I,SCIENCE

THE SCIENCE MAGAZINE OF IMPERIAL COLLEGE

ENERGY

AUTUMN 2019

I, SCIENCE
THE SCIENCE MAGAZINE OF IMPERIAL COLLEGE

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I, SCIENCE

Dear reader,

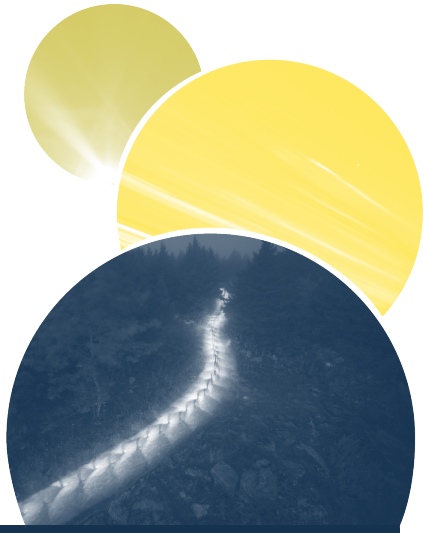
As the days grow ever shorter and the long Autumn term draws to a close, you might be feeling a little low on fuel. Luckily, with our first issue of the academic year, the new I, Science team is here to give you a re-energising boost!

The concept of 'energy' is as ubiquitous as it is elusive. In physics, it is the property which must be transferred to an object in order to heat or perform work on it. It is the power obtained from resources, which fuels our contemporary lifestyles. Energy is in the food we eat and is stored in each of our individual cells, where is sustains our physiological functions in all their complexity. It powers life itself as it is endlessly exchanged through intricate ecosystems. Energy drives the collision of mountains and eruption of the volcanoes, the strike of lightning and the destructive path of a hurricane. The very nature of our planet, solar system, universe is governed by energy.

Our talented writers have approached this issue's theme from all angles, from the tiniest of microorganisms to the largest energetic events in the cosmos – and everything in between. We invite you to learn about the orchestrators of the climate change narrative and the indigenous communities feeling its effects most strongly. Immerse yourself in Nikola Tesla's mysterious life, or Eliud Kipchoge's triumph over the limits of the human body. How about surfing the gravitational waves of spacetime, or traversing the radioactive wilderness of Chernobyl? Read on to discover what medicine could learn from superfoods, hibernation and the daily struggles of Millennial life, or explore the myriad ways in which energy production is being revolutionised.

We sincerely hope you enjoy reading our Energy issue as much as we enjoyed putting it together. ■

PRIYANKA AND CHARLOTTE
EDITORS-IN-CHIEF



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news

Harry Jenkins covers the latest.

BREXIT ON BRITISH SCIENCE

Extinction Rebellion weren't the only ones to protest in London over the past few months, as around one million protesters gathered to demand a second Brexit referendum on Saturday 19th October. Prior to the march, one of the largest public demonstrations in British history, the first figures emerged showing the negative impact that Brexit has already had on UK research.

Since 2015, Britain's annual share of EU research funding has fallen by a third, UK applications to Horizon 2020 by 40%, and the number of researchers choosing to come to the UK via EU schemes has fallen by 35%. Royal Society President Venki Ramakrishnan says scientists do not want to "gamble with their careers" by coming to the UK.

OVERHAULING CRISPR-CAS9 FOR MORE ACCURATE GENE EDITING

Researchers at the Broad Institute of MIT and Harvard have improved upon the CRISPR-Cas9 gene-editing system to produce a new technique dubbed 'prime editing'. Published in Nature, the team describes how they managed to make 175 different DNA edits to humans cells with never seen before precision.

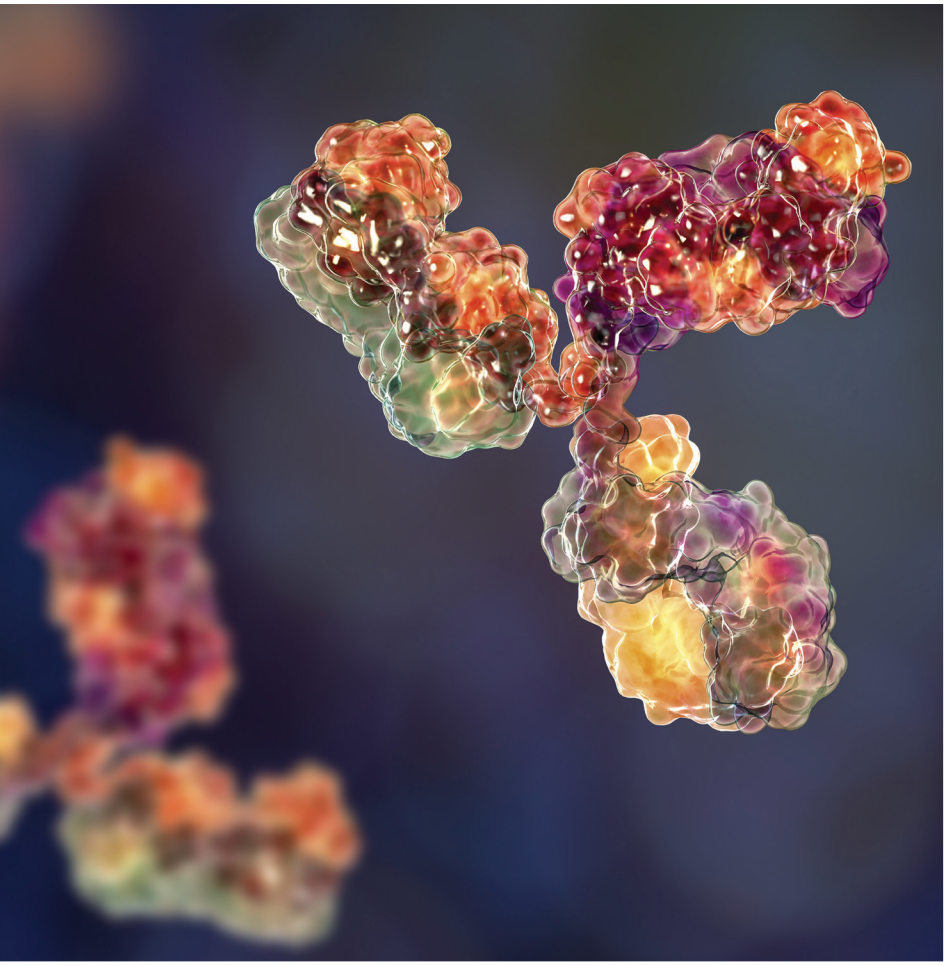
Gene editing systems aim to seek out specific DNA sequences and replace them with other ones. Currently, the CRISPR-Cas 9 system is good at the seeking side of things, but less so at the replacing. Prime editing uses an altered version of Cas 9 that's fused with another protein, which cuts the DNA in such a way that it creates fewer mistakes.

