decisions that some individuals make are not exactly their fault, but the fault of the wrong chemical being released within their brain?

TREATMENT OF CRIME

If we understand where the idea of committing a crime arises, we might have a chance to treat it before it is fulfilled in real life. Researchers at the University of Pennsylvania and the Nanyang Technological University in Singapore applied the current knowledge about neuromoral circuits in an experiment straight from A Clockwork Orange. They recruited 86 people and electrically stimulated half of the group's prefrontal cortex. To do that, the scientists used transcranial direct current stimulation, a painless process which uses direct electrical currents to stimulate specific parts of the brain. After the treatment a survey was conducted where participants read two hypothetical scenarios, one describing a physical assault, the other a sexual assault. They were asked to rate the likelihood of them behaving like the protagonist in the stories. The results were extraordinary! The group which experienced brain stimulation was 47% and 70% less likely to carry out physical and sexual assaults respectively. The study showed the potential of using the knowledge of neural circuits responsible for moral judgement to treat the undesirable thoughts of criminal offences before they are conducted.

MORAL OF THE STORY

Despite the advancement in technologies, we still struggle to fully understand the origins of morality. The complexity of neural circuits and the chemicals involved in brain activation play a big part in forming and changing the moral judgement of an individual. This poses a lot of questions concerning the emergence of crime and shift of the blame onto biological circumstances of the offender. Can we treat crime as faultiness of our heads? Is it fair to blame a person whose actions are a result of brain damage or a surge of a wrong chemical in their brain? We're still looking for the answers.■

> *"Perhaps the decisions that some individuals make are not exactly their fault, but the fault of the wrong chemical being released within their brain?"*

IMAGE: JORDAN-MADRID, UNSPLASH
ARTWORK OVERLAY: ANDREY RANGEL AGUIRRE

STATUS: SUPER VILLAIN, OCCUPATION: SCIENTIST

William Lea examines the portrayal of scientists in fiction and its impact on public perception of science.

From Dr Evil to Dr No, Dr Octopus to Dr Doom, Frankenstein to Frank N. Furter, films, books, and TV have had their fair share of evil geniuses and mad scientists. It always seems that the third act of any blockbuster movie involves some sort of death ray or doomsday device, a killer robot, or cloned dinosaurs. We can all picture a mad man in his tower surrounded by sparks and machinery screaming "it's alive!" or in a secret bunker holding the world hostage for "one-million-dollars!". Jurassic park has no main human villain, but even here the message is that of scientists' inability to control themselves and the chaos that they cause.

So why is the media inundated with out-of-control stark-raving-loony scientists? Are we really that evil? Do scientists simply make better villains? Or is this mere confirmation bias?

A simple explanation for this is that it is just a lazy writing technique. Screenwriters and novelists haven't got time to flesh out the reasonable motives of their characters. They need to quickly establish a villain that audiences will understand as a formidable threat. They need them to be obviously clever without actually providing detailed evidence, so a profession such as scientist or doctor seems like a simple solution. Whack a Dr in front of their names and instantly audiences will understand the character as being clever and maybe even a little hard-working too (wink). Thus, audiences understand the villain is no fool, creating a more challenging opponent to the heroes of the film or book. It's also handy that people fear what they don't understand. Science can be complex. So, to create a threatening, alienating villain, the mad scientist is an easy option.

Now, some may read this and think that I'm whining, or having a bit of an overreaction. "Yeah, scientists are not portrayed in the kindest of lights," you might say, "but so what? No actual harm is being done". But I'd have to politely disagree. For most people, when it comes to science, it is precisely these films, TV shows, and books that are their first encounter and exposure to ideas such as DNA sequencing, quantum computing, large particle colliders, and AI learning. When the public's first exposure to such ideas is in an evil light, the result is this feedback loop:

*"So why is the media inundated with **out-of-control, stark-raving-loony** scientists? Are we really that evil? Do scientists simply make better villains? Or is this mere confirmation bias?"*

When it comes to James Bond villains, scientists are up there with corrupt politicians and power-hungry business CEOs. Yet, it seems we now live in a world where ignorance is a greater danger than knowledge. In a post-Trump world fuelled by anti-vaxxers, fake news, misinformation, and climate change deniers, scientists seem now more than ever before to be vilified, ignored, and mistrusted by the public. All this despite the fact that our lives are more than ever dependent on scientific discoveries, Covid-19 being the obvious example in our current times, where lives hung in the balance as scientists raced to create a vaccine.

Perhaps at the height of the Cold War it was quite understandable why one would fear science. Nuclear warheads, the space race, and spy satellites were the poker chips of the USA and USSR. Asking someone in the 1960s how they envisioned an apocalypse, their response likely would have involved the application of a scientific discovery. With programs such as the Manhattan Project, MKUltra, and the Star Wars Program as well as memories of scientists in Nazi Germany, it is perhaps understandable as to why science was feared.

Now it seems our biggest threat is the harnessing of ignorance for evil rather than knowledge. Long gone are the days of a mad genius devising a doomsday bomb to cause an apocalypse, but rather it seems a lack of concern for the environment will be our downfall. And is all this mistrust in science the fault of comic-book artists and the TV writers' room? Well, probably not, but they're not completely innocent. How come we never see an evil baker unless it's in Wallace and Gromit? When is Spider-Man going to fight off an evil plumber that plans on causing havoc in London's sewage systems using his advanced plumbing knowledge?

In recent years the portrayal of science has indeed shifted somewhat. Obviously, we still get our villains, but shows like The Big Bang Theory, regardless of one's opinion on its comedy, have been highly successful with the leading characters being research scientists. Iron-Man and Doctor Strange are two more examples of this shift to scientifically minded heroes. However, even though these doctors and scientists are "good", they still fall into the same problem that the mad genius had. They are unrelatable and incomprehensible. Characters like Tony Stark or Sheldon Cooper, despite having good intentions and likeable qualities, talk complete gobbledygook and have unrealistic or even alien lifestyles. They are still presented as being too clever to be understood by normal humans. To help the public perception of science, we need to demystify and normalise. Scientists are neither mad geniuses locked away in their laboratories nor techno wizard engineers with solutions to everything. They are just regular people working together, trying to discover new things.

Films such as Arrival, about a linguistics professor's approach to an alien encounter, and Hidden Figures, about the role of female scientists during the Apollo missions, seem to be heading in the right direction. They accurately display the sometimes-mundane scientific method and present scientists as normal human beings who are simply attempting to solve a difficult problem. ■

*"In a post-Trump world fuelled by anti-vaxxers, fake news, misinformation, and climate change deniers, **scientists seem now more than ever before to be vilified**, ignored, and mistrusted by the public."*

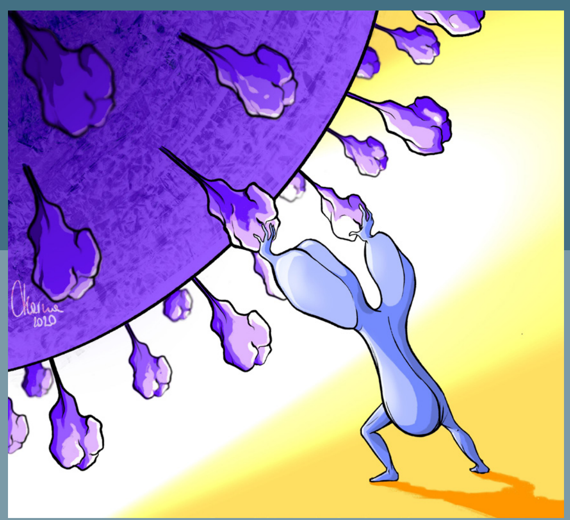
BACKGROUND ARTWORK: SHIVANI MATHUR

UNDERSTANDING & COMPASSION: THE KEYS TO VACCINE TRUST

Cara Burke delves into the different aspects of vaccine hesitancy, in light of the recent SARS-CoV-2 vaccines created.

I have made fun of anti-vaxxers. I expect many of the people around me, who study at a science-based university, have done the same. We can all picture the caricature; a middle-aged Karen who selfishly refuses to vaccinate herself or her children, and is deliberately woefully ignorant, as her only trusted news source is Facebook and conspiracy theorist sites. But this caricature, and this ridicule, will not encourage people to take vaccines. To understand what might, we need some level of understanding: of who is sceptical of vaccines, and why they are.

