I, SCIENCE

THE SCIENCE MAGAZINE OF IMPERIAL COLLEGE

diversity.

AUTUMN 2020

I, SCIENCE
THE SCIENCE MAGAZINE OF IMPERIAL COLLEGE

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I, SCIENCE

Dear reader,

The past year has indeed been a tumultuous one, throwing many key themes into pivotal focus. One such motif has been the ever-evolving concept of diversity.

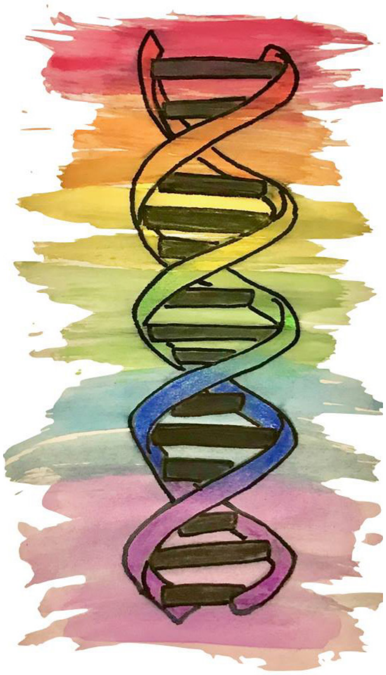
This complex world we live in is heavily influenced by the notion of diversity through various facets - whether we recognise, appreciate, or even understand it. Diversity is an integral tenet of the natural world, underpinning our society. It celebrates the individual differences that make us unique and plays a significant role in contributing to the development and progression of knowledge. Within the scientific community in particular, diversity has been a heavily discussed topic and we delve into some of these discussions through this issue of I, Science.

Our writers have approached this theme from a multitude of angles, giving insight on everything from the diversity of bacteria habitats to the importance of representation in science. We invite you to learn about the neuroscience behind cultural behaviours, the role of women in science communication, as well as the vast variations in vision systems. Immerse yourself in the intriguing universe where art and science meet or consider the implications of languages on scientific advancement. Read on to find out how soundscapes influence biodiversity conservation, how nature is inherently queer and much more.

We sincerely hope you enjoy reading our Diversity issue as much as we have enjoyed curating it!

AKILA RAGHAVAN & ALEXIA YIANNOULI

CO-EDITORS-IN-CHIEF



ARTWORK: CECILIA GRIMALDI

I,

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

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news.

Keegan Schroeder covers the latest.

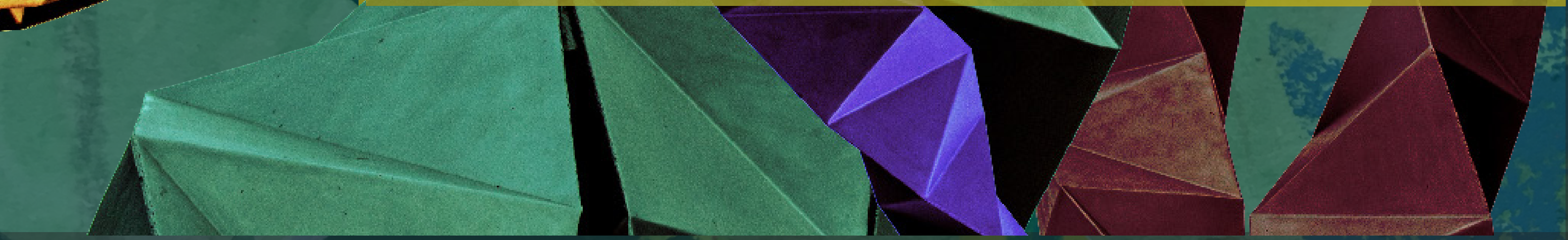
DEEPMIND ALPHAFOLD AI REVOLUTIONISES HOW WE SEE PROTEINS

One of DeepMind's AI, AlphaFold, has made waves in the field of Structural Biology after predicting multiple protein structures with accuracy comparable to currently used lab techniques. This news follows AlphaFold attending and winning 2020's Critical Assessment of Techniques for Protein Structure Prediction (CASP), which can almost be considered the "World Cup" for communities researching protein structure prediction methods.

Each living cell contains a staggering number of different proteins. The scientific community has recognised over 200 million proteins, but the structures of only a small fraction are known. These proteins are essential for almost every function the cell carries out. As such, abnormalities in proteins form the foundation of almost every human disease. Proteins have a very specific shape that dictates their function. This comes about as a result of folding (think molecular origami). For example, a protein called TP53 is altered in over half of all human cancers and is a major focus for research. Another more relevant example is the specific shape on the coronavirus spike protein. Knowing the specific folding of this protein is essential for developing a coronavirus vaccine.

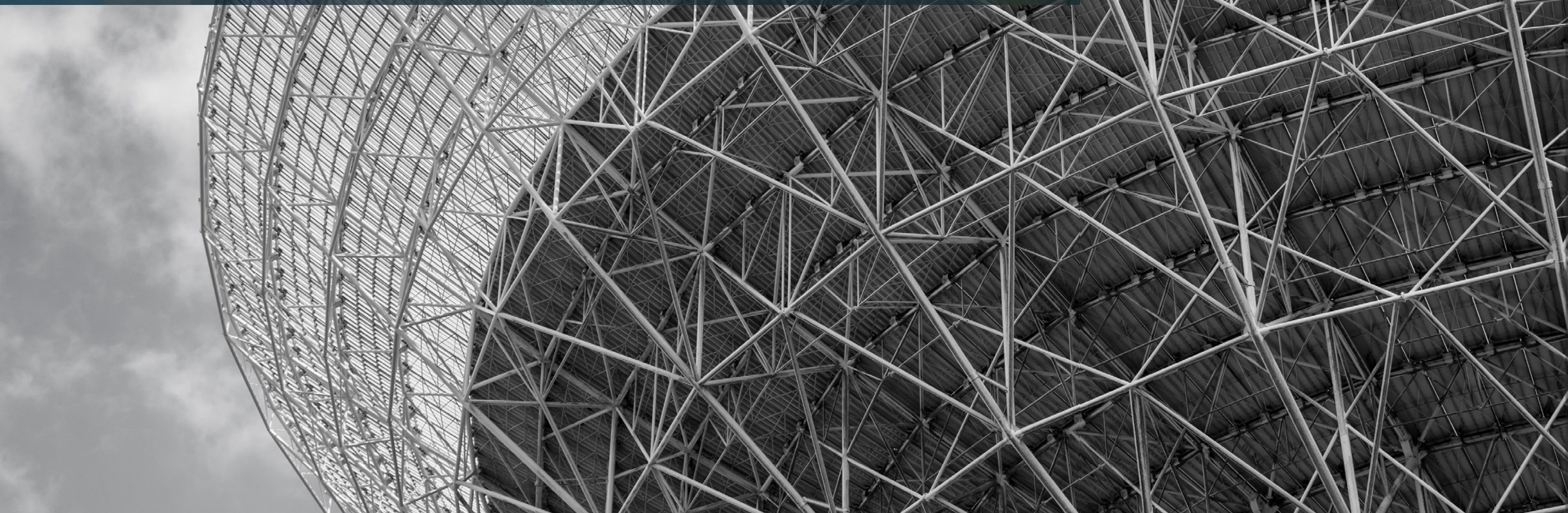
Traditional techniques for figuring out protein structure involve extremely time-consuming work from structural biologists in a lab, deploying techniques such as NMR (Nuclear Magnetic Resonance) or Mass Spectroscopy. The AI's ability to predict protein shape marks a tremendous leap forward in molecular biology.

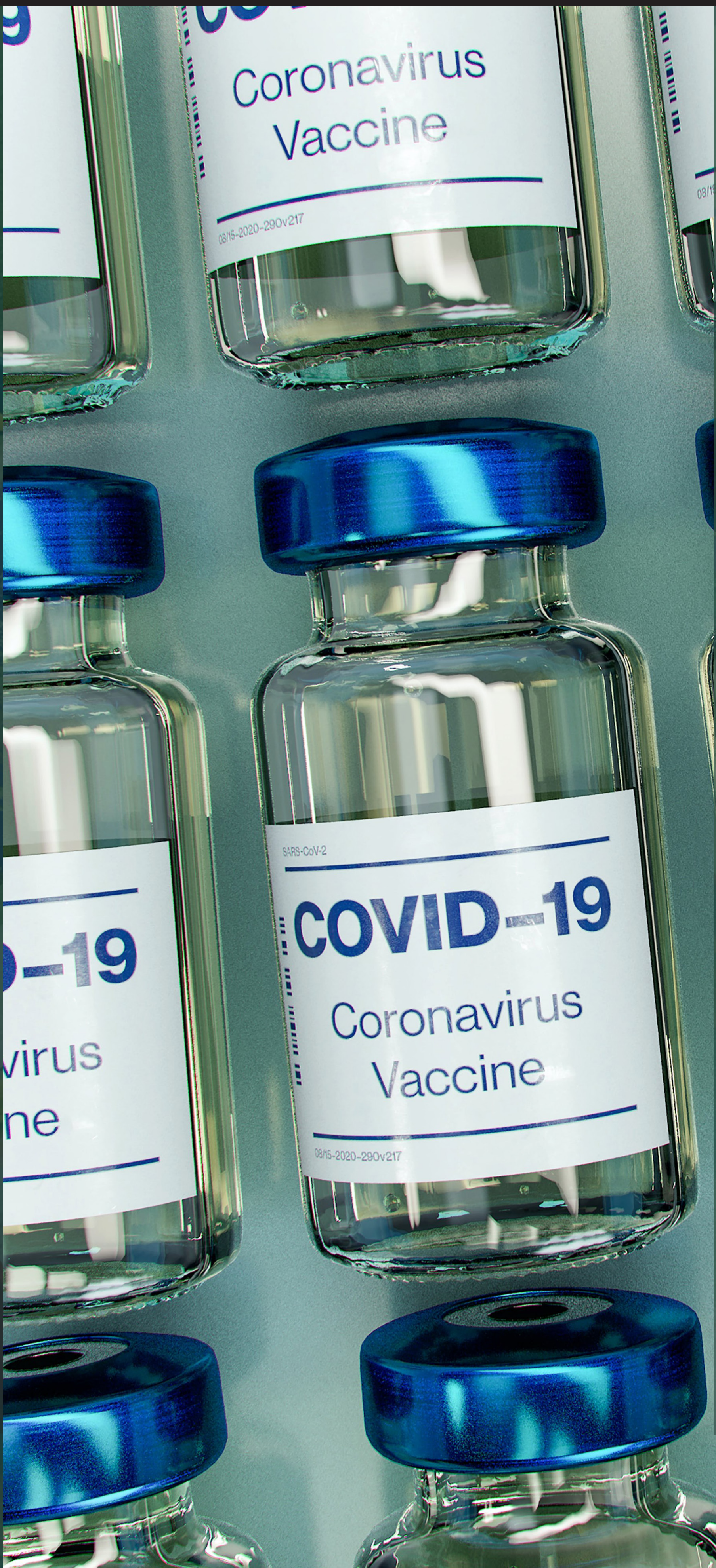
The door to new drug products from the field of drug design is beginning to close as researchers struggle to keep pace with demand. There is hope that the huge leap taken by AlphaFold will mark the opening of a new door to the world of protein design, paving the way to "green enzymes" that can break down plastic waste, and a huge range of new medicines.