This progress raises fresh hopes for the treatment of genetic disorders, but we still have a while to go before it can be used in humans.

THE 'UNTOLD SUFFERING' THAT THE CLIMATE CRISIS COULD CAUSE

A statement, published in the journal Bioscience in November, supported by 11,000 researchers across the globe, warns of potential 'untold suffering' from climate change unless radical changes to society are made. The lead author of the statement said he was driven to initiate it by the increase in extreme weather he was seeing. A key aim of the warning is to set out a full range of 'vital sign' indicators of the causes and effects of climate breakdown, rather than only carbon emissions and surface temperature rise .

This warning came just after the US notified the UN that they had begun the process of withdrawing from the Paris Agreement – the famous agreement within the UN that sets out the participating countries' commitments to combating climate change.



MEASLES WIPES OUT THE BODY'S IMMUNE MEMORIES

A study published in October has definitively shown that measles is able to wipe out your body's ability to "remember" past infections, making it harder to fight them off in the future. They found that memory B-cells, the immune cells that have a memory of past infections and can produce antibodies to fight them if re-infected, are significantly reduced after having measles.

On average, the children in the study lost 20% of the repertoire of antibodies they'd normally be able to produce, effectively resetting their immune systems to a baby-like state.

The research shows that measles is even more dangerous than we realised, which is increasingly important considering there were more measles cases in the first half of 2019 than in any year since 2006.

ENERGY PRODUCTION TRENDS

Priyanka Dasgupta describes the current trends in energy production and explores current and future energy policy objectives.

"How dare you?" the 16-year-old's voice went ringing through the ears of not just the UN Assembly, but a world in dire need of waking up from its mulled sleep.

Greta Thunberg's strongly worded speech struck at the core of many of the planet's energy production and associated climate problems. She essentially reiterated the sentiment that, "We have not inherited the earth from our ancestors but have borrowed it from our children." We need to act now.

RECENT ENERGY TRENDS

There have definitely been some changes, though.

Wind and solar energy are expected to contribute to almost half of the world's electricity by 2050. An increase in electricity demand is predicted, which might double by 2060 (in comparison to 1990 levels).

In the UK, dependence on coal has steadily gone down since the 1980s and hit a low in 2018. On the other hand, dependence on bioenergy has increased since the 1980s and went up in 2019.

ENERGY AND MITIGATION STRATEGIES

Despite these changes, the current objective to limit average global warming to 1.5°C is ambitious. This requires major greenhouse gas emission reductions.

According to the Intergovernmental Panel on Climate Change, for effective mitigation, transformations are required across all major sectors like energy, industry, transport, building, agriculture, forestry and other land use. In the real world, however, we're dealing with complex, interwoven sectors.

The big goal is to reduce net carbon emissions to zero, striking a balance between carbon sources (which emit carbon into atmosphere) and carbon sinks (which absorb carbon from atmosphere).

The main strategies for this include:

- **Low carbon solutions –** Using products that emit less carbon. This includes switching to renewable sources, electrification, and reducing carbon footprints.
- **Low demand solutions –** Lifestyle changes to reduce dependency on high greenhouse gas emitting products and increasing energy efficiency in infrastructures and technology.
- **Carbon removal –** This is the side which still requires a lot of technical development to adequately qualify as a dependable option, to sequester carbon from the atmosphere in levels which would sustain mitigation goals.

Each affects the other. For instance, current trends in Europe and the UK deem the removal of subsidies on renewable energy projects quite possible, while maintaining competitively low prices. However, this predicts an increase in demand for these energy sources, which results in a slowing down of greenfield projects (projects not constrained by prior frameworks, analogous to starting fresh in green fields). This reduces the possibility of investments in new technologies, as there would already be enough strain on maintaining these low prices if they become unsubsidised. However, experts predict that such a slowdown is temporary, as in the future these core economies will move towards meeting climate change and sustainability targets.

> "Greta Thunberg's strongly worded speech **struck at the core** of many of the planet's energy production and associated climate problems."

This has a further impact as well. An increase in energy demand would restrict our options of choosing between different mitigation strategies. For example, a high demand would mean increased dependency on low carbon sources or pressure on developing de-carbonisation technologies, for which we might not be equipped.