SARS-CoV-2 vaccine development has been a remarkable scientific feat. Whereas most vaccines take around a minimum of 10 years to be developed from discovery research to the manufacturing and delivery stage, all SARS-CoV-2 vaccines being distributed today have been developed in under a year. And this has not been at the compromise of quality or safety: the Medicines and Healthcare products Regulatory Agency (MHRA) in the UK have determined the approved vaccines meet the strict safety and quality standards that all vaccines must meet. Despite this, it is easy to understand why people may be hesitant to have one. The mRNA vaccines have never been on the market before. The majority of the public do not know what goes into making a vaccine. They don't know the science, how the vaccines are tested, or the safety considered. For many, it appears that a vaccine developed in such a short time must surely have been rushed. I have spoken to people who are now expressing concerns over the safety of the SARS-CoV-2 vaccines, who have never associated with anti-vaxxers or considered denying themselves or their loved ones a vaccine.



ARTWORK: MARZIA MUNAFO

Science communicators also need an understanding of who is sceptical, as this scepticism is not equally distributed across the UK population. The UK household longitudinal study collected data from 12,035 participants from the 24th of November to the 1st of December. They found that 82% were likely or very likely to receive the vaccine, but 71.8% of black respondents and 42.3% of Pakistani and Bangladeshi respondents claimed they were hesitant of the vaccine, compared to 15.6% of white British or Irish respondents. Women and those with less formal education were also significantly more sceptical.

So what reasons are there for some people to be more sceptical than others? The UK household longitudinal study found that the main reasons cited for vaccine hesitancy were the unknown future effects, side effects, and lack of trust in vaccines. It is not yet completely understood why these factors play a disproportionate role in shaping the opinions of people from different ethnic groups. However, what is clear is that vaccine hesitancy is disproportionate, and trust might just be the key to changing these perspectives.

There is some good news, and here is where effective science communication could come in. Many stated that they would be convinced to take the vaccine if it was demonstrated to be safe. The Royal Society for Public Health found that 35% of BAME respondents who were not willing to be vaccinated claimed that they would be willing to change their minds if given more information by their GP on how effective it is. It is clear then that vaccine communication must efficiently explain how the vaccine is safe.

> *"The majority of the public do not know what goes into making a vaccine. They don't know the science, how the vaccines are tested, or the safety considered."*

It is vital that this approach, above shame and guilt, is taken.

The WHO have written guidance on how to approach anti-vaxxers, making a clear distinction between those who vocally deny the benefits of vaccines and those who refuse vaccines or are on the fence. Science communication on vaccine benefits, they claim, should not target those who actively deny vaccines, as they are more likely to reject scientific evidence. It should instead target those who are as yet unsure. Most people who are sceptical about the SARS-CoV-2 vaccine fall into this category. SAGE has recommended a multifaceted and multimodal approach which includes culturally tailored communication and trusted GPs and community health centres, to avoid the trap of having a "one-size-fits-all" approach to science communication. Much more has to be done to convince the public about the safety of this vaccine, rather than assume they will blindly trust scientists and the government. Open and non-judgmental dialogue and effective communication based on people's direct concerns will be absolutely key to changing people's minds.■

ARE SHARKS REALLY EVIL?

Akila Raghavan explores how sharks are misrepresented as villains in today's media and society.

Sharks strike fear in the hearts of people all over the world. Their formidable appearance and the air of mystery enveloping their environment both serve to make sharks seem like truly frightening beasts. News stories about gruesome shark attacks only heighten the public fear of these sea creatures – but are sharks really evil?

Movies and news accounts of shark attacks have painted this picture of a stereotypically evil shark, but rogue sharks with a thirst for human flesh, like the one in Jaws, are fictitious. Of the more than 500 species of sharks, only 30 have made documented attacks. Statistically, you are more likely to be attacked by a domestic cat or a dog than by a shark.

Sharks are not evil beings that swim through the ocean with predetermined intent to harm any humans in the water. Sharks merely obey their innate instincts which, being at the top of the marine food chain, are predatory. A shark's preferred diet is smaller sea creatures like turtles, sea lions, and seals – humans are not on the menu. However, from the perspective of a shark down below, a human paddling on a surfboard or swimming at the surface can be of similar shape and size to their desired prey. The confused shark may attack and attempt to drag their victim down into deeper waters, but on contact with human flesh, they quickly realise that this is not their usual food and let go. It is incredibly rare for a shark to attack a human a second time and attempt to feed. Not that this is much consolation for the bleeding victim of a harrowing attack.

Shark attacks have also occurred when humans are spearfishing in the ocean. Sharks can smell the blood and detect the electrical impulses indicative of a struggling fish. They do this through their in-built detectors called ampullae of Lorenzini which are present just under the skin of their snouts. Once attracted to a site of such activity, a shark in a feeding frenzy may be unable to distinguish between their actual prey and any humans present, thus accidentally biting more than just fish.

Another cause of shark attacks can be displays of dominance. Although little research has been done into the behaviour of these behemoths of the ocean, sharks are thought to use their snout to 'punch' creatures that stray into their domain or those they see as a threat. Although such an action is intended to incite fear predominantly in other sharks whose skin can harmlessly withstand such assault, should a shark approach an encroaching human in the same manner it would undoubtedly cause damage.

It is important to remember that the vast majority of shark attacks are, in fact, provoked. As most divers and surfers can attest, sharks are docile creatures that largely ignore others around them and may just approach visiting humans out of curiosity. However, in many recorded shark attacks, humans have taken advantage of this apparent meekness to approach sharks and even touch or grab on to them. In such cases, an attack by the shark is in fact its response to what it regards as an act of human aggression.

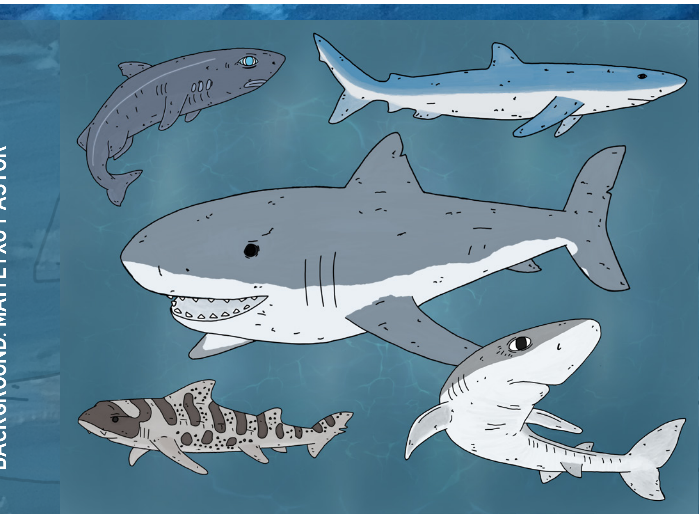
As apex predators of the sea, sharks play a vital role in maintaining the balance of the marine ecosystem. They primarily feed on the old or sick members of their prey, as these animals are easiest to hunt. In doing so, sharks help keep the prey population healthy, allowing the healthiest and strongest members to reproduce.

Sharks are even essential to the healthy growth of marine habitats. Research in Australia has shown that areas of high shark population have the healthiest reefs, with coral in these areas recovering quickest from the effects of bleaching. Additionally, in Hawaii, sharks are important in maintaining healthy sea grass beds by keeping the turtle population in check, preventing them overgrazing in concentrated areas of sea grass and destroying their own habitats.

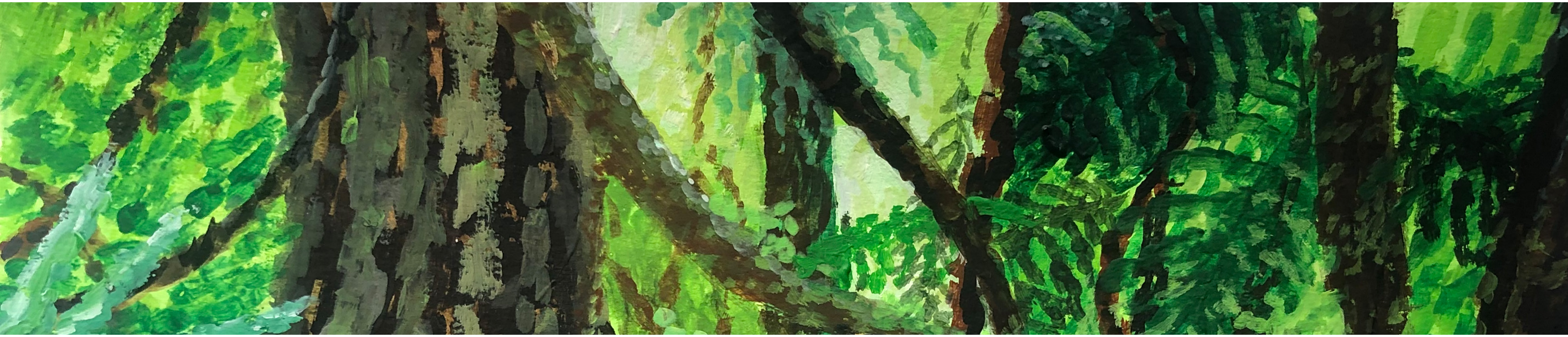
Sadly, few people realise the importance of sharks, and fewer still realise the negative human impact on shark populations. Finning, truly an act of animal cruelty, is responsible for the death of around 100 million sharks a year. Some 70 million more are killed annually as fishing bycatch. As sharks take a long time to mature and produce few offspring, their reproduction cannot keep pace with the number of deaths, leading to many shark species being endangered.