FAMOUS ARECIBO OBSERVATORY COLLAPSES

While you may not know it by name (I certainly did not!), the iconic radio telescope in Puerto Rico that served as the final battleground between 007 and 006 in the 1995 James Bond film Goldeneye has collapsed into a heap of rubble after one of the main cables holding up the radio receiver broke. In 1974, the Arecibo message, an attempt to communicate with potential extraterrestrial life, was transmitted from the radio telescope toward a target about 25,000 light-years away. The message defined a 23 by 73 pixel bitmap image that included numbers, stick figures, chemical formulas, and an image of the telescope.





UK PFIZER VACCINE ROLLOUT – HOW ARE WE IMMUNISED?

It's been a rollercoaster ride over the last few months. Here in the UK, we went from quaking in our boots at the prospect of a mutated mink coronavirus (some of us anyway!) to having an approved vaccine rollout in a matter of months. The Pfizer vaccine, which has started being rolled out across the UK, is based on a new vaccine technology called an mRNA vaccine.

As discussed in our segment on the AlphaFold AI, proteins underpin the vast majority of cellular and viral processes, including our immune system. Our immune system produces proteins called antibodies that are specifically folded to interact with other "foreign" proteins from invading bacteria and viruses, in order to prevent them from causing us harm.

A traditional virus vaccine will take a single viral protein and introduce it to the body via injection so that your immune system can create antibodies (an immune response) in preparation for a real infection. Producing these proteins in a lab is extremely time consuming.

The mRNA vaccine instead deploys Messenger RNA (mRNA) which is the molecule carrying the code used to tell cells what protein to make. This causes our body to create the viral protein within our cells to cause an immune response which is far more similar to how an actual viral infection would take place as viruses inject mRNA into our cells into order to replicate.

Unlike creating the proteins used for a traditional vaccine, creating mRNA is extremely quick and cheap – perfect for rolling out a large number of vaccines in a short space of time.

IMAGES:
BACKGROUND ARTWORK: LUCY DUKES
RIGHT: DANIEL SCHLUDI, UNSPLASH
BOTTOM LEFT: PIXABAY, PEXELS
TOP LEFT: ETHAN LACKNER, UNSPLASH; EDITED BY LEIGH WEST

HOME IS WHERE THE ECOLOGICAL NICHE IS

Alana Cullen explores how different bacteria have adapted to a range of extreme habitats.

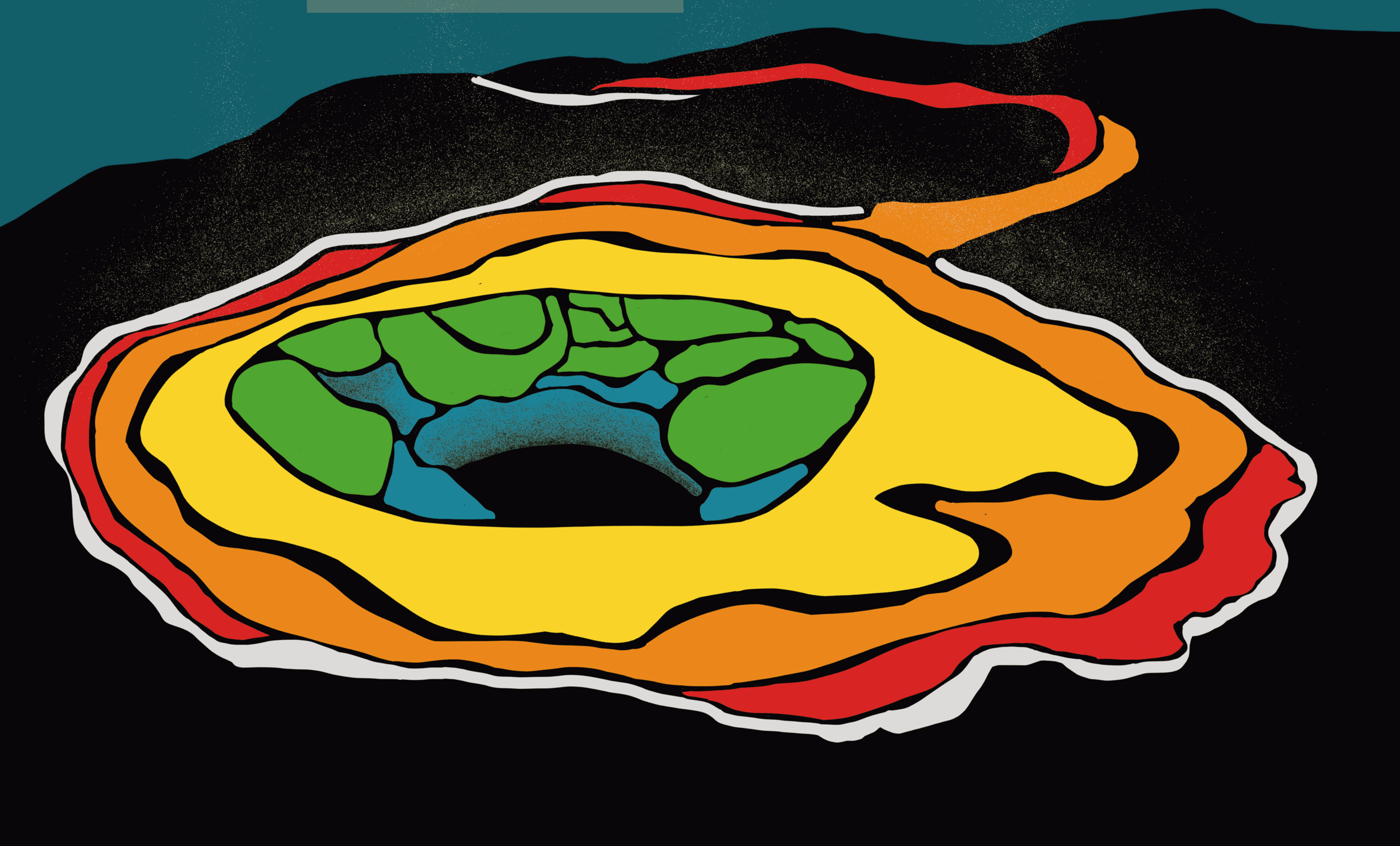
From bacteria that live at excruciatingly high temperatures, to moss piglets that can survive in space, it is clear life can thrive in the most extreme environments.

Organisms that have adapted and thrive in such adverse conditions are aptly called extremophiles. These organisms show us, and continue to reveal, the range of conditions in which life can exist. Not only are they awesome in their own right, but some of the biological tools extremophiles use to survive can be harnessed and used in the advancement of science too. Let's take a closer look at some of nature's most resilient species.

> *Organisms that have adapted and thrive in such adverse conditions are aptly called extremophiles.*

First up is the single celled *Thermus aquaticus*. This bacteria is found in the steaming pools of Yellowstone National Park, at temperatures close to boiling point. They live in association with cyanobacteria, which obtains its energy through photosynthesis. Under these high temperatures most proteins would denature, eventually resulting in death of an organism. However, *T. aquaticus* has a unique enzyme, Taq polymerase, which has adapted to produce heat stable proteins.

What's even more interesting is that this enzyme was extracted and has revolutionised the biotechnology industry. DNA extraction and replication processes can now take place at much higher temperatures thanks to Taq polymerase. It has famously been used in the human genome project, as well as in DNA finger printing technologies. This is such a wonderful discovery that Taq polymerase was named Science Magazines first ever "Molecule of the Year" in 1989.



ARTWORK: ARIANA LOEHR

Life is continually adapting to new, extreme niches that are created as a result of human activity.

Let's move from steaming pools to the roof of the earth, where the Himalayan jumping spider, *Euophrys omnisuperstes*, lives. This spider lives at heights of up to 6,700 meters, living higher than any other known species, and has even been spotted at basecamp on Everest. Food scarcity this high up is not a problem for *E. omnisuperstes* – it simply waits for the wind to blow frozen insects up the mountains. With a lack of competition around, it can feast on whatever the wind delivers. Adaptions include excellent eyesight to spot these frozen critters, and the spinning of silken cells beneath rocks which help them survive the freezing temperatures.

Next to the depths of the ocean, where green sulphur bacteria, *chlorobiacae*, inhabit deep-sea vents. These bacteria are unique to the black smoking chimneys and use sulphur for their energy source. They also harvest geothermal light from the dim 'vent glow' over a mile beneath the ocean surface. This is the only known organism to survive off geothermal light instead of solar. The fact these bacteria can survive without solar energy gives hope that life could survive on other planets too, such as Europa, one of Jupiter's moons. Could they live under the icy surface?

The jack of all trades, tardigrades, are polyextremophiles and can survive almost all environmental extremes. Known as moss piglets or water bears, these 8-legged animals, with claws on each foot, are just 0.5mm long and oddly cute. Their size is no means to underestimate them though, as they can survive in space. In 2007 thousands were sent into space on a satellite, and upon its return, not only had many of them survived, but females laid eggs, which produced healthy young. They can survive radiation and also up to 150-degree Celsius heat and being frozen to almost absolute zero. They can even survive up to 120 years of dehydration, by going into a deep state of suspended animation, which closely resembles death. During this paused state, known as cryptobiosis, their metabolism slows to 0.01% of the normal rate, and they will reanimate upon contact with water. These superpowers promoting survival beyond natural extremes are all enabled by the same mechanism; the body makes a unique protein called a damage suppressor, which repairs any DNA damaged under extreme conditions.

Life is continually adapting to new, extreme niches that are created as a result of human activity. In 2016, the world's first naturally evolving plastic eating bacteria was found in a landfill site in Japan. *Ideonella sakainesis* decomposes polyethelene terephthalate (PET), one of the world's most common plastics. It uses two enzymes to break down the plastic into carbon dioxide and water. These could also help solve our plastic problem if they are engineered to digest PET at a much faster rate.

Each of these species demonstrates the diversity of life on earth, and just how resilient that life can be. Adapting to live in adverse conditions means reduced competition, and the making of a unique home. In studying these species, scientists can generate new biotechnologies that accelerate our understanding of the limits of life on earth, and potentially beyond.

THE PEOPLE VS. THE NATION

Legal action against governments for their climate change response has become commonplace over the last few decades – Lily Shepherd takes a look at the diverse range of people behind these ground-breaking lawsuits.

ARTWORK:
DANIEL GONZÁLEZ-FRANCO

Across the world, people from a wide range of socio-economic backgrounds are taking their governments to court for not doing enough to combat climate change, basing their cases on human rights, fraud, and disclosure arguments. A 2020 study by the London School of Economics' Grantham Institute found that there have been over 1000 new climate litigation cases since 2012, almost 75% of which were brought against governments. And many of the litigants are winning. The same LSE report found that, since 1994, 42% of cases in the United States and 58% of cases outside the United States had outcomes favourable to climate change action.