CHANGES IN POLICY

The World Energy Council mentions ideals of achieving the Trilemma: "secure", "affordable" and "environmentally sensitive" energy.

They came up with an interesting metaphor for possible scenarios in 2015-2060:

- **Modern Jazz –** Market driven approach which stresses affordable access to all. The focus is on economic growth. Moderate carbon emissions: ~1,491 gigatons
- **Unfinished Symphony –** Strong policy-driven approach, with foresight and unified, coordinated policies amongst nations. Allows sustainable economic growth but ensures long term benefits. Least carbon emissions: ~1,165 gigatons.
- **Hard Rock –** Scenario in which we remain fragmented between nations and sectors, which is beneficial for short term or local solutions, but isn't sustainable. Most carbon emissions: ~1,642 gigatons.

New policy reforms which are in need of becoming common trends include strategies like Carbon Pricing (adding a cost to carbon output to discourage emissions); Feed-In Tariffs (rewards or payments to encourage investment in renewables); phasing out current negatively impacting systems; removing fossil fuel subsidies; and effective, sustainable transport/urban planning.

The shift from the 2°C to 1.5°C warming target requires the enforcement of highly stringent frameworks, integrated policy, and increased regulation in order to achieve 'net-zero carbon' energy economies by 2040-2060. This would also entail innovation and development in technology and significant transformations of lifestyle, economies and structural strategies. Numerous studies call for urgent actions in accomplishing short-term reduction of emissions to potentially contain them by 2030. Another focus could be public investments to allow for innovation in technologies to produce higher efficiency or develop decarbonisation systems.

The need for an integrated policy framework is essential to avoid risks of carbon-leakage from fragmented sectors, which could upset the balance between mitigation approaches and sustainability goals. The real world situations are quite distant to the 'idealised' policy reforms. A strong reinvigoration of devotion is needed to treat the matter much more urgently, as left to current trends, our 'best efforts' might not be enough. ■

SHARING IS CARING?

Sze Liew investigates the possibility of transnational energy grids.

Imagine buying your weekly grocery but suddenly plans arise for you to eat out. You end up having extra food in your fridge. The food is going off and you cannot possibly eat any more, so into the bin it goes. Sounds like such a waste! Why not share it with your flatmates? This same principle can be applied to energy.

Currently, decarbonisation efforts including modern biofuels, wind power, and hydropower, account for only 18% of total global energy consumption. However, renewable energy consumption could be increased if its production and resources were shared.

Different regions across the world experience different weather conditions and seasonal variations, which translates to differences in peak renewable energy production and consumer demands. A transnational connectivity grid could be built to eliminate intermittency issues in energy demand and supply between countries, by aggregating renewable energy sources. For example, in the summer months, hydropower energy produced in Nepal and Bhutan could be exported to India when consumer demand peaks during a heatwave. In exchange, solar and wind energy produced in India can be exported to Nepal and Bhutan during the dry seasons when hydropower energy production decreases. As a result, energy supply and demand would be stabilised across the countries, increasing global energy security and shifting energy reliance from fossil fuels.

Access to energy is strongly correlated to a country's economic wealth and potential for growth. As such, disparity between high and low-income countries in energy consumption level still exists. For example, 65 million people in Southeast Asia still lack access to electricity because of undeveloped energy distribution networks and the increase in fossil fuel prices. Building transnational energy networks and delocalising energy sources may develop new energy markets in poorer countries – a sustainable approach to economic development.

Sounds like a no brainer! So why is this not explored further in today's energy market? As it is said, it is always difficult to achieve something fruitful when there are so many players involved. In Central Asian countries, those in the fossil fuel industry generally have links to government officials. Delocalising domestic energy production and shifting towards affordable renewable energy could diminish profits generated by fossil fuels. This has led to a lack of government coordination and motivation for funding. Electricity prices and market differences between countries have also led countries to favour self-sufficiency. Moreover, the unreliability of renewable energy resources is amplified by climate change and increases the uncertainty of energy supply/demands trends. As such, coal still plays a major role in mitigating this problem as a reliable source of backup energy.

> "Renewable energy consumption could be increased if its production and resources were **shared**."

With China pursuing policies to open its economy and becoming the largest single investor in renewable technologies at US$103 billion in 2015 (the same as Europe, India, and the US combined), it may play a role in spearheading this movement. China has established the Global Energy Interconnection initiative by promising the interconnectivity of 720 gigawatts of energy across continents and oceans by 2050. It aims to reduce the need for potentially environmentally damaging renewable power plants, such as hydro-dams, and utilise electricity from established power plants in nearby countries instead. China has the most advanced technologies in high-voltage electricity transmission and investment in developing renewables means high research output in the latest technologies.

However, building "supergrids" to enable transnational energy sharing could potentially displace local communities, such as by blocking major river passages of indigenous communities, and unbalance ecosystem biodiversity. Moreover, the monopolisation and reliance on China for these projects could create an imbalance in geopolitical power hierarchies, much akin to Europe's reliance on Russia's gas pipelines.

The take home message? We may not be able to rely on each other for free food. You might end up wanting to eat what you have offered to others because you got too hungry! The relationship needs to be mutually beneficial, so that there is trust. We also need to look for other sources to diversify our options, in case the relationship becomes precarious. ■

DIETARY DIVAS:

A SCIENTIFIC LOOK AT THE SO-CALLED SUPERFOODS

Josie Clarkson dissects the incredible claims fuelling the superfood industry.