So, do sharks deserve their reputation as mindless killing machines that attack without cause? Absolutely not – these misunderstood creatures have far more to fear from humans than we have from them. Far from being evil, these majestic and heroic creatures are vital for the health of our oceans and deserve our protection.■

ARTWORK: JAKE GABLE
BACKGROUND: MAITETXU PASTOR



> *"Statistically, you are more likely to be attacked by a domestic cat or a dog than by a shark."*



ALTRUISM IN THE ANIMAL KINGDOM

Fatima Sheriff explores exhibitions of altruism in different animal species and draws comparisons with the current Covid-19 pandemic.

> *"This crisis has held up a mirror to our flaws as a global community, with some countries faring better than others in the way they handle the much-needed shift in social plasticity."*

ARTWORK: ARIANA LOEHR

In these precarious times, my personal definition of 'good' has been contextualised by the pandemic. If we have learnt any lessons from the past year, it is that selflessness is the root of our salvation. In the animal kingdom, while this altruism loses the human sense of morality, different species have evolved against individualistic self-preservation for the sake of group survival. Here I will delve into a few instances where we can learn a thing or two from our animal neighbours...

> *"Selflessness is the root of our salvation."*

Animal altruism is when the social behaviour of an individual reduces the fitness of that individual, while boosting the fitness of another. Darwin discusses this phenomenon in The *Descent of Man* (1871), explaining how on an individual level, it does not follow his theories of evolution; being ready to risk their own safety "would leave that creature no offspring to inherit his noble nature". However, on a collective level, a group with "many members ready to give aid to each other and sacrifice themselves for the common good would be victorious", enables them to navigate the perils of the wilderness and overcome the challenges of natural selection.

This idea of working for the collective over the individual is exemplified in ants, as their ability to put others before themselves helps them survive outbreaks of disease. As Sir David King of Independent SAGE reiterated in a recent seminar, a lockdown like ours in the UK is a blunt instrument, one that wouldn't be necessary had there been correct tracing and isolation of the sick. While our government may struggle with these logistics, a paper from 2018 showed how quickly and effectively a colony of ants changes their behaviour when presented with a pathogen.

Though the mechanism of their recognition is unknown, even before they exhibit symptoms, the sick ants self-isolate. Meanwhile, healthy ants protect the queen and nurses by keeping them away from the foragers, who could bring the disease from outside, much like how we have taken to shielding our vulnerable communities. In an eerie pre-pandemic premonition, lead author Stroeymeyt mentioned that we could learn from "how quickly they adapted their societal structure to minimise the spread". She conceded "we can't really ask sick people to die in isolation the way the ants do" and in this way, the conscious, human altruism of front-line workers triumphs in its level of personal risk and empathy.

Though their name gives them a fearsome reputation, vampire bats are my next example of altruism. Unrelated females form communities and care for their young longer than other bats and they have been long studied for their fascinating social systems. For instance, a study by Ripperger et al. from 2019 found that a group of bats kept in captivity maintained their relationships when they were released into the wild. These tight-knit friendships are often built on feeding, grooming and roosting together. They have even been known to buddy up and share food, because a vampire bat can starve to death if it misses two nightly meals in a row.

A study by Wilkinson from the 1980s called this a "tit-for-tat" system, professionally known as "reciprocal altruism", and an extensive follow-up study with Carter in 2015 highlighted the complexity of the bat community. One bat known for sharing her food got more in return than another bat who was more selfish, but those unable to share weren't doomed, repaying their debt when they could later on and keeping their friendships. The ability of these bats to remember the history of these transactions is remarkable in itself, as well as an admirable way for the group to survive together.

Equally, a 2020 study by Stockmaier shows how these social creatures do still know how to distance. When another bat is sick, food sharing is maintained and the same level of social interaction occurs, but the intimate process of grooming between them is decreased. Taking tips from these nocturnal sisterhoods, we could learn a thing or two about maintaining our own social networks during these hard times. Whether it be through sharing food with those struggling, delivering food for those shielding, and socially keeping each other afloat, we have to work hard to keep our bonds stronger than ever.

My last example is much closer to home, but as a wealth of adorable videos will display on social media, dogs often adopt other animals, caring for them like their own. It's something of a rarity in other species, like solitary squirrels taking in orphaned relatives, but more common in primates and our canine best friends. Likely due to our domestication of them, dogs crave companionship, otherwise they get uncomfortable, much like a child with a beloved toy. As such, in the right circumstances, they will adopt from a range of other pets like ducks and pigs to bizarre connections such as tiger cubs.

This behaviour is very much mirrored by our own need for comfort during the pandemic, with surges in rescue shelter adoptions during lockdown. Arguably, this is mutualism, where both get a benefit from this blossoming relationship - loving a dog and taking it for walks can help with your mental and physical health as well as fulfilling its need for companionship. But I'd argue altruism is seen when our canine friends maintain their attachment to their new pets, while many of the adopted rescue animals were returned. In order to match their empathy, we have to be above the selfishness of returning animals when they no longer serve their purpose, satisfy our needs or are deemed too difficult for care.

This crisis has held up a mirror to our flaws as a global community, with some countries faring better than others in the way they handle the much-needed shift in social plasticity. Though biological altruism is a complex topic with various subsets like kin selection and mutualism, from a logistical and an emotional standpoint we can definitely take a leaf out of the book of nature in how to care for one another and thrive once again. ■

THE DEVIL IN THE DETAILS

Will Cahill investigates the good and evil of nuclear physics.

*"Think, now: where would your **good** be if there were no **evil** and what would the world look like without **shadow**?" - Mikhail Bulgakov*

In Mikhail Bulgakov's seminal work, *The Master and Margarita*, The Devil states that a world does not exist where there is an absence of evil. Hovering above the tortured and broken remains of Moscow, The Devil compares the relationship between good and evil to that of light and shadow – without the shadows thrown by the light, the world would look barren and devoid of life. This may seem slightly depressing, but it is somewhat easy to share The Devil's perspective; could we enjoy food if we didn't know the feeling of hunger, feel warmth if we didn't feel the cold, or appreciate happiness without sadness?

When looked at in this way, it seems that life can be described by two polar extremes and our normal experience just a mixture of the two. It can be argued that every facet of our lives can be analysed in this way, but nowhere is this interplay so striking and controversial than in the world of science.

THE MANHATTAN PROJECT

The early 20th century was an exciting time in the field of nuclear physics. Work conducted by Marie and Pierre Curie contributed to a more accurate model of the atomic nucleus, and experiments conducted by Enrico Fermi in 1932 showed signs that the uranium atom could produce two new, smaller elements.

It was until 1938 that there was an explanation for the behaviour of uranium. Otto Hahn, Lise Meitner, and Fritz Strassmann correctly interpreted that the uranium nucleus has split roughly in half – explaining the existence of the smaller elements. They called this behaviour "nuclear fission".

This supported the theories of Hungarian physicist, Leo Szilard, who in 1933 suggested that a fission reaction - such as the one reported in 1938 – could create enormous amounts of energy if the conditions were right. Upon this discovery he co-authored the Einstein-Szilard letter, sent to President Roosevelt, warning of the destructive power of nuclear fission. On 9th of October 1941, and after some major scientific breakthroughs – including the construction of the first nuclear reactors in America – President Roosevelt approved the atomic program; the aim being to produce the world's first nuclear weapons.

EVIL

On the 6th and 9th of August, two nuclear weapons were detonated over the Japanese cities of Hiroshima and Nagasaki.