So, who are the heroes behind these cases? There are hundreds of individuals and organisations working for climate justice. We'll look at just a few of them.

> *There are hundreds of individuals and organisations working for **climate justice**.*

ASGHAR LEGHARI

Leghari is a Pakistani farmer who successfully sued the Pakistan government for violating his human rights by failing to tackle climate change (*Leghari vs. The Federation of Pakistan*). The evidence brought forward demonstrated that Leghari did not have sufficient access to water, food or energy as a direct result of the government's failure to act.

The court found that the government had failed to carry out their National Climate Change Policy (2012) and the Framework for Implementation of Climate Change Policy (2014-2030). As a result of Leghari's case, the government were required to demonstrate how they would ensure proper implementation of their policies. Pakistan now has a Climate Change Commission, a 'climate change focal person' in several government ministries, and an action plan for carrying out their promises – all as a result of this case.

XIUHTEZVCAL MARTINEZ, EARTH GUARDIANS AND OUR CHILDREN'S TRUST

Martinez is a 20-year-old environmental activist who is Youth Director of Earth Guardians, a conservation organisation set up by his family. His father is of Aztec heritage and he was raised in the tradition of the indigenous Mexica. He is one of the 21 youth plaintiffs who filed a climate lawsuit against the United States federal government in 2015 (*Juliana vs. United States*). All 21 youth plaintiffs were members of Earth Guardians and were represented by the organisation *Our Children's Trust*.

Their complaint asserts that the US government's actions have caused a worsening of climate change, which has violated the constitutional right for life, liberty and property for younger generations. It also asserts that the government has failed to protect the atmosphere, which they have a sovereign duty to protect under the Public Trust Doctrine, by allowing the continued use of fossil fuels.

In 2016, US District Judge Ann Aiken declined to dismiss the case after the US Department of Justice, backed by fossil fuel industry groups, argued for dismissal on the grounds that there is "no constitutional right to a pollution-free environment". Judge Aiken stated that she had "no doubt that the right to a climate system capable of sustaining human life is fundamental to a free and ordered society" and used recent case law that ruled gay marriage as a fundamental right to prove that the right to a sustainable climate could be fundamental, even if it was not constitutional. Sadly, the case was dismissed earlier this year, although the plaintiffs are appealing this decision.

THE PORTUGAL SIX

This year, six young Portuguese activists between the ages of 12 and 21 launched a case against 33 countries in the European Court of Human Rights. Four of the plaintiffs live in central Portugal, where wildfires have destroyed homes every year, killing more than 100 people in 2017. The others live on the coast in the capital city of Lisbon, which is threatened by rising sea levels.

The 33 countries include all 27 member nations of the European Union, as well as the UK, Norway, Russia, Switzerland, Turkey and Ukraine. The six allege that all 33 countries they are filing against have made inadequate efforts to reduce their greenhouse gas emissions, which has threatened the physical and mental wellbeing of them and many other people of their generation, violating their human rights.

If the case is successful, the countries will be legally bound to the commitments they made in the 2015 Paris Climate Accord and will be required to address their role in contributing to overseas emissions.

AMY ROSE, CLIENTEARTH

Rose is the Legal Director of ClientEarth, an environmental law charity that holds governments and companies accountable for their environmental policies, or lack of them. They have received numerous awards and accolades for their work, including being named the most effective environmental group in 2017.

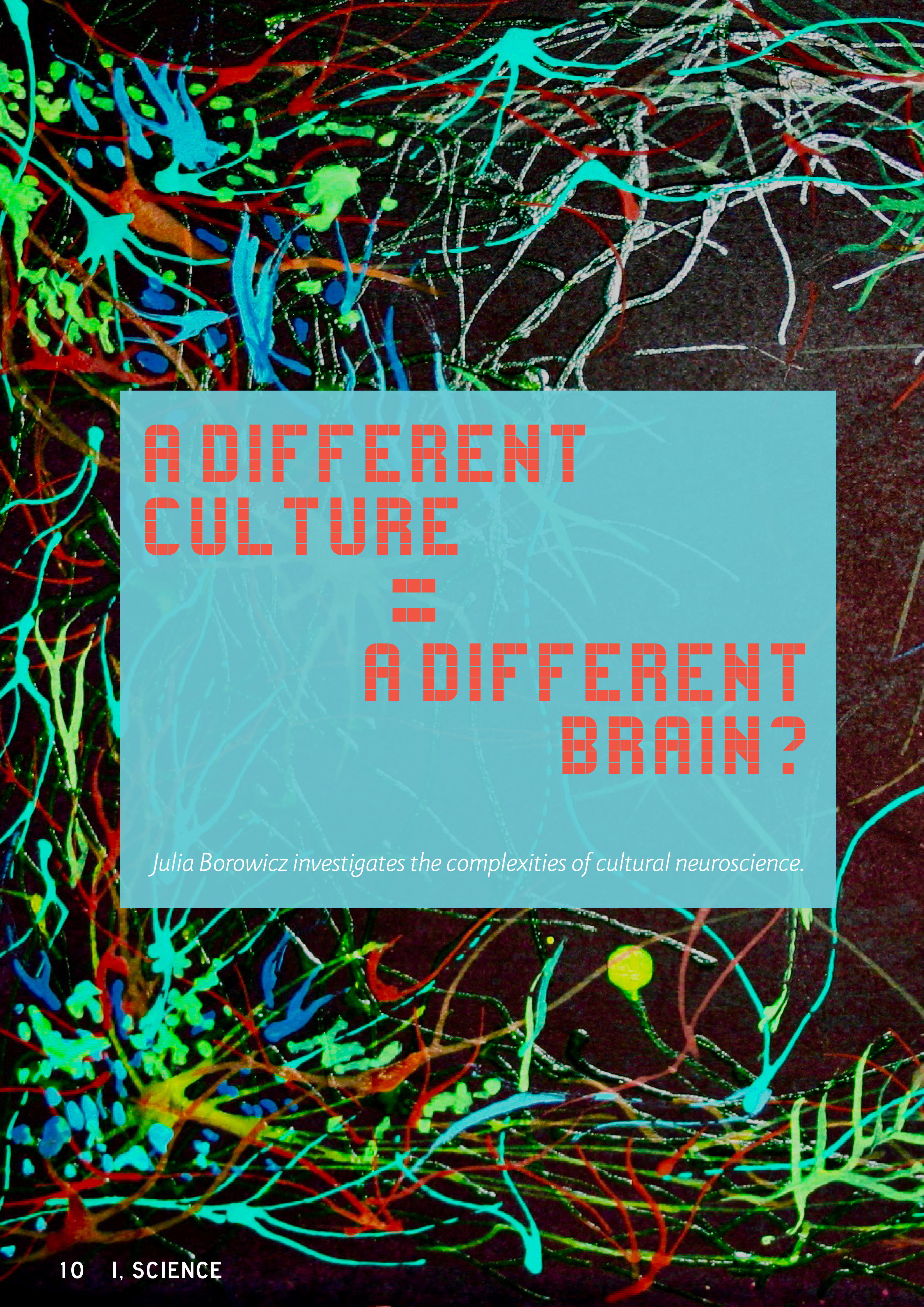
Rose oversees the management of ClientEarth's diverse and growing litigation portfolio and supports their legal teams to bring a wide range of climate and environmental cases across Europe and around the world. Her specific focuses are climate finance – using law to ensure that money stops flowing into industries that contribute to climate change; and climate accountability – using law to hold governments and businesses to account over their climate change actions. ClientEarth have 167 active cases tackling environmental challenges and have already won countless cases – including three in the UK's High Court.

GRETA THUNBERG AND EARTHJUSTICE

In 2019, sixteen young people from around the world, including Swedish climate activist Greta Thunberg, filed a petition to the United Nations' Committee on the Rights of the Child. Their complaint asserts that their human rights are being violated by the failure of their national governments to address the climate crisis. They are supported by Earthjustice, an environmental law charity. If their complaint is admissible, the Committee for the Rights of the Child will have the power to make recommendations to all nations under scrutiny. While the recommendations themselves are not legally binding, all nations have committed to follow any recommendation made by the Committee for the Rights of the Child. Their obligations to carry out these recommendations are therefore binding.

> *These cases are not being brought forward by big legal corporations and wealthy men in suits – they are being brought forward by children, young people, indigenous peoples, local communities and grassroots organisations from all across the globe.*

These cases are not being brought forward by big legal corporations and wealthy men in suits – they are being brought forward by children, young people, indigenous peoples, local communities and grassroots organisations from all across the globe. While there is still so much to do to tackle the climate crisis, and while it is sad to see some of these cases being dismissed, there is certainly some hope to be found in the stories of these activists. They have shown us the power of speaking up and holding your government accountable for their actions.



A DIFFERENT CULTURE = A DIFFERENT BRAIN?

Julia Borowicz investigates the complexities of cultural neuroscience.

As a foreigner living in the UK, I've had more than one opportunity to experience first-hand the cultural differences between the natives and I. After all this time, the annoyance of not knowing what the polite thing would be to say has persisted and only become more frustrating. Living in London and attending a multicultural university like Imperial College London, it's easy to notice the different perceptions of the world, or of yourself held by the people from the cultures around us. A relatively new field of science has emerged to help quantify those differences and give insight into their origin within the brain.

WHAT IS CULTURAL NEUROSCIENCE?

Cultural neuroscience seeks to establish the neural networks and connections within the brain that can be associated with specific cultures. Scientists can ask a question or show an image to a subject and, using functional magnetic resonance imaging (fMRI), identify the mechanisms underpinning people's choice of behaviour and ideals. Cultural neuroscience can explain some of these mechanisms.

WE OR I?

Before the idea of cultural neuroscience, the differences between Western and Chinese cultures had been observed and described by cultural psychologists. Cultural neuroscience has given an explanation to one of the major differences – the two distinct types of self-representation. The Western independent self and Chinese interdependent self. When Americans are asked whether they think they are honest, their brain looks different than when they are asked about the honesty of their mother. However, for Chinese people the brain looks almost identical. According to a Ying Zhu study from 2007, "Chinese individuals use MPFC (medial prefrontal cortex - which is a part of frontal lobe of the brain) to represent both the self and the mother whereas Westerners use MPFC to represent exclusively the self".

In the same way that our parents and environment influence our psychiatry throughout childhood, the culture we are raised in can shape our mental function, leading to our distinctive neural networks and brain activation patterns.

This suggests that the collectivist aspect of Chinese culture and the enhanced individualism in Western society might have influenced the way the brain works and shaped the self-representation.

CULTURAL IDEALS

The two types of self-representation are not the only example of a cultural difference being explained by neuroscience. Preferred behaviours and cultural ideals can also be explained by the variations in brain activation. In a study including Japanese and American participants, subjects were shown two types of pictures – some portraying dominant postures, others portraying submissive ones. As predicted by Jonathan Freeman and his colleagues, the reward circuits of the brain in Japanese people fired up when seeing the submissive silhouettes. The opposite happened for Americans. This showed how certain attributes are favoured within certain cultures and how cultural ideals are shaped.