While superfoods seem to be one of the latest dietary fads, they were actually on the menu of our ancestors, albeit with slightly different branding. Garlic was considered a superfood across the ancient world, including Egypt and Greece, where it was used to enhance physical strength by minimising fatigue. But surely garlic is too commonplace to be worthy of the 'superfood' title? In fact, the Oxford Dictionary defines a superfood as any "nutrient-rich food considered to be especially beneficial for health and well-being". Despite this broad definition, the superfoods of today (the likes of chia seeds and acai berries) tend mainly to boast high levels of antioxidants.

The job of antioxidants is to clear up free radicals – molecules with a spare electron, which makes them unstable. When most molecules react with a free radical, it leaves them highly unstable. This can cause uncontrolled chain reactions leading to a type of cell damage called oxidative stress. But what makes antioxidants special is that they can react with free radicals without becoming reactive themselves.

Normally the levels of antioxidants and free radicals in the body are fairly even, but if this balance is tipped in favour of free radicals, oxidative stress occurs. It is thought that too much can ultimately result in the development of diseases such as Alzheimer's, Parkinson's, cancer and type 2 diabetes. To prevent this, the idea is to keep your antioxidants topped up by eating foods rich in them. But does this really work, or is it a clever fear-mongering marketing ploy?

Research testing the effect of antioxidants on the human body is problematic: naturally occurring antioxidants do not exist in isolation, but separating them is not reflective of their place within the diet. Numerous studies have found that people who eat foods high in antioxidants — such as blueberries and pecans — tend to be healthier and have lower risk of disease. However, these individuals are also more likely to have other healthy habits, such as exercising and getting enough sleep. In addition, the foods they eat will contain a variety of beneficial compounds other than antioxidants, such as vitamins and minerals.

> "Numerous studies have shown that people who eat foods high in antioxidants tend to be **healthier** and have lower risk of disease."

Moreover, the quantity of antioxidants used in these trials to produce the positive results is massive. Take, for example, the prickly pear, made famous by Baloo in the Jungle Book when he teaches Mowgli how to eat them. Researchers investigating the beneficial effect of prickly pears made their participants eat 500g of the fruit's pulp. Prickly pears weigh between 70g and 100g, so eating over 5 of them in a day is somewhat unrealistic for the average person. Baloo could pick them (carefully with his claws, not his paws) from the trees around his home, but to reach us in the UK, the fruit must fly roughly 5,000 miles from Mexico, where they are most abundant.

The prickly pear is not the only food with these issues — most of today's superfoods are only exciting and appealing because they are novel and exotic. While it is enjoyable to enrich your diet with foods from around the world, they come with a high environmental price tag. And this often isn't the only price tag which is high: most superfoods are marketed as such to create exclusivity and demand, meaning stores can charge astronomical prices.

Back to the science of antioxidants: why would our bodies produce these aggressive and harmful free radicals in the first place? Free radicals are not kamikaze pilots on a mission to self-destruct. In fact, the body's immune system capitalises on their destructive power to destroy invading bacteria, with immune cells possessing more antioxidants than most other cells, to pacify the free radicals once their job is done. As you can see, it's oversimplifying their complex relationship to shun free radicals and pump your body with antioxidants.

Superfoods are full of much more than just antioxidants, but a common misconception is that each superfood contains all the key healthy nutrients. In reality, each superfood has its own individual cocktail of healthy compounds. For example, quinoa is rich in vitamin B3 (also known as niacin), which is the initial compound in the chain of reactions leading to energy release. Therefore, B3 is vital for producing energy from food and underpins numerous important bodily functions, such as DNA repair. This can then be extrapolated by the media to make claims that quinoa reduces tiredness. There is usually truth at the core of these health claims, but they are often exaggerated and oversimplified; i.e. eating a bowl of quinoa for breakfast after a bad night's sleep won't compensate for the hours missed.

It is true that each superfood contains a handful of helpful nutrients in high

a few
SUPERFOODS

strawberries
blueberries
eggs
garlic
kale
broccoli
almonds
salmon
spinach

quantities, but no single food is a miracle cure for disease. The secret to health and longevity is a diet filled with fruits, vegetables and grains (some of which will meet the criteria to be a 'superfood'), with a range of vibrant colours that often signify different vitamins and minerals. Lots of vegetables that are already commonplace in our diets can be boosted to superfood status, simply by how they're stored and cooked. For example, leaving mushrooms on the windowsill elevates their vitamin D levels and doing the same with tomatoes makes them redder in colour, boosting their nutrient content. Similarly, cooking certain foods like carrots and spinach releases more nutrients than eating them raw.

> "A bag of kale will **not undo** the damage done by a burger."

It will come as no surprise that the take home message is that a bag of kale will not undo the damage done by a burger. Binging on enough blueberries to have a significant nutritional effect will cost you a fortune and propel you way over your recommended sugar intake. But eating a balanced diet, which may happen to include some superfoods, like broccoli and eggs, will equip your body with all the nutrients it needs to stay as healthy as possible. ■

THE TESLA ANGLE

McKenna Castleberry writes about her research into Nikola Tesla and his mysterious "death ray".

There is one picture of Nikola Tesla that has mesmerized me since I was a child. Tesla is sitting under a large Faraday cage with a Tesla coil on top of it. The picture, while in black and white, shows the streaks of white-hot electric sparks shooting out from the coil. Tesla is calmly sitting under this cage, as if it's just another Sunday morning of doing a crossword puzzle. I can imagine the whirring and sizzling of the coil above, filling the thick silence with electricity.