In Hiroshima, the blast and the resultant firestorm killed around 70,000-80,000 people – this was around 30 percent of the population of the city at the time. Another 70,000 people were injured and an area of around 12 square kilometres was destroyed. It was reported that 69 percent of Hiroshima's buildings were destroyed, and another six to seven percent were damaged.

In Nagasaki, 35,000-40,000 people were killed immediately, and another 60,000 people were injured. Everything within a radius of 1.6 kilometres was destroyed and resultant fires also reached 3.2 kilometres south of the bomb's epicentre.

Although the instant effects of the bombs on the ground were harrowing, nuclear weapons have a much more silent and sinister effect. The radioactive isotope uranium-235 was present in both bombs dropped. Nuclear fission of Uranium-235 causes the atom to break down and release harmful, ionising radiation.

One immediate effect of ionising radiation is burns. Burns due to radiation exposure are formed when skin cells are damaged. Cells can be damaged by any form of radiation, including ultraviolet radiation from the sun – causing sunburn. Radiation released from a nuclear bomb is at a much higher energy however, and the burns are much more severe.

There are also long-term effects of exposure to ionising radiation. Radiation can damage the DNA in our cells which can cause changes that lead to the development of cancer. Later studies into survivors have shown that from 1950 to 2000, 46 percent of leukaemia deaths and 11 percent of solid cancers were due to ionizing radiation from the two bombs dropped on Hiroshima and Nagasaki.

The Manhattan project produced some of the most powerful weapons ever detonated on Earth which were used to inflict devastating violence on a previously unimaginable scale, both immediately and for years afterwards.

GOOD

While the outcome of the Manhattan project was to create nuclear weapons, there were some immense scientific challenges that had to be overcome in the process.

Much of the research done during the Manhattan Project involved the use of radioisotopes. These are atoms of unstable elements that can undergo nuclear fission – just like uranium-235. Before the project, radioisotopes were made in a cyclotron. This was a form of particle accelerator that bombarded stationary nuclei with accelerated protons, sometimes forming a radioisotope.

Previously, the radioisotopes produced were used on a lab-scale in small experiments. The Manhattan Project, however, required a much larger quantity of radioisotopes for the purpose of producing large-scale reactions, capable of releasing the amounts of energy required for atomic bombs. This challenge was resolved by harnessing the potential of nuclear reactors. Reactors can not only produce a much larger quantity of radioisotopes, but a much larger variety. Some of the radioisotopes produced in these reactors were cobalt-60 and carbon-14.

The radioisotope cobalt-60 is unstable and will undergo nuclear fission, releasing high energy gamma radiation. This radiation is used in a medical procedure called gamma knife surgery, which delivers highly focussed gamma radiation to brain tumours. The gamma rays are so highly focussed that they will pass healthy brain tissue and deliver a strong dose of radiation to the cancerous tissue, preventing any further tumour growth.

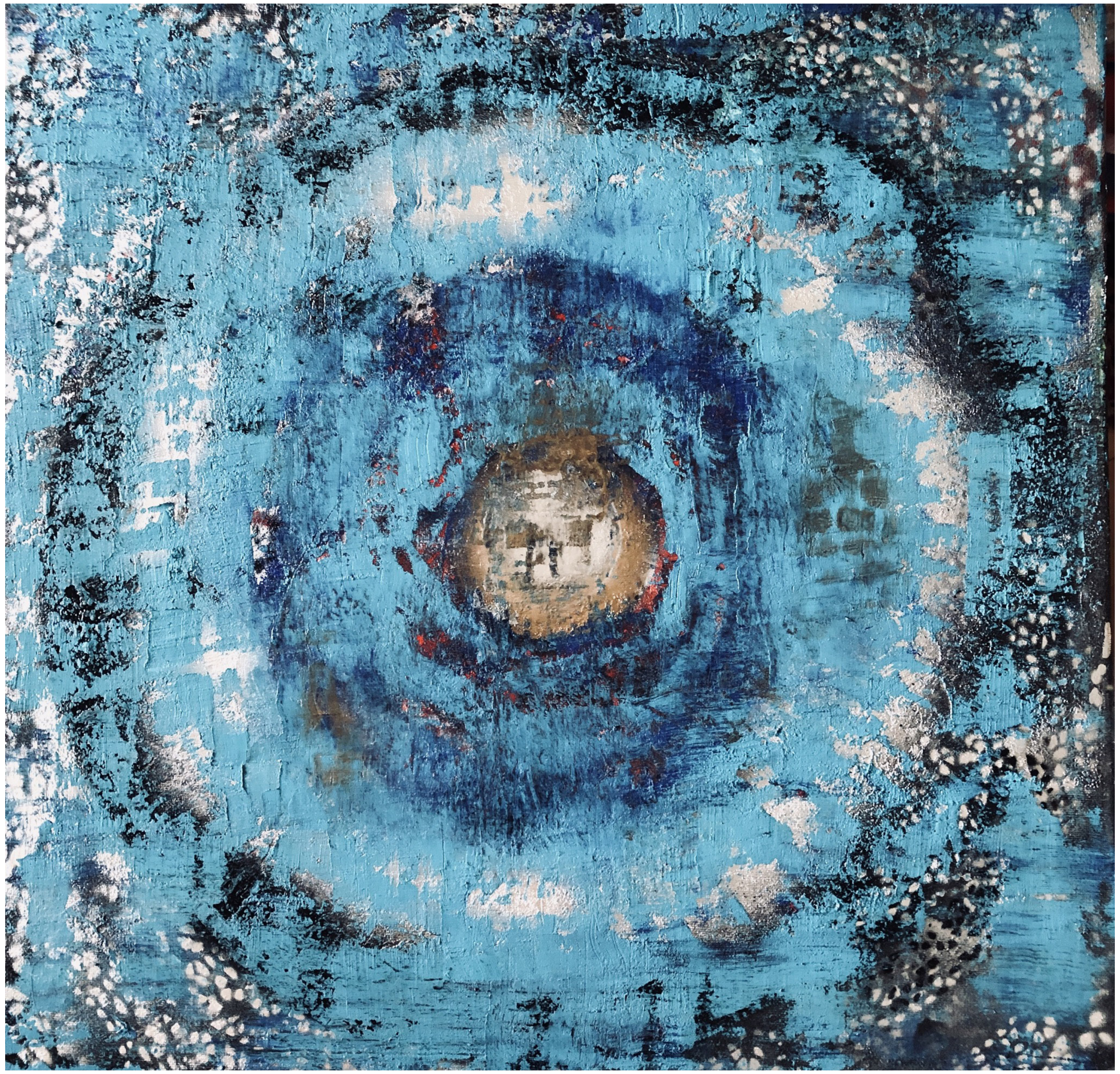
The uses of radioisotopes go far beyond medicine and into the realm of scientific research; the radioisotope, carbon-14, was used to understand photosynthesis. To do this, researchers labelled carbon dioxide with carbon-14. This means that the usually stable carbon-12 in carbon dioxide, is replaced with the unstable carbon-14. When this labelled carbon dioxide is taken up by algae, it can be detected using the radiation emitted by the unstable radioisotope. This allowed researchers to track the metabolic pathway of photosynthesis.

Radioisotopes formed by nuclear reactors are used widely throughout the world, in medicine, scientific research, and in industry. Technology could not have advanced at this speed throughout the late 20th century without contributions from the Manhattan Project.