THE CHICKEN OR THE EGG?

So far, we've explored how we can explain behaviours through the use of brain imaging and how culture can shape our mental function. However, the relationship between culture and the brain is not as obvious as it seems. Can the differences within cultures be attributed to the differences within the brain? Or perhaps the differences within the brain give rise to social differences? Could the similarities between individuals constitute culture? In much simpler words – which came first: the chicken or the egg? However easy the question may seem, the answer is not black and white. There is no significant evidence supporting one theory or the other and it could be a two-way relationship. In the same way that our parents and environment influence our psychiatry throughout childhood, the culture we are raised in can shape our mental function, leading to our distinctive neural networks and brain activation patterns. On the other hand, there are some theories that suggest a reverse relationship.

Cultural neuroscience seeks to establish the neural networks and connections within the brain that can be associated with specific cultures.

THE CULTURE GENE

At Northwestern University, Joan Chiao has shown that people living in collectivist cultures (like the Chinese culture) are more likely to have a certain serotonin transporter gene (the S-allele) than people in individualistic cultures. The S-allele correlates with higher rates of mental health disorders such as depression and higher levels of anxiety. This could mean that people in those cultures would therefore have a higher incidence of depression. Surprisingly, it is not true at all as Chiao has found that people from a collectivist culture are less likely to get depressed. As she says, this might suggest that collectivism co-evolved as a protection against the S-allele. This would suggest that not only does culture influence mental development, but the inherent differences in genes might have influenced the development of different cultures too!

WHERE ARE WE NOW?

Despite constant developments, cultural neuroscience still faces a lot of criticism which calls for improvement. It could be argued that some experiments are based on harmful stereotypes. We must reach a sophisticated understanding of the complexity of culture so that we are not led to rely on simplified and generalized ideas. Where could that lead us? Such improvements in the field of cultural neuroscience would open the doors to thoroughly understand the misconceptions arising from interactions between different cultures and to comprehend human cognition, perhaps even consciousness, and what shapes it. We would understand that we don't just say different things...we think differently!

ARTWORK: LUCY DUKES

THE DIVERSITY OF DOGS

Akila Raghavan explains how man's best friend is a remarkably diverse species.

The animal kingdom is incredibly vast and comprises of millions of different species, ranging from tiny organisms made of only a few cells to the humongous blue whale. However, there isn't much variation within each species – with the unique exception of man's canine companion, the dog.

The differences in the many dog breeds can be quite stark when we compare and contrast, for instance, the tall and lanky Great Dane with the tiny trembling chihuahua, or the fluffy Samoyed with the hairless Chinese Crested, or even the squash-nosed pug with the long-snouted borzoi.

Dogs are thought to be the first domesticated animals and have been our furry four-legged friends for well over 20,000 years. It is widely believed that this species, known as *Canis familiaris*, originated from a common wolf ancestor, and that at some point along the evolutionary process, wolves and dogs went on their separate ways.

Over the years, humans and dogs have remained closely attached and, in realising how useful dogs can be, humans started breeding them for specific purposes, be it for hunting, herding, or even for sport. Thus, domestic dogs are selectively bred for favourable characteristics like their shapes, sizes, or coat colours and textures. There are now hundreds of distinctive breeds and they look very different from each other. However, they all still remain firmly within the same genetic species.

The differences in the many dog breeds can be quite stark when we compare and contrast, for instance, the tall and lanky Great Dane with the tiny trembling chihuahua, or the fluffy Samoyed with the hairless Chinese Crested, or even the squash-nosed pug with the long-snouted borzoi. Barring certain physical restrictions, all the different breeds in the dog species are capable of mating with each other and producing healthy, fertile offspring. However, these puppies may not bear much resemblance to either parent, such as in the case of corgis.

Studies into these various breeds revealed that all dog DNA is nearly identical and that the expression of only a mere handful of genes was accountable for the variations in the size and appearance of dogs. In 2007, a team of geneticists were able to establish that the gene IGF1 that codes for insulin-like growth factor 1, a growth hormone, played a key role in determining the size of a dog. One allele type of this gene was found across all the small dog breeds involved in the study and thus was concluded to be the genetic factor that led to diminutive dogs.

Further investigation into the differences between breeds has also shown that there is a genetic basis for social behaviour in dogs, just as in humans. For example, certain breeds like miniature schnauzers have been found to be more aggressive and fearful of strangers while on the other hand, these behavioural traits are almost never seen in breeds such as Labrador retrievers. It was also seen that the oxytocin receptor gene OXTR in German shepherds is linked with a higher level of sociability in the breed, but is also a genetic component leading to a higher sensitivity to noise.

The phenotypic diversity in dogs has made the species one of great scientific curiosity and has provided research teams with a viable model on which to study the genetic origins of diseases. Through sequencing the genome of various dog breeds and making associations, scientists can uncover the genetic basis for phenotypic variations. Such studies can have profound implications for research into population genetics and even conservation of endangered species. This makes dogs highly important to humanity – beyond the call of being man's best friend.

ARTWORK: WORLD OF DOGS, JAKE GABLE

EYE, SCIENCE

Keegan Schroeder investigates the diverse and complex nature of vision, and how no two pair of eyes are the same.

Vision is a tremendous thing. Not only does it bestow upon you the immense privilege of reading I,Science (check out our website and YouTube channel while you're at it), it is also paradoxically both one of the most highly conserved and yet wildly diverse senses in nature. Visual systems can be broadly categorised into two classes: compound and non-compound, but within these classes there is a huge range of complexity. For example, some species deploy multiple lenses to increase image size and focus (birds of prey) while others don't use a lens at all.

Compound eyes are the eyes of the arthropods (insects and crustaceans) and are composed of thousands of repeating units known as ommatidia. The image produced by compound eyes is a combination of picture elements (aka pixels) from each ommatidia in the same way a TV produces an image. The density of picture elements forms the image resolution. As such, what compound eyes offer in their tremendous view angle and ability to detect fast movement (hence the immense challenge of swatting insects) they lack in resolution. For a compound eye to deliver the resolution of a human eye it would need a radius of 11 meters. Hardly practical.

Non-compound eyes comprise a great range of visual systems from simple "pit eyes" to more complex lens-bearing eyes which have evolved on at least seven separate occasions in vertebrates, cephalopods and others. In almost all animal groups one can find examples of simple eye spots or pits which consist of a small indent (allowing the angle from which light shines to be detected) filled with optic cells. These are in fact what gives the pit viper its name, which in addition to its regular reptilian eyes also has "loreal pits". These are simple pit eyes used to detect infrared and help in hunting and temperature regulation. An analysis in 1977 postulated that pit-like eye structures have evolved independently up to 65 times.

> *It is also paradoxically both one of the most **highly conserved** and yet **wildly diverse** senses in nature.*

That said, tracking the evolution of eyes in different species is notoriously challenging. The phylogenetically unrelated eyes of fish and squid are physically similar in a great many ways, while human and fish eyes are far more commonly related by evolutionary descent despite appearing distinctly different.

The former example of the fish and squid is what's known as convergent evolution, where similar or near-identical features evolve in species in different time frames, likely because the number of physical solutions of interpreting light as an image is somewhat finite. What is highly intriguing about vision is that while there is such variety in its structure and evolutionary history, there are also extremely ancient and highly conserved processes that underlie its development.

PAX6 is a gene that produces the Pax-6 protein. It is a transcription factor that is produced in the early stages of embryonic development. Transcription factors are proteins that activate many other genes by binding to DNA. PAX6 acts as a "master control gene" for the development of eyes. Where Pax-6 is found ectopically (in parts of an embryo where it ought not be), or found in greater amounts, it can lead to the growth of extra eyes. Humans containing two defective (mutant) copies of PAX6 develop conditions such as aniridia, where the iris fails to develop. PAX6 is found in almost all animal species and is highly conserved, meaning there is very little difference in the gene between species. A PAX6 gene from a mouse can trigger eye development in the common fruit fly, a species with an entirely different visual system of compound eyes!

Vision is a wonderful, complex, diverse sense with extremely old roots. The high conservation of essential genes like PAX6 across the animal kingdom highlights how ancient and fundamental vision is to the existence of life on Earth.

> *While there is such variety in its structure and evolutionary history, there are also extremely ancient and highly conserved processes that underlie its development.*

ARTWORK: YASMINE AND ZAZA, CLÉMENCE VAZARD

I BELIEVE THAT SCIENCE BENEFITS FROM DIVERSITY, BUT I MIGHT BE BIASED

Dave Warrell considers the need for a diverse range of voices and biases in the scientific community.

Modern science is the most successful way we have of gathering knowledge. I am willing to take a punt that most of the facts we know today are thanks to science. Before science, knowledge was largely based on religious texts and Aristotle. Thankfully, a series of brilliant minds developed the scientific method, to which we owe much of science's success. The scientific method grounds our theories in reality and promotes the idea of objectivity. In so doing, it aims to prevent things which we as humans are all too prone to, like bias and self-interest, from influencing what we know. Inevitably, there are times that bias creeps back into science; during this pandemic we have seen individuals falsify data for their own gain, to the detriment of science.

But science has an answer to this. If independent scientists think something is fishy, and cannot repeat the experiment and reproduce the results, the knowledge is called into question. 'Bias!' They cry, and the scientific community responds. Bias is once more tweezered out of our body of knowledge like the unwelcome splinter it is and, over time, it continues to be eradicated from the system. This way, no one scientist's bias can ever break science. It would require a biased system for us to be misled. Unfortunately, through no deliberate intention of any scientist, a biased system is exactly what we have.

This is the crux of the issue: people are generally unaware of their own biases. This is why a scientific method is important. But what if the vast majority of those who have ever contributed to science shared the same biases? These biases would not be obvious to most people generating and interrogating the results. So, while individual biases would be plucked out of science, the biases shared by the scientific community would remain in the system. And it just so happens that most of the people who have ever contributed to science are from a particular group: white men.

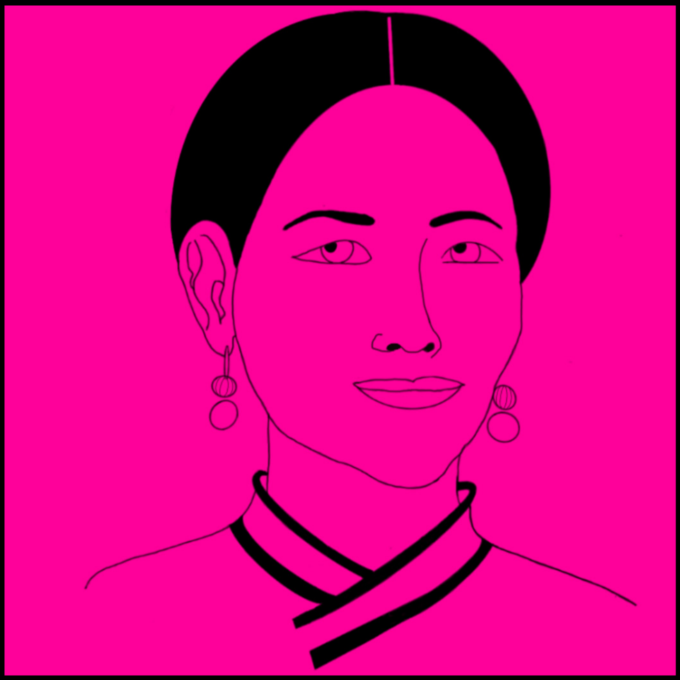
Now, I have no problem with white men - I am one. But the problem with any group dominating science is that their primary concern is unlikely to be representing the standpoints of others and, even when their intentions are to do so, they are limited by their own perspective on the world.