How did Tesla get there? And was he really safe under the electric shower of his invention? I later found out that this picture was taken using double exposure, overlaying Tesla's portrait with the activity of his machine. Even knowing that, I still found the photograph mesmerizing.

From first seeing that picture, I was hooked on Tesla. I wanted to know everything about him, and his all-too-famous fight with Thomas Edison. There was one thing that seemed to be missing from my research. What happened to Tesla after his moments of fame? Tesla seemed to just vanish after his famous debut at the first Chicago World's fair, demonstrating the powers of electricity. He also worked with Marconi and helped develop the radio for later use. It didn't make any sense to me. How could someone just disappear after such achievements?

> "From first seeing that picture, I was **hooked** on Tesla. I wanted to know everything about him."

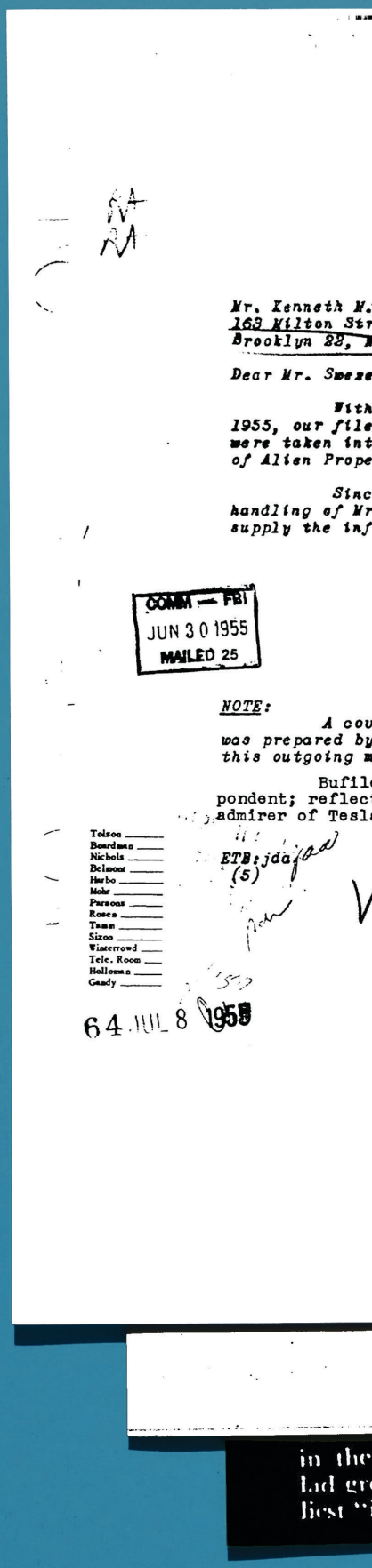
I did some digging, and found various articles on the mysteries surrounding Tesla's death. My pulse quickened as I scrolled through the article on History.com. It turns out that Tesla spent his last few decades living in one hotel room in New York City, after a lab fire humiliated him in the press. He became more deranged as his health declined, becoming obsessed with the number three, and constantly washing himself and his clothes. The few times he wasn't in his hotel room, he was out feeding, and (as he claimed) communicating with the pigeons of New York.

It seemed to me that Tesla may have been hiding something during this time period, perhaps a new invention. In his later pictures, Tesla's eyes seemed to be gloating, almost mischievously hinting that he knew something I didn't. I imagined him hunched over in his hotel room, an antique dresser used as a lab bench as he continued to play with ideas that had haunted him throughout his life. His eyes were sallow and bloodshot. Nights staying up working had taken their toll on him.

Tesla died on January 7th, 1943 in his hotel room, and rumors swirled that immediately after his passing, the U.S. Office of Alien Property broke into his safe and took all his work. I had to reread the sentence in the History.com article. The U.S. Office of Alien property? What could Tesla be working on that this government office had to immediately take away all his work? I scrolled down hastily, and almost missed the next paragraph in the article because I was so excited. As my eyes ran over the page, I held my breath.

Tesla had apparently invented a sort of "death ray" that would have been used to fight enemy forces during World War II. The government didn't want the invention falling into the wrong hands, and immediately took possession of Tesla's technology. The U.S. government has held Tesla's work ever since. It was only recently that they planned to ship it back to Belgrade in Serbia, Tesla's hometown, for the Nikola Tesla Museum. The article stated that apparently 80 boxes of Tesla's notebooks, lab journals, and other documents had been shipped, but only 60 boxes actually made it. My eyebrows furrowed. What happened to the other 20?