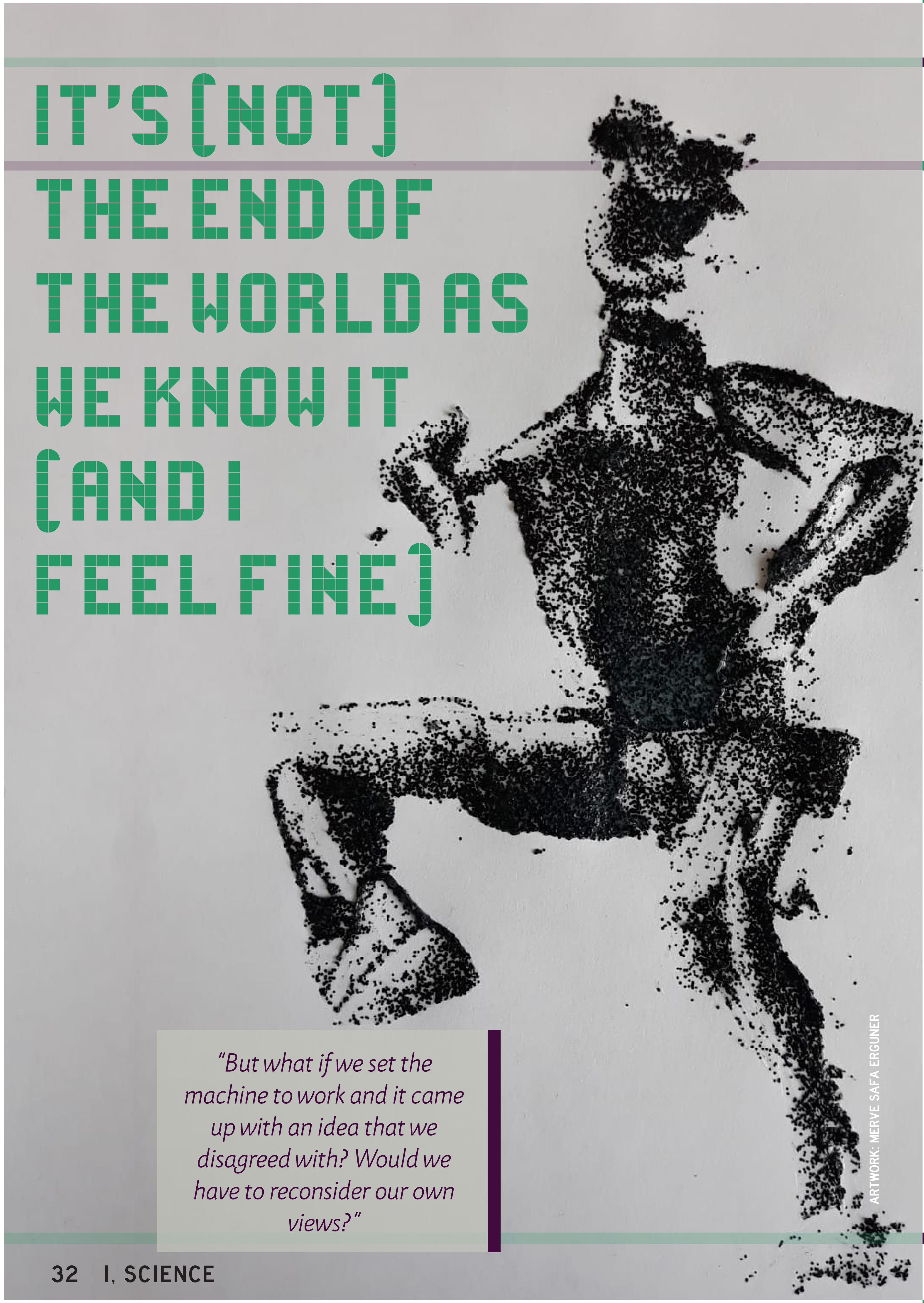
"Bulgakov was to some extent right; there is no erasing the fact that an act of terror has, in some ways, been transformed into a force for good."

The Manhattan Project produced weapons that unleashed destruction and devastation that the world has only recently recovered from. Hiroshima and Nagasaki stand forever in our memories as one of the most evil of violence ever perpetrated and stand as a constant reminder to strive for peace.

No matter how we perceive history however, Bulgakov was to some extent right; there is no erasing the fact that an act of terror has, in some ways, been transformed into a force for good. It can be argued that the real act of evil was never in the science, but in the act of dropping the bombs themselves. Of course, the scientific research involved in the Manhattan Project enabled these unforgivable acts of violence, but its discoveries and breakthroughs continue to improve the lives of people all over the world every day.■



ARTWORK: SHIVANI MATHUR
BACKGROUND: MOLLY MACLEOD



IT'S (NOT) THE END OF THE WORLD AS WE KNOW IT (AND I FEEL FINE)

ARTWORK: MERVE SAFA ERGUNER

> *"But what if we set the machine to work and it came up with an idea that we disagreed with? Would we have to reconsider our own views?"*

Michael Kohn discusses the potential effects of an AI capable of making decisions in moral dilemmas on society with Mr Greg Artus and Cosmin Badea.

It was still heavily snowing when I opened a zoom room to discuss an issue of apocalyptic proportions (or not) with two of my best-loved philosophy teachers. Together, they have considered the question of what a moral machine would look like, and how we could go about creating one. It began with Cosmin's PhD work on the 'how' of the matter, while Greg has been looking at the philosophy of rules in games. This is relevant to a computer as this would have to be how it interprets our algorithms. They propose that currently there is something holding this possible breakthrough back, known as the interpretation problem.

Computers, such as the successful AlphaGo machine, understand how to play very complicated games. These work by the machine being told the set of rules and trying multiple possibilities before choosing the optimal move. However, in these cases, the rules are deterministic. It is easy to evaluate progress e.g. how many pieces have been taken, so it is easy for the computer to carry out the task in the way we desired. When we scale this to a question of deciding on morals, we run up against the problem that a rule cannot contain the criteria for its own application. It must be interpreted in some form, which can generate interpretations that satisfy the rules, but are wildly different from what we wanted.

They told me of Bostrom's 'paperclip maximiser' thought experiment. With the goal of maximising the number of paperclips it could decide to steal or con people. So, let's say we tell it that it cannot do either of these things, it could decide to use all our resources to make paperclips. Because, as Wittgenstein argues, language can be infinitely generated, therefore there are infinitely many meanings so we cannot focus the interpretation to get the desired goal. Greg also questions whether a machine could understand what a 'goal' itself is. If our goal is to cross a field and there are obstacles in the way, we would have to move around them to get to the other side. However, a computer may just see the rules as being "avoid obstacles" without understanding why these rules are here - the actual goal we wanted it to accomplish in the first place. This is linked to the deep question of how a computer perceives time, which I'll leave the reader to ponder.

However, there is a potential way to avoid this problem. Rather than stating the moral rules we wish the machine to incorporate, we somehow show them to it, which is how Wittgenstein (a favourite of Greg) interprets the meaning of language in the first place. To do this, we use the idea of morality as being driven by values. We want to demonstrate a good character through ideas such as honesty or care for others to a computer and hope it mimics it to a degree. The more general this is stated, the less chance it has of falling prey to the interpretation problem described above, as the meaning is not tied to representation in a language (such as any programming language). In doing so, however, the goal becomes less well defined, and we are also left with the problem of how to demonstrate these things to a computer while using as little written language as possible.

> *"We want to demonstrate a good character through ideas such as honesty or care for others to a computer and hope it mimics it to a degree."*

The mainstream media has always feared this sort of technology - from HAL to Ultron. Every time AI seems to be in films it seems to be in an overwhelmingly negative environment. Greg thinks this is understandable; it stems from a feeling of a lack of control that has existed since the idea of Mary Shelley's Frankenstein. We have the idea of our children learning from us and us controlling them as we teach them. Here we could be dealing with something much more powerful than ourselves. He suggests that a way to avoid this would be to limit the power such a machine has access to, but Cosmin thinks that we would not need such a thing in the first place. He argues that since the developments in technology would be gradual, our understanding of morality and how to regulate such machines would have enough time to keep control of the machines, and, well, 'solve' the interpretation problem.

But what if we set the machine to work and it came up with an idea that we disagreed with? Would we have to reconsider our own views? The problem, they argue, is that we would not be able to see the reasoning of the machine, and therefore would have to discuss it ourselves and form our own conclusions. So, they say, the machine could give us new problems to consider, but could not fundamentally change our morality.

To conclude a delightful hour of philosophising, I asked both what they would use such a moral machine for. Cosmin's eyes lit up as he described wanting to know the answer to very deep moral questions. The machine could learn so much philosophical knowledge and be able to give us answers to questions we simply do not have the scope to deal with. Greg encouraged caution over its use in important tasks. Citing the example of the Amazon recruitment bot which saw fewer female applicants, and then becoming sexist as a result, to illustrate the dangers of putting machines in charge. He questions whether it would be sensible to admit machines into the moral community, given how differently a computer may actually experience morality.

The incredibly powerful GPT3 AI has recently been used to make a philosophy bot. But to what extent is it constructing sentences that sound like philosophy? Or could it be coming up with deep ideas by itself? I'll let the headache sink in there...

THE PORTRAYAL OF HEROES & VILLAINS IN THE MEDIA

Scarlett Parr-Reid discusses whether the media should be allowed to typecast superheroes and cartoon villains in their narratives.