That is one of the many reasons that diversity is important. We need to bring different people with different biases to the table so they can identify and question the biases of others. All races, genders and cultures have their own opinions and own biases, so all need a say in directing and interpreting research for it to be truly unbiased. Especially when that science concerns them directly, and especially when those groups are those who have been least involved in science: the economically, politically, and socially disadvantaged.

A lovely idea, but can it actually translate into better science? Well, if you consider citations a marker of the quality of science, then a 2018 paper published in Nature Communications written by AlShebli, Rahwan and Woon shows that a greater diversity of ethnicity among authors of a paper correlates positively with citations. If you don't agree with that as a measure, how about revolutionising a whole field of study? Jeanne Altmann was a primatologist who, by redefining how we measure primate behaviour, brought the previously overlooked behaviour of female primates to light. She redefined behavioural ecology and it is certainly no coincidence that she is a woman. How about Malone Mukwende who wrote a medical handbook because he repeatedly found himself asking the question 'But what would this look like on dark skin?' Both individuals brought fresh perspectives, spotted biases, and acted on their observations to improve their respective fields.

There's little doubt (as little doubt as there can be in science, anyway) that diversity is important in helping to identify and ultimately reduce bias. If we take science to be the ultimate quest for the truth, there's no way of reaching the finish line without a diverse range of views to guide the way. So, what can we do to increase diversity?

We need to exclude a different set of biases. Biases don't just exist in scientific research. I have them, you have them, research group



ARTWORK: THE UNDERDOGS, RHIAN DAVIES

If we take science to be the ultimate quest for the truth, there's no way of reaching the finish line without a diverse range of views to guide the way.

leaders and those sitting on admissions and funding committees have them. Everyone in a position of power in science (and the world at large, but I need to pick my battles) needs to educate themselves on identifying their own biases, accept that diversity is a positive thing and set about achieving it. Wanting diversity is not enough – it has to be actively pursued.

That's all very well, but how can scientific leaders actually do this? As you may have worked out, I am neither a scientific leader nor under-represented, so I am not the voice of authority here. But *Nature* and *Scientific American* have collaborated on a number of articles this year entitled 'Achieving Diversity in Research.' I encourage all of you, especially those in positions of power, to look the collection up and take some time to reflect on what you could be doing differently. Every article provides valuable advice, or at the very least insights into the barriers faced by underrepresented groups in science.

So, much like the scientists we credit with the scientific method, we find ourselves acknowledging science's potential but getting frustrated by bias. Thanks to them, we know how to act. We need to create a method for excluding our biases. The first rendition of the method won't be perfect. But it will be employed and moulded over time, subject to revisions , all with the end goal in sight: eliminating bias from science.

We need to bring different people with different biases to the table so they can identify and question the biases of others.

FUNGI: A CASE OF DR JEKYLL OR MR HYDE?

Freya Bolton discusses the vastly divergent roles that various types of fungi play, from beneficial to pathogenic.

Fungi can be found everywhere, playing a huge role in the dynamic web of interactions between organisms great and small. They may be tiny, but they are without a doubt important. I am sure you have all heard of penicillin, the antibiotic derived from the *Penicillium* fungus accidentally discovered by the great Scottish scientist Alexander Fleming. It is one of the most common antibiotics used to date. Although this fungus has saved millions of lives and has even been ranked as one of the most important discoveries of the millennium, not all of its relatives are benign. The number of fungal species has been estimated from anywhere between one to more than five million and, although only 300 have been identified as being pathogenic, the effects of these organisms can be catastrophic.

The UK government has recently banned single-use plastics, but who would have thought a fungus might be one of the solutions to this problem?

There is one in particular, called the chytrid fungus, that causes an infectious disease in amphibians. This pathogen, *Batrachochytrium dendrobatidis*, was only discovered less than 30 years ago, however, it has already been detected in over 500 species of amphibian globally. It has also been responsible for the decline of more than 200 of these species, even causing extinctions, such as that of the Costa Rican golden toad. The fungus embeds itself in a frog's skin and breaks down the keratin in it, which is a key structural protein forming amphibian skin and mouthparts. The animals respond by thickening their epidermis, but this affects their gas exchange and water and salt balance; a salt imbalance can lead to a cardiac arrest. This deleterious disease has a 90% mortality rate and has contributed to the disappearance of 50% of amphibian species in affected areas.

How did this fungus spread globally? In the 1930s, African clawed frogs started to be exported around the world, not by the pet trade, but by the medical industry. Researchers found that if the urine of a pregnant woman was injected into a female of this species it would ovulate within 12 hours, making an efficient pregnancy test. This discovery meant that demand for these amphibians increased massively, and they were shipped across the globe. Unbeknown to the researchers, these African clawed frogs carried the deadly chytrid fungus, which was identified 50 years later in Costa Rica. However, there has been new research suggesting that frogs are showing resistance towards the disease. There might be hope after all.

Fusarium oxysporum is another pathogenic fungus that is a cause for concern. Scientists are still trying to find a way to prevent the fungus from destroying bananas, the UK's favourite fruit. A wilting disease was reported in Australia in 1876, and then again in plantation crops of Panama and Costa Rica 14 years later; the causal soil-borne fungus was only discovered in 1910. Over the years, only a few banana clones have been developed into global commodities, including the Cavendish banana, which today accounts for 99.9% of bananas traded worldwide. The development of this monoculture has negatively affected the banana industry, which is worth $30 billion a year. Low genetic diversity has resulted in a lack of natural resistance in this population, so this fungus has had devastating effects on banana plantations. After receiving $10 million from investors, researchers are starting to use gene editing techniques to create a hardier version of the Cavendish banana. It's interesting to think this could all have been avoided had the genetic diversity of bananas not been diluted.

However, while the above are examples of the minority of fungi that cause disease, there are several species that can be used to benefit other animals. Honeybees are central to sustaining our future, they are the main pollinators for plants across the world. A staggering 14 million flowers are pollinated per day by a single beehive. Nevertheless, it has not been easy for these creatures. They have faced the deformed wing and Lake Sinai viruses, infestations of Varroa mites, and deadly pesticides sprayed on crops; eight species of bee have been added to the endangered list as a consequence. But all is not lost, as new research has found some salvation for bees. A mushroom extract fed to bee colonies showed a 79-fold reduction in deformed wing virus and a 45,000-fold reduction in Lake Sinai virus. Both parasites are found at high levels in bee populations that have had a colony collapse, so this fungal medicine will give declining populations a chance to rejuvenate.

Another huge global issue is plastics, whose exposure was heightened by the BBC programme *Blue Planet II* in late 2017. Since the 1950s, humans have created more than 8.3 billion tons of plastic of which only 9% has been recycled. Additionally, 73% of current worldwide beach litter is plastic. As a consequence, plastic is killing more than 1.1 million seabirds and animals every year. The UK government has recently banned single-use plastics, but who would have thought a fungus might be one of the solutions to this problem? A publication from the Royal Botanic Gardens at Kew reported that scientists have identified a fungus that is able to break down plastics. It has the potential to revolutionise recycling and to help address the conflict between the environment and this cataclysmic waste.

Fungi are a diverse group of organisms. They can cause members of ecosystems to thrive or struggle. Some species can be small wonders of the world, such as the fungal medicine for bees, but others, like the deadly chytrid fungus in frogs, can be catastrophic for the survival of wildlife. Although tiny, they surprise us every day with the secrets that scientists reveal.

The number of fungal species has been estimated from anywhere between one to more than five million and, although only 300 have been identified as being pathogenic, the effects of these organisms can be catastrophic.

ARTWORK:
BACKGROUND:
FORMULA SEQUENCE PROCESS,
AUDREY AGUIRRE
FOREGROUND:
LICHEN, MICROSCOPIC PHOTO,
PATRYK STARZYKOWSKI

"Apparently theres only so much diversity an old white male scientist can take"

cartoon

By Ariana Loehr

INSIDE THE KALEIDO-SCOPE OF SCIENCE-ART

Ushashi Basu delves into the fascinating realm where science and art meet.

Many online dictionaries (because does anyone refer to real dictionaries anymore) and free online encyclopaedias will try to define "art" for you. They will tell you that art is a simple range of human activities that involves creating things.

But is it really that simple to define art? Is it so easy to confine art into one sentence?

Art, in all its forms, draws humans in and exposes a part of us that is not always visible. Art lets us interpret and explain. Art lets us appreciate and understand each other, and gives physicality to our strangest thoughts. Jodi Picoult, in her new book *The Book of Two Ways*, says "[art is] anything that manipulates our emotions." Art possesses the immense capacity to communicate ideas and concepts we wouldn't normally be able to express or explain. Art charms the soul in a way something like science cannot.

The varied forms of artistic expression allow us to take just about any scientific concept and project it onto something that engages the public and gives them the ability to retain information in a unique way.

Consequently, this opens up a multitude of ways complex subjects in science can be communicated through art. The varied forms of artistic expression allow us to take just about any scientific concept and project it onto something that engages the public and gives them the ability to retain information in a unique way. Science and Art by themselves are finite, restricted. But their amalgamation allows to reach new, uncharted territories in terms of understanding the world and widens our perception of everything around us.

The forms of artistic expression we use to communicate and popularise science are incredibly diverse and are actually all available at the tip of our fingers. Type 'science-art' into your Google search, and you will be showered with pages that list science artists and sci-art work that we absolutely need to take a closer look at. This list is endless, ranging from Matthew Gardiner's "Oribotics" – origami and robotics – to silk tapestries of sounds in the ocean, meticulously embroidered by artist Lindsay Olson. Would you like to visit an exhibition which displays the intricacies of the bone structure of humans and cows? Sci-artist Ross Quesnell is your guy. If you want to visualise the boundaries between time and space, and actually look at reality, Fabian Oefner has got you. Oefner works with hyperrealism, creating renditions of moments in time that almost didn't exist. For example, in his "Disintegrating" series, he photographed every piece of an exploding car and then rearranged them into one photograph, creating an image of a moment no one actually witnessed.