The article seemed to finish on a questioning tone, and I scrolled up frustrated that there weren't more answers. At the top of the page was a link to an article titled "The Missing Tesla Files: the FBI declassifies…" with the rest of the title cut off. Curious, I clicked, and was brought to a new article explaining that in 2016, the FBI declassified some of Tesla's work according to the Freedom of Information Act. I couldn't believe my luck when there was a link to the FBI vault itself. I gasped as I found full PDFs with Tesla's handwriting, scribbles, and notes from J. Edgar Hoover, director of the FBI, himself, discussing Tesla's work. For the next two hours I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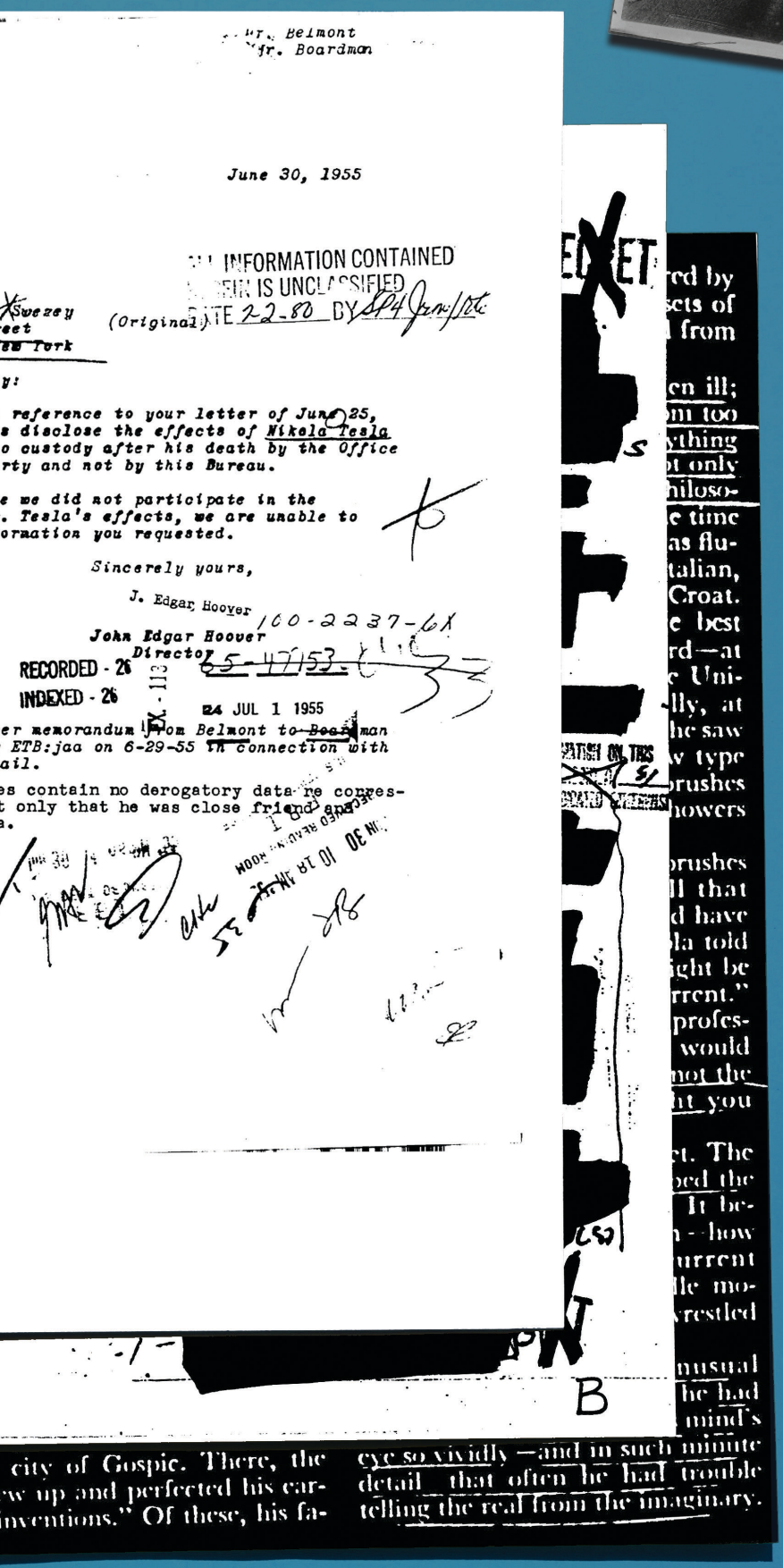

Mr. Belmont
Mr. Boardman

June 30, 1955

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Sincerely yours,

J. Edgar Hoover

John Edgar Hoover
Director

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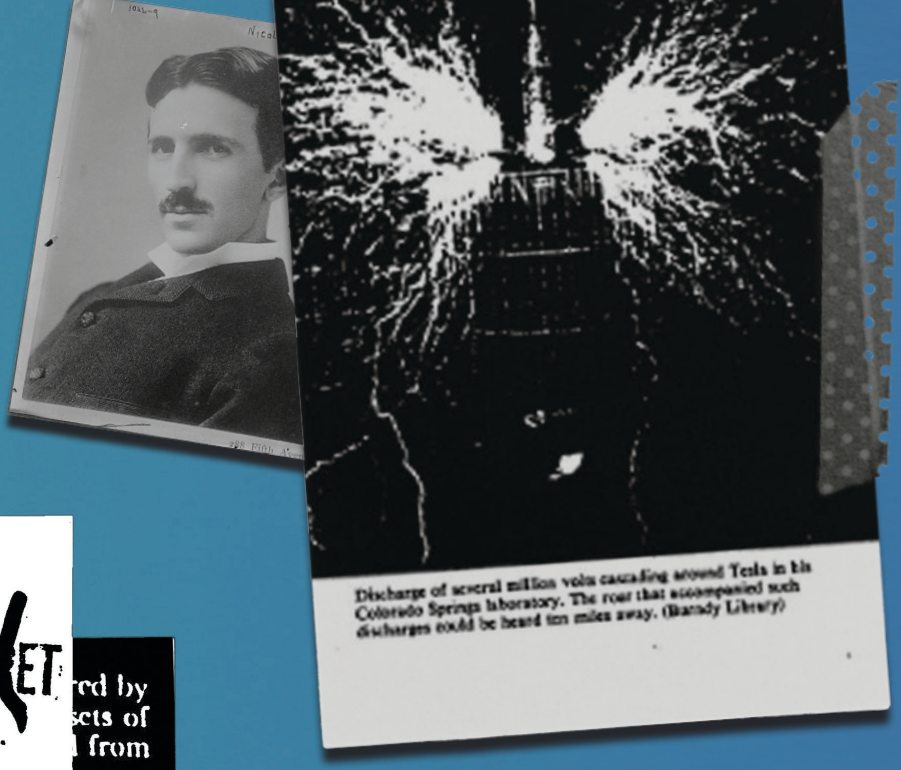


Discharge of several million volts cascading around Tesla in his Colorado Springs laboratory. The roar that accompanied such discharges could be heard ten miles away. (Barnaby Library)

scrolled through the FBI files, trying to find some mention of Tesla's "death ray" or any other reason that these secrets were being held.