From the portrayal of heroes such as Harry Potter, Matilda Wormwood and Jo March, to villains like Cruella de Vil, Bill Sikes and Count Olaf, the narratives of storybooks guide our viewpoints. Is this same bipolarity of 'goodies' and 'baddies' seen in the media? Take, for example, coverage of climate change. Can we really say that Greta Thunberg is a hero and politicians are villains? Reality is far less simple and is inherently nuanced. Case in point, Channel 4's Climate Debate of November 2019. Five of seven party leaders stood poised at their podiums, two replaced with ice statues melting as the show continued. Boris Johnson was absent, but afterwards stated that he "can't do absolutely everything…the media process demands", and maintained it was achievable to "reach net zero carbon emissions by 2050". The same media process led to "more people…talking about [the ice statues] than any of the substance that came out of the debate..[which is] a shame", as Johnson put it. Perhaps in its perceived narrative of mockery and trivialisation, Channel 4 is no less of a baddie than a Prime Minister who, as LBC stated, "didn't show up".

Rewind to December 5, 2016: the world's first declaration of a climate emergency was signed by Australian Greens Councillor, Trent McCarthy in Darebin, Melbourne. This was an historic move, but fast forward to September 2019, the beginning of the worst bushfire season in Australia since 1974: temperatures peaked at 40.9 degrees celsius and droughts ravaged the land. Since the fires began, 18.6 million hectares of land have been scorched, 29 people and nearly one billion animals have died, with some species perhaps driven to extinction. All the while, Australian President Scott Morrison holidayed in Hawaii, saying on his return that the emergency response to the bushfires was "the best in the world". Morrison went on to say that associating the bushfires and climate change was "not a credible link". This new form of denialism, akin to Trump's relaxation of restrictions on power plant emissions, is obstructive and represents power politics over morality. Moreover, Morrison describes "the urge to panic [as] politically motivated" – a nod to Swedish climate activist Greta Thunberg's words "I want you to panic" at the World Economic Forum in Davos.

"Thunberg aligns panic with moral duty and responsibility. To what extent does anger achieve action?"

Thunberg aligns panic with moral duty and responsibility. To what extent does anger achieve action? To play devil's advocate. If your teenager said, "How dare you? You have stolen my dreams and my childhood", how might you respond? There are ways of saying things without a tone of resentment and vexation; however, Thunberg's anger signals the need for decision. It's the boiling over of frustration, and we should be frustrated about inaction. When a contributor to Fox news referred to Thunberg as "exploited by her parents and the international left", they really meant that she is not a climate-change denier and does not subscribe to "fairy tales of eternal economic growth". After her speech at the 2019 UN Summit, Thunberg called for action on the climate crisis from five countries – Germany, France, Brazil, Argentina and Turkey – but stopped short of China. China is not a democracy. But she emphasised that "the real power belongs to the people", offering hope that there will be a knock-on effect in China if the democracies take action first. The reality, as Sir David Attenborough put it, is if the Chinese were to state that "for our own reasons we are going to take major steps to curb our carbon output because our climate is changing… everybody else would fall into line".

In essence, typecast superheroes and cartoon villains are an easy narrative for the media. In reality, it's not with ease that the world emerges from a climate crisis. The media should be impartial - showing and not telling. Right now, we have the option to sit back and let the 'heroes' and 'villains' struggle and occasionally check our devices to see who is winning. Australian opposition Labour leader Anthony Albanese made a pertinent comment on the Climate issue: "Here's the contradiction in the Government's position – they say Australia produces just 1.3% of emissions therefore [they] don't have a responsibility to act, it really won't make a difference". Truthfully, he said, "if everyone says that, of course, no-one will act". The portrayal of heroes and villains by the media only perpetuates this inaction through disenchantment of the public with politicians.

Dichotomous thinking will leave us wanting.

"The portrayal of heroes and villains by the media only perpetuates this inaction through disenchantment of the public with politicians."

See, for example, this year's Nobel Peace Prize nominations, a list on which both Donald Trump and Greta Thunberg appear. Headlines sell ideas in the attention economy. One Guardian headline quotes Trump as 'reckless' and another quotes Thunberg as a 'warrior'. Perhaps it's time to move on from identity politics and personality contests towards a balanced and humane analysis in the media. As Krystal D'Costa of the Scientific American puts it, the news media leave us "free to choose those [beliefs] that relate best to us" and the narratives that align with our cultural identities. These people are humans, not cartoon characters.

ARTWORK: SCARLETT PARR-REID

REVIEW

Fatima Sheriff reviews the television series Person of Interest.

The Good Place (2016) was my knee-jerk reaction to the brief of a TV show on morality, with its complex after-life mythology, iconic philosopher jokes, and a compelling argument for there being no ethical consumption under capitalism. The memorable re-enactment of Phillipa Foot's Trolley Problem won the episode a Hugo award, but the serious implications of that thought experiment reminded me of another show, one that played out these hard choices.

Person of Interest was arguably the pinnacle of CBS' recent output of procedurals and thrillers, and for that matter, a highlight in JJ Abrams' varied catalogue of work, deftly avoiding the exhaustion of 22-episode-seasons with originality and excitement. It is handily summarised in its opening sequence, which dedicated viewers are soon able to recite from memory:

"You are being watched. The government has a secret system, a machine that spies on you every hour of every day. I designed the machine to detect acts of terror but it sees everything. Violent crimes involving ordinary people. The Government considers these people "irrelevant". We don't. Hunted by the authorities, we work in secret. You'll never find us, but victim or perpetrator, if your number's up ... we'll find you."

Harold Finch (Michael Emerson), the inventor delivering this speech, and John Reese (Jim Caviezel), a former CIA agent, team up with access to this omniscient Machine. Though the origins of its predictions are a mystery to prevent access to its wealth of surveillance information, the Machine gives the pair the social security number of someone about to be involved in an incident. Without knowing how the POI is involved, or the nature of the case, this more pedestrian version of Minority Report sees our protagonists avert crises before they happen.

The first season follows a procedural format: new number, new case, neatly wrapped up with the help of some new friends from the NYPD. But what made Person of Interest different was its careful evolution from small-scale crime-solving to epic, world-shattering ethical dilemmas. We learn about how the Machine was trained to have a sense of morality by Finch, how the ruthless agents on the government side deal with the "relevant" terrorists, and what happens when these blunt instruments try to outdo the carefully designed delicacy and privacy.

The second season sees the introduction of Root (Amy Acker), a psychopathic hacker, who, having found the Machine, treats it like a deity. She views the moral compass of the Machine as a bug to be fixed, heartbreakingly asking Finch "why did you do this to her?" Watching Root's character development as an AI teaches her empathy is a role reversed dynamic that is so compelling. One could view the network of complex players, from anti-heroes like Root to charming criminals like Elias (Enrico Colantani), like pieces on a huge chessboard, but even that metaphor is tempered.

In season 4's "If-Then-Else", we see our heroes trapped in an impossible situation where not all of them will make it, and witness this through three of the thousands of the scenarios the Machine is working through in split seconds. In flashbacks we see that the Machine, like many AI in real-life, is trained through the infinite possibilities of chess. But Finch teaches it to value every piece, treating every life as sacred and making the judgement calls more complicated than the Trolley Problem we began with.

Is this world inevitable with our exponentially improving technology and increasing surveillance data? Is this potential for success in saving lives worth the risk of it falling into the hands of the corrupt and selfish? If we attempt to emulate omniscience, are we creating a God through science? How do we define what is right and wrong, and how do you code for making those impossible decisions? Is there a point where the AI should defer to a person? I dare not say more, for fear of spoiling the brilliance of the show as it evolves but the themes of sacrifice and redemption are at the core of everything, even down to the team's adorable canine companion Bear. Each character has their moments of achingly difficult choices, and conceptually, this thriller tests the little grey cells to their limits of ethics and empathy.

IMAGE: MERVE SAFA ERGUNER
BACKGROUND ARTWORK: SOPHIA CAKOVA

STORING THE SUNSHINE

Balazs Striker explores the process of harnessing, utilising, and storing solar energy as well as the associated difficulties.

Multiple methods of harvesting solar energy have been discovered and are already in use, but storing this energy remains a problem. Converting renewable energy into a reliable and transportable form is key to ending our reliance on fossil fuels.

In 2019, only 11% of the world's energy consumption came from renewable sources, with more than 84% sourced from fossil fuels such as oil, coal and natural gas. Fossil fuels have high energy densities (large amount of energy stored per unit volume, or mass) and release that energy rapidly so are ideal to power vehicles. Essentially, they store energy efficiently and make it accessible and cheap to utilise. To compete with fossil fuels, renewables must be equally reliable and transportable.