The "Illuminating the Self" exhibition which opened in January 2020 involved science artists, Susan Aldworth and Andrew Carnie, creating mixed media art installations to engage the public in discourse about epilepsy and the use of technology in the brain. This was part of Newcastle University's CANDO project which aimed to create tiny, light sensitive brain implants for preventing seizures. Jiyong Lee will be more than elated to use carved glass to explain cell division to you. Slovenian new media artist and ex-researcher Špela Petrič creates plant-human hybrid entities, and works towards understanding plant emotions and creating connections with them using state-of-the-art technology. I could go on and on about the myriad of techniques science artists have used to convey scientific knowledge to the public while also sharing their talent and finesse with the world. This only reinforces the fact that an artistic approach to science has incredible potential to shape the way science is communicated in the 21st century, and hopefully thereafter.

The expression of science through art doesn't stop with exhibitions and elaborate artwork. Science is found in theatre and in acclaimed plays such as *Arcadia* (1993) and *Life of Galileo* (1938); science can also be found in poetry and metric verses dating back to the 5th century. Science busking events, poetry slams, and even science music video competitions bring scientists and communicators from across the world to present their science in the most exclusive way possible. Let's not forget the "Dance your PhD" competition, sponsored by the Science and the American Association for the Advancement of Science (AAAS), which encouraged scientists and doctoral students to turn their PhD theses into dance routines. Another, albeit more subtle, form of science communication through art is taxidermy. In carefully crafting animal models to resemble the living animal to the highest degree, taxidermists combine their nimble artistic skills with their knowledge of anatomy.

The human imagination is capable of accomplishing anything it wants to, and art and science are both examples of it. They're both only as vast as we want (or need) them to be, and so much is yet to be discovered, invented, and created. By bringing them together in these diverse ways, sci-artists have not only given us the opportunity to expand our knowledge in a limitless manner but also emotionally connect with the knowledge. It's almost like looking through the funkiest kaleidoscope you've ever seen: it presents itself in different ways every time you look inside. In an age consumed by the lifelessness of the internet, an artistic outlook could prove to be the most organic method of not only transmission and dissemination of information, but of staying in touch with the humane side of things, as Ursula K. Le Guin once said.

ARTWORK: ROWAN AFFLECK

THE SOUND OF SCIENCE

Gemma Ralton examines the use of bioacoustics in biodiversity conservation.

We are on the brink of a sixth mass extinction. The once rich, biodiverse forests of our natural world are being transformed into an eerie distressing silence.

With up to a million species at risk of disappearing within decades, biodiversity concerns represent a hot topic in the scientific community. Human activity has caused the loss of hundreds of animal and plant species at an alarming rate as a result of deforestation, urbanisation, hunting, and over-fishing.

Similarly, the impacts of climate change on species and ecosystems are already beginning to materialise. Catastrophic forest fires, mass bleaching of coral reefs, and extreme weather events have already impacted the natural world and are predicted to rise in frequency. It is forecasted that up to 50% of species will lose their suitable habitat conditions under the highest greenhouse gas emissions scenario.

Aside from climate change, the current COVID-19 pandemic is impacting the world's biodiversity and our ability to protect it. Field and lab work have largely shut down with consequences for teaching, data collection and networking that are still unclear.

In the face of these urgent challenges, scientists have searched for alternatives to replace the need for human presence in the field, yet still allow for proper documentation and conservation of biodiversity. Enter, the field of bioacoustics…

WHAT EXACTLY IS BIOACOUSTICS?

In recent years, the development in artificial intelligence, data storage and audio recorders have converged to make sound a powerful tool for ecological research. Bioacoustics, otherwise known as ecoacoustics, uses animal sounds as signals of ecosystem health, or cues and proxies for biodiversity. It is an interdisciplinary field, combining biological and acoustic sciences and using sound technologies to store, record and analyse large collections of animal communication data.

Bioacoustics, otherwise known as ecoacoustics, uses animal sounds as signals of ecosystem health, or cues and proxies for biodiversity.

Traditionally, the processes involved in how and why animals communicate, including methods of sound, have long held a great fascination for scientists. Fundamentally bioacoustics is based on two key hypotheses with the first being the 'acoustic niche hypothesis' which suggests that sound diversity might reflect biodiversity. For instance, each organism develops an independent signal, unique from other species and through which it can be identified by, to avoid competition. Second is the 'acoustic adaptation hypothesis' which suggests animals evolve distinct calls that best travel across their particular habitat, giving each habitat its own unique footprint.

HOW EXACTLY COULD BIOACOUSTICS AND MONITORING SOUNDSCAPES HELP WITH REGARDS TO BIODIVERSITY CONSERVATION?

A soundscape is a sound or combination of sounds that arises from a particular environment. In general, tracking species and monitoring the diversity in a particular ecosystem can help scientists understand how environmental changes are disrupting the ecological connections among species and, therefore, can enable ecologists to create better plans for nature reserves and conservation efforts in the future. Bioacoustic recording stations would enable conservationists to figure out how species' reproductive patterns are changing in response to weather and climate alterations by locating specific sounds in the soundscape such as breeding calls. Similarly, scientists can also isolate human generated noises, establishing the sources of noise and how this affects a particular species.

One example of where this technique is becoming increasingly popular is in bird biodiversity research. The monitoring of birds comes with many challenges. For example, their fear of humans, ability to camouflage, rare occurrence, and their use of protected areas that are difficult to access all impose great challenges to scientists. Therefore, bioacoustics offers an excellent opportunity to study birds, combatting these issues.

A great example of where bioacoustic monitoring has been revolutionary to bird research is in the monitoring of the Cory's Shearwater species that are most detectable at night and breed on inaccessible cliffs and in remote areas. Their distinctive calls make sound a useful proxy for monitoring the species, particularly in identifying the striking differences between the males higher pitched calls compared with the females low and raspy voice. The vocal monitoring of these birds and of other species too can help to understand the seasonal concentrations and movements during migration too, providing an insight into what features are particularly important for migratory species.

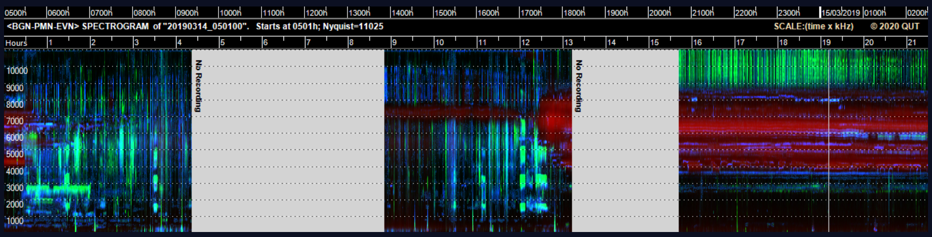
BIOACOUSTIC MONITORING AND CLIMATE CHANGE

Interestingly, bioacoustics can also be used for purposes other than measuring species biodiversity, for example in measuring the indicators of climate change. For instance, increasing global temperatures can cause drastic changes to ecosystems including the melting of glaciers, increases in extreme weather events and increased disease risk. Such biotic and abiotic effects of climate change can also affect environmental acoustics and thus the communication between animals. This in turn can lead to changes in entire soundscapes and affects biodiversity.

Birds represent some of the most important indicators of climate change, particularly in tropical ecosystems. While bird songs offer some of the most beautiful sounds to listen to, their singing has a purpose, such as attracting a mate or establishing their territories. As the climate gets warmer, there will be increasing pressure on birds to advance the time of their breeding to earlier in the seasons. This can be monitored through listening to the birdsongs, which should crescendo up towards the loudest peak of the mating season. By monitoring these sounds, scientists can help deduce patterns occurring as a result of climate change, not only in birds but in other animals too.

Research Spotlight: Jenna Lawson

Jenna Lawson, PhD researcher at Imperial College London, uses acoustics to better understand the ecology of the spider monkey and the threats to this species. Through her findings, she was able to create an immersive audio-visual experience, journeying from biodiverse forests, untouched by humans, to disturbed plantations of palm and teak, where a haunting silence exists due to the loss of life as the natural forest ecosystems are removed. She hopes that her research, combined with land-use data, will help to design biological corridors and management plans to help conserve the spider monkey species.



Another example of where soundscapes are proving a useful tool is in the monitoring of oceans, particularly in relation to ocean acidification. This occurs as a result of increased CO_2 in the atmosphere, which is subsequently absorbed by oceans. As oceans become more acidic, the sound absorption is reduced, meaning both natural and anthropogenic sounds will travel further. Many marine species, such as larval fish, are thought to rely heavily on sensory cues to avoid noisy reefs that indicate the presence of predators. Therefore, monitoring acoustic communications between marine species, including marine invertebrates, fishes, and whales, will help to explore how species are responding to these changes in ocean salinity and therefore how they are impacted by climate change.

By monitoring these sounds, scientists can help ***deduce patterns occurring as a result of climate change,*** *not only in birds but in other animals too.*

A world without the diverse calls, songs and sounds of the natural world seems a devastating thought. Thankfully, more research using bioacoustics is beginning to take shape all over the globe, providing promising solutions for standardised long-term automated monitoring of animal populations, particularly those most threatened by extinction.

ARTWORK:
RESONANCE, OIL ON CANVAS, SHIVANI MATHUR

BACKGROUND:
24-HOUR SOUNDSCAPES, JENNA LAWSON

IT'S ALL GREEK TO ME...OR IS IT?

Alexia Yiannouli explores the origins of scientific language, and how it has changed throughout history

The language of science has undergone many changes throughout the ages. Aristotle's findings were written in Greek, Newton's in Latin, and Einstein's in German. Regardless of which language has been used over time to dominate scientific research, it has always been implied that there should be a dominant language. A language which could function as a unifying force, and allow for the widespread exchange of scientific knowledge and ideas. But could this homogenisation of language be making science more exclusive, rather than more accessible?

Many believe Latin and Greek to be the roots of scientific language, with the word 'science' even originating from the Latin '*scientia*' meaning knowledge and expertise. The roots of scientific language can be traced even further back to the hieroglyphs of Ancient Egypt. It wasn't until the late Medieval period, during the 13th and 14th century, when Latin took charge as the universal language of science. During its reign between the 15th and 17th century, scientists operated bilingually, using their native languages for more casual discussion with their peers, and Latin to communicate their discoveries to the wider scientific community. Galileo Galilei was a pioneer of this practice, publishing his work first in his native Italian and subsequently translating it into Latin, so that more people could read it.

By the early 20th century, German had taken over as the dominant language of science. However, societal opinion of the German language was drastically altered by the events of the First and Second World Wars. As a result of the negative connotations associated with the language, this infiltrated into people's opinion of German science, with many post-war European countries banning German scientists from attending international conferences. English and French then became the prevailing modes of communicating scientific research on a global scale. This anglicisation of science represented the emergence of English as a lingua franca; a language used to enable communication between people who do not share a native language. It demonstrates how sociological, political and historical factors have worked together to shape the language of science. The language we refer to as 'English' is evidence of this, created and shaped from a hodgepodge melting pot of many linguistic origins.

A lingua franca can make knowledge and information accessible to more people, and it can also diversify science by uniting scientists and promoting the exchange of scientific research and ideas across a much larger platform. Such accessibility would not be possible if science were communicated globally in a multitude of different languages; it would likely complicate the transmission of information. However, whilst there is clear justification for having English as science's predominant language, it must also be recognised that a lingua franca can also drive science towards being more exclusive and dismissive of certain knowledge.