> "I couldn't believe my luck when there was **a link to the FBI vault itself**."

The documents within the FBI files ranged from 1945 to approximately 1969. A lot of them were blacked out with marker or written over with notes. In the margins, someone had scribbled the word "secret" over and over again, as if to remind me. Many of the PDFs were either scanned in or microfilm, making it hard to read. The parts I could read discussed the use of the Tesla "death ray", but no mention of whether such an invention was working. Oddly enough, every few pages of the Tesla files were newspaper clippings about Nikola Tesla. Why would the FBI store newspaper clippings in their vaults? The clippings were retelling the facts of Tesla's inventions, with few of them mentioning his new "death ray." There were also a few interviews with J. Edgar Hoover and other political figures discussing the possession of Tesla's work. I tried to read them, but the printing was smeared. Perhaps that's why the FBI released these documents after all. You can barely read them.

I can only imagine Tesla having a laugh as he watches the government struggle to understand his work. Perhaps they kept all of it just to be safe, and the items they did release are merely decoys for Tesla's real work, still sitting safely six feet underground in a vault with thick walls and a locked door. ■

THE HUMAN RACE

Emma Needham investigates how Eliud Kipchoge accomplished a sub-two-hour marathon.

Eliud Kipchoge recently made history in Vienna when he became the first person to run a marathon in under two hours, beating his own world record. Before this, there had been lots of predictions made about how and when a human being might pass that threshold, with many coming to the conclusion that a sub-two-hour marathon was either impossible or generations away.

For the world's fastest marathon runner, understanding the complicated interplay between lots of energy transfers is key. What might seem to us to be the tiniest detail, such as the degree to which the course curves, could make the difference between making and missing that record.

So, how did he do it?

PREPARATION

- **Training** – To prepare, Kipchoge and his team were running a grueling total of up to 140 miles (230 kilometres) per week at their training camp in rural Kenya.
- **Nutrition** – Kipchoge's diet was surprisingly simple with little variation, virtually completely plant based and sourced from local farms to the camp. This is in complete contrast to Western athletes, who obsess over elaborate schedules of consuming protein, macronutrients and supplements in the lead up to a race.

There was only so much preparation Kipchoge could do, as a large part of his record attempt would depend on his environment. Kipchoge's team carefully crafted a course in Vienna for the attempt, to maximise his chances.

THE COURSE

- **Time zone** – Vienna has only a one-hour time difference from Kipchoge's Kenyan training camp and so sleep adjustments were minimal.
- **Climate** – In October, Vienna has the ideal climate for marathon running: it was 10°C on the day, humidity was low and there was no rain. This meant that less energy was needed to cool the body down or grip a slippery course. Rain or humidity would have also marginally increased the weight of the runner's clothing, increasing the work required to propel him forwards.
- **Shelter** – The course was mainly surrounded by large trees, shielding the runner from winds.
- **Altitude** – Vienna is only 165m above sea level; this low altitude would have allowed Kipchoge to absorb more oxygen compared to a course at a higher altitude.
- **Shape of the course** – The course was designed to curve gradually, as running in a turn uses more energy than in a straight line because more forces are at play.
- **Elevation** – Over the entire course, elevation only changed by three metres. A flat course means that more energy can be put into moving forwards rather than doing work against gravity when moving uphill.

> "What might seem to us to be **the tiniest detail could make the difference** between making and missing that record"

Considering nutrition, the course, and conditions on the day might seem like pretty standard marathon preparations. So, what made this race different to a normal marathon?