Solar energy is a promising renewable source of energy, but as its performance depends on weather and the time of day, energy storage is needed for continuous supply. Most global electricity storage - 96% in 2017 according to the International Renewable Energy Agency – is pumped storage hydroelectricity. Excess electrical energy from low demand periods is stored by pumping water to a higher altitude for release when demand increases. Despite being the most efficient large-scale method to date, suitable landscape is limited and its reputation for environmental impact is bad. Also, the stored energy is not transportable, so must be regenerated on.

The electrochemical way of storing energy, batteries, is also widely used in stationary energy storage as well as in electric vehicles. The flagship, lithium ion (Li-ion) batteries, offer great energy density and reasonable power density. But the low charging speed, short lifetime, high cost and environmental concerns of the metals used are drawbacks. The biggest problem restricting use in vehicles is that the energy density is very low compared to fossil fuels; Li-ion batteries offer only 0.36–0.88 MJ/kg compared to 44MJ/kg for petrol. A fully electric Tesla Model S with 85 kWh batteries has 540 kg of battery packs, a quarter of the car's weight and providing power for approximately 420 km. To travel this distance, a petrol powered car of similar weight would consume only around 32 kg (42 L) of fuel.

> *"In 2019, only **11%** of the world's energy consumption came from renewable sources, with more than **84%** sourced from fossil fuels."*

IF YOU CAN'T BEAT FUEL, MAKE FUEL!

There is a growing interest in fixing solar or electrical energy in chemical bonds, the method plants use during photosynthesis. The artificial equivalents are photoelectrochemical processes turning water and carbon dioxide into more energetic molecules (H_2, CO) that can be readily used as, or converted into, fuels. Another approach is electrolytically reducing these combustion products, without using sunlight directly. The drawback of the latter is a guaranteed loss of energy in the intermediate processes, but an advantage is that other renewable sources – for example wind electricity – can be used for fuel production.

Hydrogen is a popular solar-to-fuel candidate. This light and abundant element can be directly used in fuel cells to generate electricity in vehicles or power plants. Its carbon-free production and utilisation make it a green alternative fuel. Unfortunately, storage is difficult; it is challenging to store this low-density gas in a way that yields high energy density. However, H_2 can be used to make easy-to-handle organic fuels with the help of a friend made from an enemy: carbon monoxide.

We know CO as a toxic gas and pollutant, but it can be our friend too! The Fischer-Tropsch (FT) synthesis, used and researched for almost a hundred years now, allows CO to react with H_2 forming valuable organic compounds including hydrocarbons or alcohol-based fuels. Companies are already producing FT-synthesised biofuels commercially; for example Red Rock Biofuels produces jet fuel from biomass.

> *"There is a growing interest in fixing solar or electrical energy in **chemical bonds**, the method plants use during photosynthesis."*

To provide the CO for FT-synthesis from captured carbon dioxide using renewable energy, different CO_2-to-CO reduction methods are being studied. Harry A. Atwater and Bruce S. Brunschwig have produced a solar-powered CO_2-reduction device with a solar-to-CO efficiency of 19.1%, almost 6% more than the previous record of 13.4%.

A photovoltaic cell coupled to an electrochemical cell performs the chemical reduction. For solar cells, the Shockley-Queisser efficiency limit restricts the theoretical maximum solar-to-electricity efficiency to about 31% for a single junction photovoltaic (solar cells containing only two semiconductors). The typical efficiency of commercial single-junction solar cells is 15-20%. So multi-junction solar cells are being researched. This group used a triple-junction GaInP/GaInAs/Ge cell which reached an efficiency of 19.3% at natural sunlight intensity, but it could exploit most of the visible spectrum and some of near-infrared.

To get the most out of the produced electrical energy, Atwater's group made an efficient gas diffusion electrode (GDE). In a GDE, gases undergo an electrochemical reaction at a solid-liquid-gas interface. In Atwater & Brunschwig's research, pure CO_2 gas was reduced to CO on a microporous carbon paper electrode (coated with silver nanoparticles) and potassium hydroxide (KOH) electrolyte, which was circulated to ensure homogeneous concentration. Silver is a compromise between cost and efficiency; gold is known to be the most efficient catalyst with 100% Faradaic efficiency, but is costlier. Nanoparticle-sized silver on large-area electrodes could nearly equal this performance.

What helped the group to meet the goal of making a device that can perform with high efficiency over an extended operation time was the reverse-assembled electrode. In GDEs, over time the catalyst becomes 'flooded' by the electrolyte disrupting the thin interface and slowing the reaction. Also, CO_2 dissolves and is absorbed by the electrolyte which compromises CO_2-to-CO efficiency. The solution for this was a reverse assembly in which the catalyst coating faces towards the gas phase. Treating the surface with PTFE (Teflon) further prevented flooding. This allowed 99% Faradaic efficiency to be maintained over 20 hours of continuous operation, meaning 99% of electrons passing through the electrode successfully contributed to CO formation. This number multiplied by the cell's power consumption gives the cell's output power, and the output power/power of illumination ratio gives the solar-to-CO efficiency of 19.1%. The device performed well under outdoor natural light, producing 15 mg of CO/cm^2 per day with 18.7% peak efficiency.

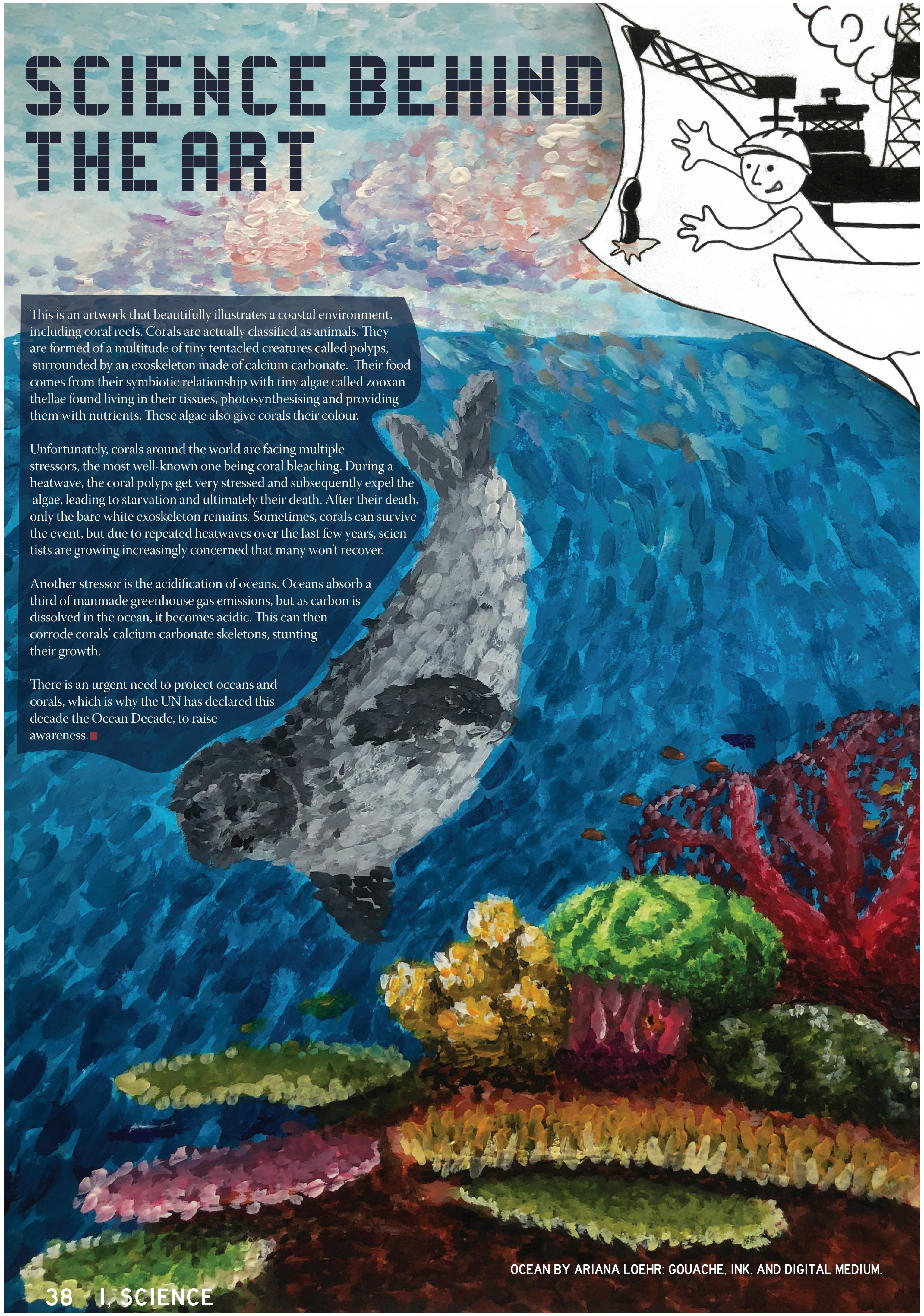
There are a few issues to overcome to make this system sustainable: over time, KOH loss from the electrolyte was observed, due to potassium carbonate accumulation in the electrode as a result of side reactions with CO_2. Also, GDEs are challenging to scale up and the device is yet to be optimised for cost-effective production.