Consider scientists in non-English speaking countries; they might be conducting excellent research, but how can their findings be shared with the world if they cannot be translated? This could be even more prominent in developing countries, where English might not be so easily spoken. How much scientific knowledge is going unnoticed because researchers cannot access the language they need to tell the rest of the world? The problems of having one language predominate in science was effectively demonstrated by a 2004 article on Avian influenza, which was published in a small-scale Chinese veterinary journal. The report remained largely undetected by the global scientific community, until Avian influenza began to spread to other parts of the world. In fact, it was not reported globally until six months after it was first published; despite the original journal calling for urgent attention of the infectious disease spreading rapidly across most of southeast Asia, resulting in the culling of millions of chickens.

> Language should serve to break down barriers, not build them.

This demonstrates how an inaccessibility to English can make it difficult for scientists to display their knowledge on a global level. Across the world, native English speakers are a minority. It is estimated that less than 20% of the global population can speak English, and only 5% of those can be classed as native speakers. Scientists whose first language is not English might encounter more difficulties with articulating their findings, even in translation. Errors still happen - some things just don't translate as intended, and the process of translation isn't fool proof. But although these mistakes should be acknowledged, they should also be apprehended with less criticism, especially of minor linguist errors in scientific texts. So long as the science is sound and displayed well, we can surely can let the odd spelling mistake or grammatical error go? As a result of these problems that have been outlined, the research of non-English speakers is at constant risk of going unrecognised, remaining concealed by the mother tongue it was discovered in. This limits the diversity of the voices heard within the global scientific community, and ultimately begs the question: should someone's linguistic capability be of detriment to their scientific advances? We must therefore consider the extent to which English, functioning as a lingua franca, might limit scientific knowledge and the global communication of ideas.

So, what can be done to address this gap in diversity? There are many barriers to consider and overcome in order to increase diversity within the scientific profession. Although language is just one of those barriers, it is one of the main ways we are able to communicate ideas and knowledge to other people. If there was not such an over reliance on English, scientists - and communities in general - could hugely benefit from making an effort to learn other languages. There would be more scientists able to translate content for those whose research might not otherwise have been published, and people might even learn a thing or two about other people's cultures and ways of life. Language should serve to break down barriers, not build them. The language you speak should not be a disadvantage to your science, especially not for the sake of a slip in syntax or a simple spelling mistake.

The research of non-English speakers is at constant risk of going unrecognised, remaining concealed by the mother tongue it was discovered in.

ARTWORK: PATRYK STARZYKOWSKI

QUEER NATURE

Jay Balamurugan sheds light on how the natural world is intrinsically queer throughout history.

Nature is queer, in every conceivable sense of the word. No two ways about it – the natural world is filled to the brim with examples of entirely unconventional biology, stretching the limits of our imagination. Using the term *unconventional* in this context is perhaps a little too anthropocentric. We as humans view the world through an extremely specific lens – one that has been restricted by centuries of societal dogmas, cultural constraints, and biological limitations. This has resulted in a false understanding of what nature *is* – and what nature *can be.*

Let us whittle away at this concept. Human understanding is inherently a little flawed. We want the world to conform to our standards and fit neatly into our pre-assigned boxes. When the world does not quite fit those standards or fit as neatly as we might like, we often push it to do so, and in turn cause harm. We force square pegs into round holes, breaking off the edges because we refuse to see them.

Nature is queer, and we have been far too blind to it. For the longest time the natural sciences have been conducted in an overtly heteronormative manner – resulting in widespread belief systems centred around the notion that all life is entirely binary. It is only recently that science has opened its doors to a brighter, more vivid world; one bursting at the seams with incredible diversity and unbelievable oddity.

Bonobos? Entirely, unequivocally, no-doubt-about-it, bisexual. Yes, every last one.

I have maybe been a little abstract thus far. What exactly am I talking about?

I am talking about gay penguins.

And gay giraffes. And intersex dogs. And transgender lions. And bisexual bonobos. And asexual pythons. And sexually-fluid frogs. And, well, an uncountable number of other fantastically queer creatures across the breadth of the animal kingdom and beyond.

Colonialist, heteronormative science has turned a blind eye to these facets of our world, not just across our own species, but across those of every other. Case in point – some of the first scientists to traverse the Antarctic in the early 1900s refused to report their findings of, in their words, 'sexually depraved' penguins, because it did not quite fit their worldview, and their findings have only recently been unearthed. You would think this was a direct consequence of its time – but even to this day, queerness in nature is still regarded as anomalous. Researchers have been made to defend their findings – for instance, that male lions will court and have intercourse with each other to strengthen social bonds, and that female lions can grow manes and take on masculine pride roles – against bigoted individuals with few reasonable counterarguments. Continuing across the savannah, hyenas are even more inclined to engage in same-sex pairings – females have pseudo-penises which are used to mount individuals of both sexes, and this behaviour is known to establish hierarchal positions within a pack. And of course, we absolutely cannot ignore gay giraffes because up to a whopping 90% of sexual intercourse engaged in by males was with other males. Primate research has stirred up even more controversy due to their nature as our closest relatives. Bonobos? Entirely, unequivocally, no-doubt-about-it, bisexual. Yes, every last one.

We do not have to delve into the exotic reaches of deep jungles or vast savannahs to find ourselves more examples of this. Animals we interact with on a regular basis can be just as queer. A quarter of all black swan pairings are gay. Pigeons have been seen regularly forming same-sex pairings and incubating abandoned eggs together. Domestic sheep have so much gay sex that farmers have had to separate them to get them to breed with individuals of the opposite sex. The oldest tortoise in the world, a 188-year-old gentleman named Jonathan, was found to have been mating with another male tortoise for at least 25 years.

Here is the real kicker – this is *barely* the tip of the iceberg.

We have only just begun covering a few select examples across a massive, multi-layered spectrum of sexualities present across the animal kingdom. Over 1,500 species have been seen to express non-heterosexual behaviour. We have yet to even explore chromosomal and hormonal sex, gender, reproductive behaviours, non-sexual social bonds, and fluidity across all of the above. Reptiles, amphibians, and fish have all been seen to switch sexes when the environment favours it. Some do not even need a member of the opposite sex to reproduce, as was the case when a 62-year-old python laid a clutch of eggs at the St. Louis Zoo just a couple of months ago having not seen a male in well over a decade. There are invertebrate species which have entirely different sex chromosomes between *individuals*, instead of between sexes. These are only a few examples of how far evolution will push biology when it is advantageous to a species – and that is just within the animal kingdom.

Want to get really, *really*, out there?

Fungi have up to *36,000 different sexes.*

If the world is truly this diverse, why are these facts not more commonly known? Why are these incredibly common instances of queer behaviour still regarded as anomalous? A lot of our recent history has been marred by prejudice and bigotry, and that spills over very readily into science – I imagine I do not need to expand on this an awful lot further for examples to pop into your mind. So much of this hate and cruelty has been justified by the notion that queerness is unnatural. It is not. Queerness is a fact of life, as natural as the earth beneath our feet, as natural as the cosmos up above. As much as it is in every other form of life as it is in humanity. Were it to have had a detrimental effect on any species, it would have been long eliminated by ways of natural selection. At the end of the day however, it does not, and should not matter. Natural or unnatural, queerness is not something to be feared and hidden away. As we understand it through decades of evolutionary science, diversity across all boards only serves to strengthen a species – and this lesson is one we should take in stride for our own betterment.

Nature is queer, and it is about time we embrace that.

ARTWORK: RHIAN DAVIES

It is only recently that science has opened its doors to a brighter, more vivid world; one bursting at the seams with incredible diversity and unbelievable oddity.

the original communicators

Fatima Sheriff reflects on the often-overlooked but vital roles that women have played in scientific research, education, and communication.

> *"Sir Venkatraman Ramakrishnan, who has just handed over the presidency of the Royal Society to Adrian Smith, was the first non-white leader but, as yet, no woman has held the post."*

In the 17th century, The Royal Society was founded, an elite organisation seeking to fulfil Francis Bacon's idealistic view of science. Its presidents were aristocratic thinkers from architect Sir Christopher Wren to Sir Isaac Newton to Sir Ernest Rutherford. Revolutionaries no doubt, but all men. Sir Venkatraman Ramakrishnan, who has just handed over the presidency of the Royal Society to Adrian Smith, was the first non-white leader but, as yet, no woman has held the post.

In 1902, Hertha Ayton applied for a fellowship, but it wasn't until 1945, a staggering 285 years after its foundation, that a female Fellow was accepted (not counting Queen Victoria). Though prestigious in reputation and contributing enormously to the discussion and publication of radical new ideas, The Royal Society is an example of how until recently, Western science excluded women from recognition.

Women generally had no access to formal academic education; they often had to teach themselves, alongside other duties, and, in turn, teach others. But a few icons paved the way for early science communication.

Growing up in an academic, intellectual household in the 1770s, Jane Marcet benefited from her brothers' tutors and textbooks. When she was 15, her mother died and she took over running the household, hosting her father's intellectual guests. In 1799, she married a doctor, who became a lecturer and a Fellow of the Royal Society. Her interest in chemistry was piqued alongside his, and they set up a home laboratory. Her skills as a hostess were extended to visitors of the Society, and she was able to attend talks and lectures.

Having proof-read her husband's work and made the most of her access to cutting-edge scientists, Jane decided to write her own series of books, *Conversations*, covering topics from economics to botany to chemistry. Through the scripted exchanges between a teacher, Mrs B, and her students, Marcet explained scientific knowledge of the time, like the works of Humphrey Davy, accompanied by her own drawings of equipment.

With *Conversations on Chemistry* subtitled *Intended More Especially for the Female Sex*, her down-to-earth approach was aimed at women and children who didn't have specialist knowledge. The attitude of Mrs B mirrored what Marcet's upbringing must have been like; although her parents didn't believe women could be innovators, they insisted their children be well-versed in many fields. In writing out these teacher-student conversations, Marcet enabled others to experience the same respect and access to higher learning. The audience was there, a popular periodical called *The Ladies Diary* or *The Women's Almanak*, which ran from 1704-1840, specialised in engaging women with maths through puzzles. However, most contributors were men, ironically using female pseudonyms, like 'Ann Nichols'.

Marcet's ability to translate complex ideas and break through the jargon appealed to a wide audience, including a young Michael Faraday. *Conversations in Chemistry* became one of the first elementary level textbooks, was reprinted 16 times, and, from the 12th edition in 1832, was printed under her own name. Decades later in Henry James' novella *The Turn of the Screw* (1898), the books are mentioned by the central character as standard texts. Marcet understood the value of dialogue between laypeople and experts, and how the connection between the two is the best way to build a bridge for those without access to higher education.

Born a year earlier than Marcet, in China, Wang Zhenyi was raised in a similar way, encouraged by her elders in a household full of books. She lived in a society where women were considered inferior, but was undeterred in her pursuit of knowledge. Teaching herself, she became accomplished in several fields. On learning maths, she said: "There were times I had to put down my pen and sigh. But I love the subject, I do not give up." She wrote articles simplifying concepts like Pythagorean theorem and when she mastered Mei Wending's book at 24, she rewrote it in simple language as *The Musts of Calculation*, so anyone could learn the basis of multiplication and division.

Wang Zhenyi's contributions to astronomy were brilliant yet simple, explaining the movements of celestial bodies to show how equinoxes and eclipses occur. For the latter she devised an experiment, using a table as a globe, hanging up a lamp as the sun and moving them according to her knowledge of orbits to show how the light could be blocked. Alongside these, she was a skilled equestrian and also wrote iconic poetry, inspired by her travels and her opinions on gender equality. Though she died at just 29, her contributions are celebrated and in 1994, a crater on Venus was named after her.

Both of these science communicators highlighted the importance of at-home science, of the everyday inspirations of genius. The German scientist Agnes Pockels, born later in 1862, and limited by her circumstances, did this to an even greater extent. She desperately wanted to study physics like her younger brother, but women weren't allowed in universities and she had to care for her elderly parents. Her brother passed on as much knowledge as possible and she learnt with what she had in her kitchen.

In doing the washing up, Pockels became fascinated by soaps and oils, and their interactions with water. She made her own equipment, the Pockels trough, to examine these, and began observing the surface tension of water under different conditions. The English scientist Lord Rayleigh was observing similar phenomena so, encouraged by her brother, she wrote to him with her findings. Rayleigh was so impressed, he had the letter translated from German and published in *Nature*, encouraging her to keep writing. Several of her papers were published and, although her parents' health and the war prevented her pursuing her field, the Pockels trough was invaluable for the studies of Irving Langmuir, who won the Nobel Prize in Chemistry in 1932. Commentators at the time said: "Part of his achievement was thus founded on original experiments first made with a button and a thin tray, by a young lady of 18 who had no formal scientific training."

Science communication has since flourished as a field, and its importance is becoming more globally recognised. The stories of these women show how fundamental it was for people without training to gain access to knowledge, to help them perform science without specialised equipment, and how simplifying the entangled, supercilious mess of academia uplifts future generations.

ARTWORK: LUCY LIPSCOMBE

SCIENCE BEHIND

Alienor Hammer reveals how two artists have closely linked scientific

This artwork seeks to highlight the issues in the Amazon. Titled 'Dance the Amazon,' it seeks to weave together the natural and man-made elements that can be found in the rainforest. Through this, the artist, Laurane Le Goff, wanted add depth and meaning to clothing.

In February 2018, Laurane took part in Labverde, a residency mingling science, art and environment. She spent eleven days in the Amazonian rainforest surrounded by an international and professional team composed of scientists, curators, and 17 other artists from all around the world. By observing the colours, structures, and the abilities of lichens on trees, she realised that the symbiosis seemed to reflect nature's fragile balance and that the natural processes were completely interconnected, noticing the different cycles in the rainforest.

As an example, water, which is essential for life, is recycled time and time again, creating different cycles in the rainforest. Indeed, as heavy rain falls, the water is intercepted by the trees' branches or absorbed by the roots. As the day goes on and the temperature increases, the water evaporates, contributing to the following day's rain. This water recycling process is known as convectional rainfall.

A damaged fishing net, found in the Anavilhanas National Park, made Laurane realise that it was part of those same cycles and became a representation of the various flows it went through in this complex ecosystem. By embroidering lichen patterns to repair it and using the topography of the Adolfo Ducke Forest Reserve (near Manaus) as a lining pattern, she intended to highlight the interplay of issues found in the Amazon. Designed as a random pattern, the embroidery connects the industrial, the recycled, and the handmade, to find a new meaning for the creations that we wear.

CLOSE UP OF THE PIECE, AUGUST 2018 - NOVEMBER 2018, LINEN VEIL, DMC COTTON THREADS, WATERCOLOR, DAMAGED FISHING NET.

THE ART

concepts in their respective work.

In this piece entitled "Dirty Money", the artist, Molly MacLeod, wanted to show how diverse we are as individual beings. Our physical bodies both unify us through our related experiences and also represent our immense diversity as individual beings. Each of us has our own unique biological imprint, leaving traces of ourselves wherever we go. With the Covid-19 pandemic, we are more aware than ever before of these traces we all leave behind.

In early January 2020, before the realisation of a global pandemic, Molly designed a public engagement project at TATE Gallery, London. Participants were asked to play with coins that triggered sounds when touched, composing their own exclusive soundscapes. Hundreds of individuals touched the coins, each leaving their unique set of bacteria behind. She then swabbed each coin and cultured the bacteria present to create a new collaborative artwork, where each individual participant contributed a piece of themselves to the final outcome of the piece.

Recent research at Howard Hughes Medical Institute shows that skin bacteria found on keyboards and computer mice could help identify who used those objects, and maybe one day help in forensic evidence. This research, along with Molly's artwork, demonstrates just how diverse and complex the human microbiome is.

BOOK REVIEW

Fatima Sheriff reviews Why I'm No Longer Talking to White People About Race *by Reni Eddo-Lodge.*

Based on her essay that captivated the nation, Reni Eddo-Lodge's *Why I'm No Longer Talking to White People About Race* is a thought-provoking read that highlights the relationships connecting race, gender and class.

From the beginning, the title empowers black readers to recognise their ability to set healthy boundaries in order to avoid exhaustion and its provocative honesty presents an attractive challenge for readers to confront the realities of racial inequality. So often in our media and workplaces, black people are deputised as spokespeople when it comes to issues of race. As the title points out, there needs to be more recognition of the fatigue it causes to shoulder the representation of an entire community. Social justice is a joint effort, not a burden to be shouldered by the oppressed alone.

Building up with important history and covering everything from class to feminism, this book is an introduction into understanding how these intersect with race. For those with limited understanding of these societal dynamics, Eddo-Lodge's book is concise but uses key British examples UK readers who only associate racism with America need to hear about. It's a national conversation, being amplified by the likes of historian David Olusoga and filmmaker Steve McQueen in his *Small Axe* series, but this is an excellent starting point.

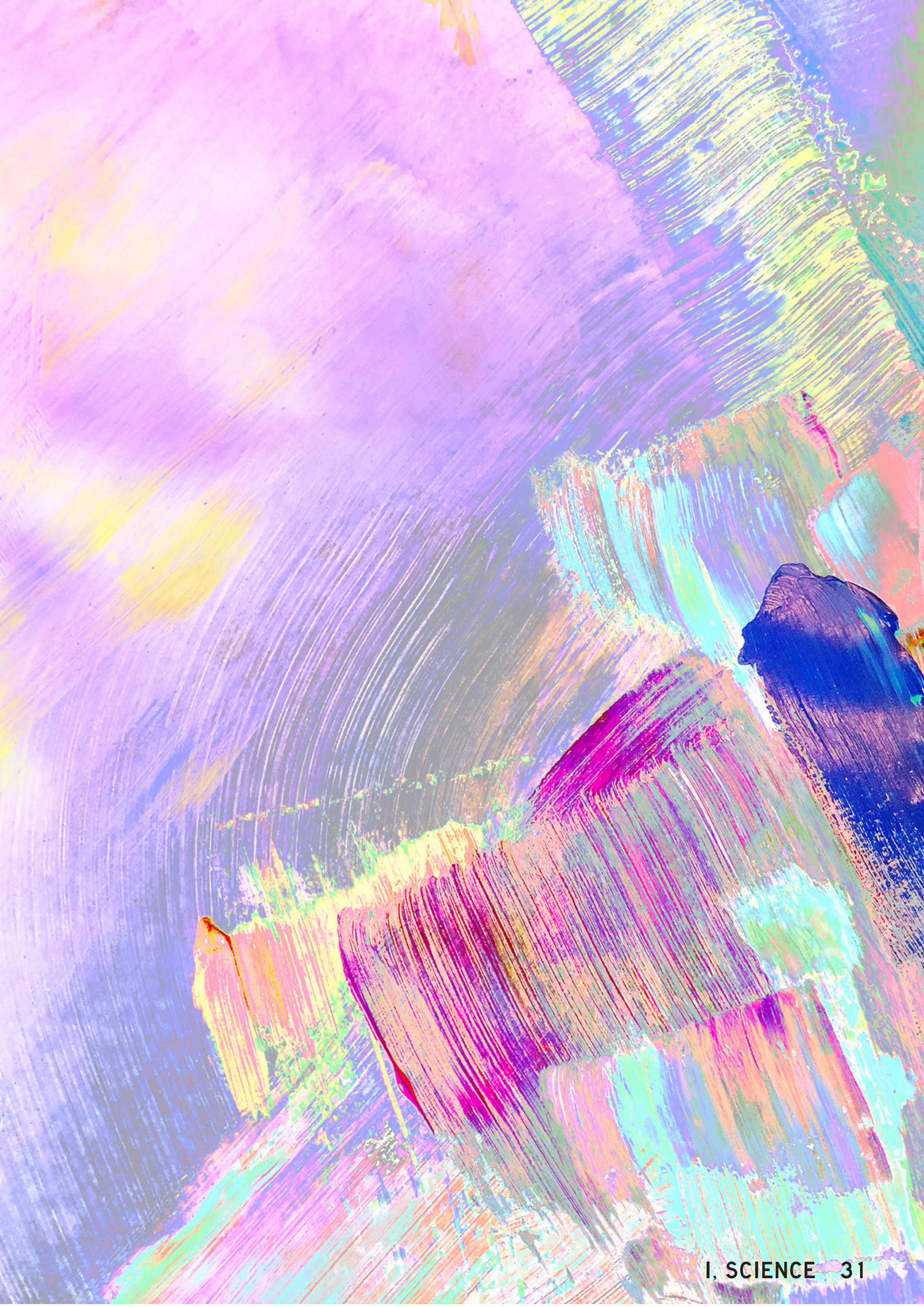
Alongside the historical cases Eddo-Lodge sheds light on, we hear about her own experiences as a writer and spokesperson talking about these issues. The personal touch makes the book more memorable and for the readers of this magazine, who are likely to live in London, the later chapters cover how gentrification impacts non-white communities. The diversity of our beautiful capital means we can easily forget how insidiously racism creeps into everyday life.

The phrase "call-to-arms" is often overused in reviews, but this is an incisive, direct book that will lead non-black readers to see their world for what it is. It was certainly interesting for me as an Asian British reader, who fits somewhere in-between in terms of what I face and what I benefit from in a racist system. As we can see from our current Home Secretary, being non-white doesn't equate to being progressive and we all need to actively combat systemic bias wherever we see it.

Why I'm No Longer Talking To White People About Race is essential reading. It's a succinct read that will shift your perspective for the better. It is frankly embarrassing it took a global pandemic and the latest wave of the Black Lives Matter movement for me to read it, but it has been a bestseller for a year now, so more and more people are absorbing its timely message.

"If we wait for unity, we'll be waiting forever. It invites inertia... We cannot escape the legacies of the past, but we can use them to model our future... It's on your shoulders and mine to dismantle what we once accepted to be true."

ARTWORK: SOPHIA CAKOVA




I, SCIENCE