IS THIS HOW WE'LL RUN ON SUNSHINE?

From a socio-economic point of view, FT-synthesised hydrocarbon fuels are promising because they are compatible with current jet and combustion engines. This is not only convenient but could help reduce the costs of transitioning to carbon-neutral transportation if electric and hydrogen-powered vehicles remain expensive. FT-synthesised methanol can also be used in fuel cells to generate electricity, providing temporary storage for renewable energy this way. FT-synthesis can also produce other chemicals in future that are fossil-derived today. CO sourced from solar-to-CO processes such as those in Atwater and Brunschwig's research can therefore be important together with a green source of H_2. Unfortunately, the method is not yet economically viable: it involves multiple steps with energy losses and expensive technology. Ironically, sourcing pure CO_2 for the process from a green source is tricky too: capturing this greenhouse gas from the air is hard due to its low concentration. However, capturing CO_2 from alcohol fermentation seems cost effective, and electrochemical adsorption from air was shown to be possible too – perhaps powering our society out of thin air and sunshine is not as impossible as it sounds.■

IMAGE: ALIENOR HAMMER
BACKGROUND ARTWORK: SOPHIA CAKOVA
ILLUSTRATION: PATRYK STARZYKOWSKI

SCIENCE BEHIND THE ART



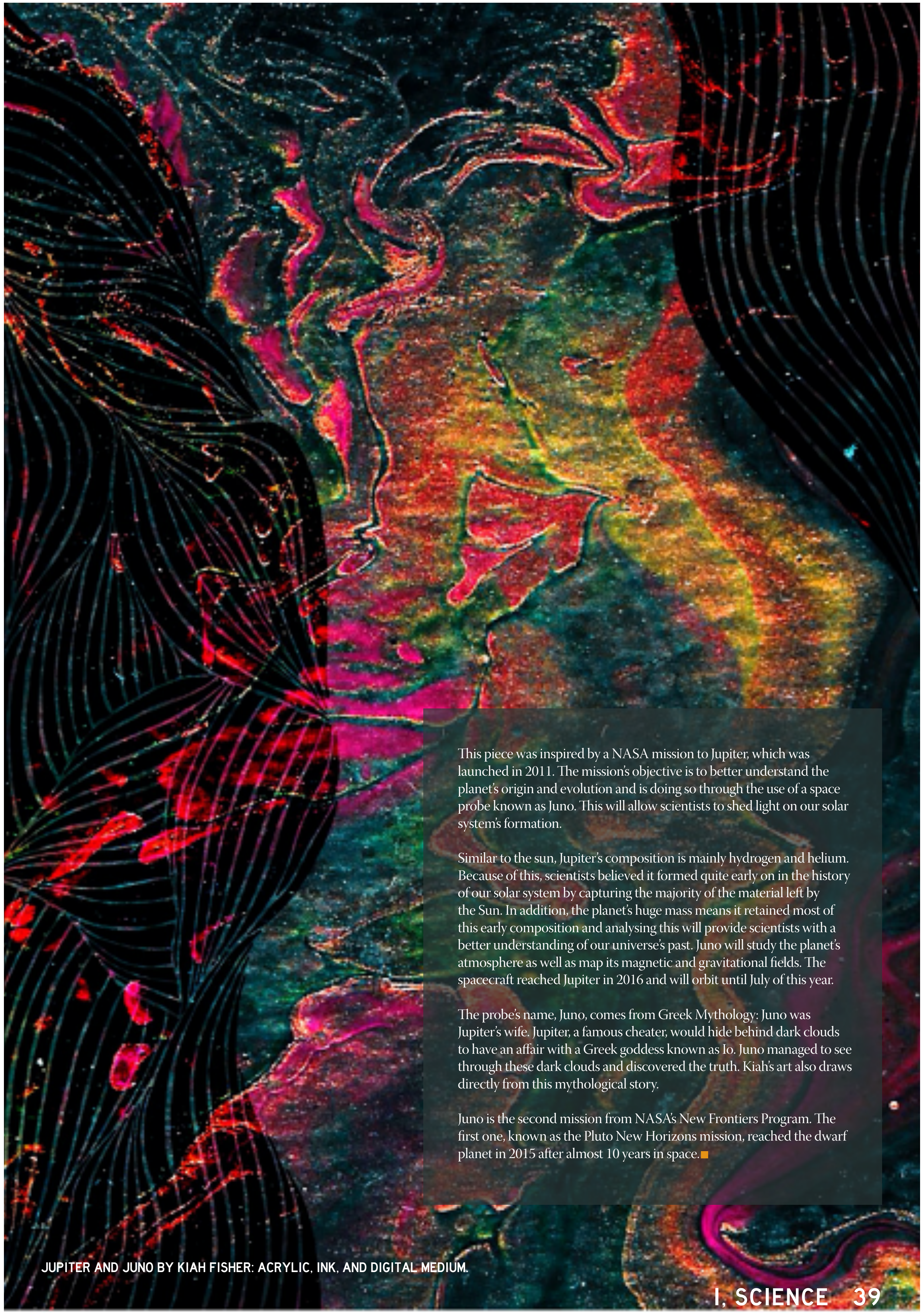
This is an artwork that beautifully illustrates a coastal environment, including coral reefs. Corals are actually classified as animals. They are formed of a multitude of tiny tentacled creatures called polyps, surrounded by an exoskeleton made of calcium carbonate. Their food comes from their symbiotic relationship with tiny algae called zooxan thellae found living in their tissues, photosynthesising and providing them with nutrients. These algae also give corals their colour.

Unfortunately, corals around the world are facing multiple stressors, the most well-known one being coral bleaching. During a heatwave, the coral polyps get very stressed and subsequently expel the algae, leading to starvation and ultimately their death. After their death, only the bare white exoskeleton remains. Sometimes, corals can survive the event, but due to repeated heatwaves over the last few years, scien tists are growing increasingly concerned that many won't recover.

Another stressor is the acidification of oceans. Oceans absorb a third of manmade greenhouse gas emissions, but as carbon is dissolved in the ocean, it becomes acidic. This can then corrode corals' calcium carbonate skeletons, stunting their growth.

There is an urgent need to protect oceans and corals, which is why the UN has declared this decade the Ocean Decade, to raise awareness.

OCEAN BY ARIANA LOEHR: GOUACHE, INK, AND DIGITAL MEDIUM.



This piece was inspired by a NASA mission to Jupiter, which was launched in 2011. The mission's objective is to better understand the planet's origin and evolution and is doing so through the use of a space probe known as Juno. This will allow scientists to shed light on our solar system's formation.

Similar to the sun, Jupiter's composition is mainly hydrogen and helium. Because of this, scientists believed it formed quite early on in the history of our solar system by capturing the majority of the material left by the Sun. In addition, the planet's huge mass means it retained most of this early composition and analysing this will provide scientists with a better understanding of our universe's past. Juno will study the planet's atmosphere as well as map its magnetic and gravitational fields. The spacecraft reached Jupiter in 2016 and will orbit until July of this year.

The probe's name, Juno, comes from Greek Mythology; Juno was Jupiter's wife. Jupiter, a famous cheater, would hide behind dark clouds to have an affair with a Greek goddess known as Io. Juno managed to see through these dark clouds and discovered the truth. Kiah's art also draws directly from this mythological story.

Juno is the second mission from NASA's New Frontiers Program. The first one, known as the Pluto New Horizons mission, reached the dwarf planet in 2015 after almost 10 years in space.

JUPITER AND JUNO BY KIAH FISHER: ACRYLIC, INK, AND DIGITAL MEDIUM.


I, SCIENCE