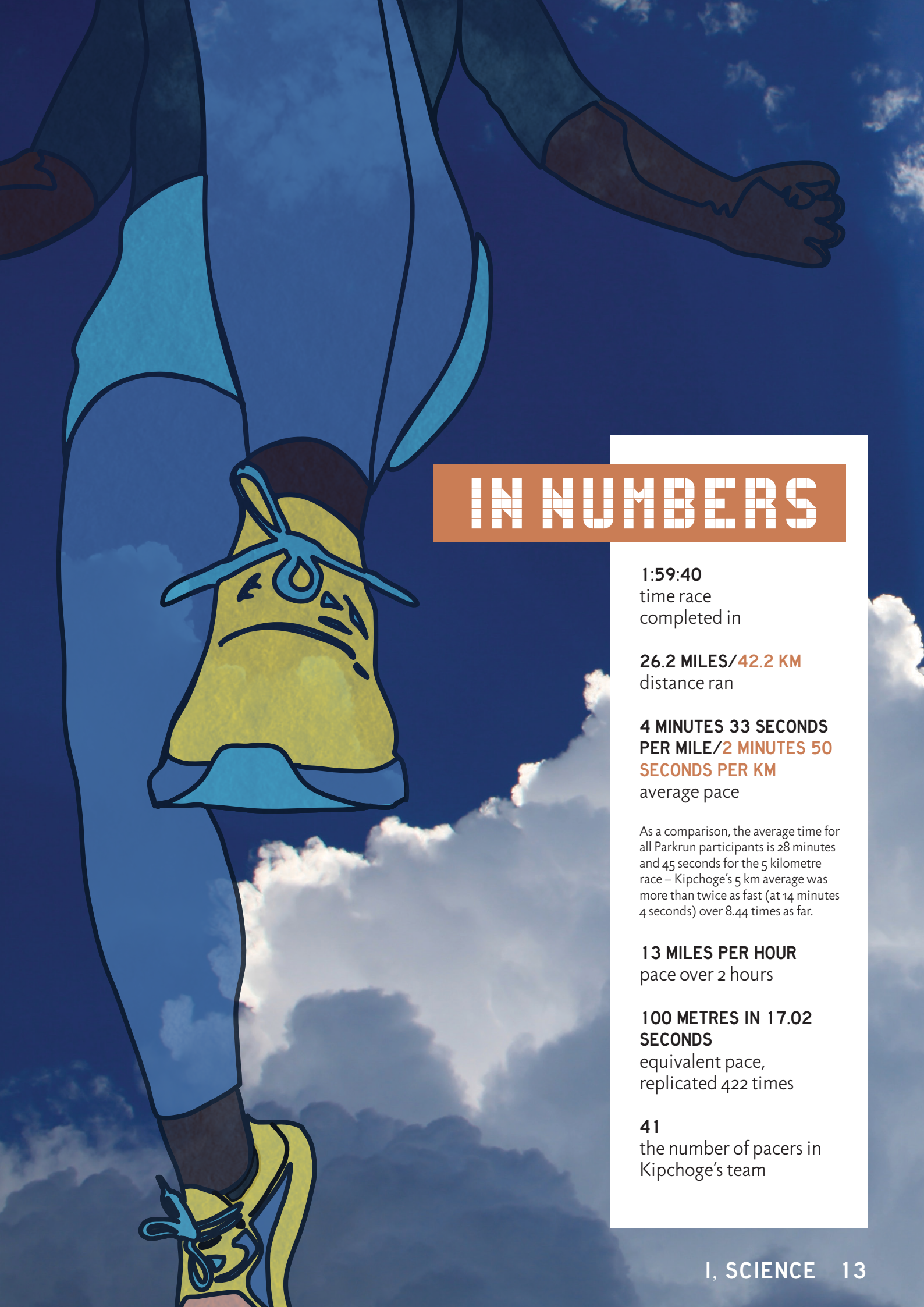
RACE SPECIFICS

- **Reducing drag** – A rotating team of 41 world-renowned runners created a peloton-like V-formation in front of Kipchoge, kept perfectly in step by laser lines on the road projected by a pace car, allowing Kipchoge to move coolly in the slipstream. Two pacers also ran behind to propel him.
- **Shoes** – Nike created a custom pair of shoes for the race and, although official specs haven't been released, by looking at similar shoes from Nike, sources have speculated that they had carbon fibre plates with air or foam pockets for cushioning. Visible in photos of the trainers from the race is a greater amount of tread than previous, similar models – for greater traction.
- **Nutrition** – Marathon runners usually take on additional fluid and carbohydrate during a race, but it was the method of supply which was unusual on this occasion. A precise cocktail of gels and fluids were delivered to Kipchoge periodically by the team's cyclist.
- **Mentality** – The event was held solely for Kipchoge and thousands of spectators lined the course to cheer him on, enhancing his already unwaveringly positive outlook.

In light of all of this help, Kipchoge's achievement is not recognised as an official world record and sticklers have tried to diminish his achievement. In a nod to another form of energy, the race was sponsored by petrochemicals giant, Ineos, who have been under fire this year for plans to frack for shale gas in the north of England and the east midlands. This led some sceptics to call the attempt a public relations campaign to improve Ineos's image and sell Nike's spongy-soled, record-breaking shoes.

> "Kipchoge's achievement is **not recognised** as an official world record."

Despite the chatter, Kipchoge is unfazed, and the achievement has been compared to the moon landings, or the Everest conquest of Sir Edmund Hilary – no less impressive with the help of technology. "I am happy to inspire somebody" Kipchoge said "and even if they say it's not a world record, I have broken a barrier. Which makes a difference in human life, in a human family. That's my evidence." ■



IN NUMBERS

1:59:40
time race completed in

26.2 MILES/42.2 KM
distance ran

4 MINUTES 33 SECONDS PER MILE/2 MINUTES 50 SECONDS PER KM
average pace

As a comparison, the average time for all Parkrun participants is 28 minutes and 45 seconds for the 5 kilometre race – Kipchoge's 5 km average was more than twice as fast (at 14 minutes 4 seconds) over 8.44 times as far.

13 MILES PER HOUR
pace over 2 hours

100 METRES IN 17.02 SECONDS
equivalent pace, replicated 422 times

41
the number of pacers in Kipchoge's team

WHO IS REALLY DIRECTING THE CLIMATE CHANGE NARRATIVE?

Matilda Jones discusses how her experiences at the Student Energy Summit informed her opinions on the fossil fuel industry.

This summer I attended the international Student Energy Summit (SES) at Imperial College London. As a Biochemistry student unfamiliar with the energy sector, I hoped to gain an insight into how the energy industry is working to prevent the 2°C increase in global temperatures, which marks the 'tipping point' into irreversible damage to the planet. On the opening night, it was boldly announced that the attendees were the people who were going to 'stop climate change'. I had a lot of hope and was excited to see what would happen over the following days.

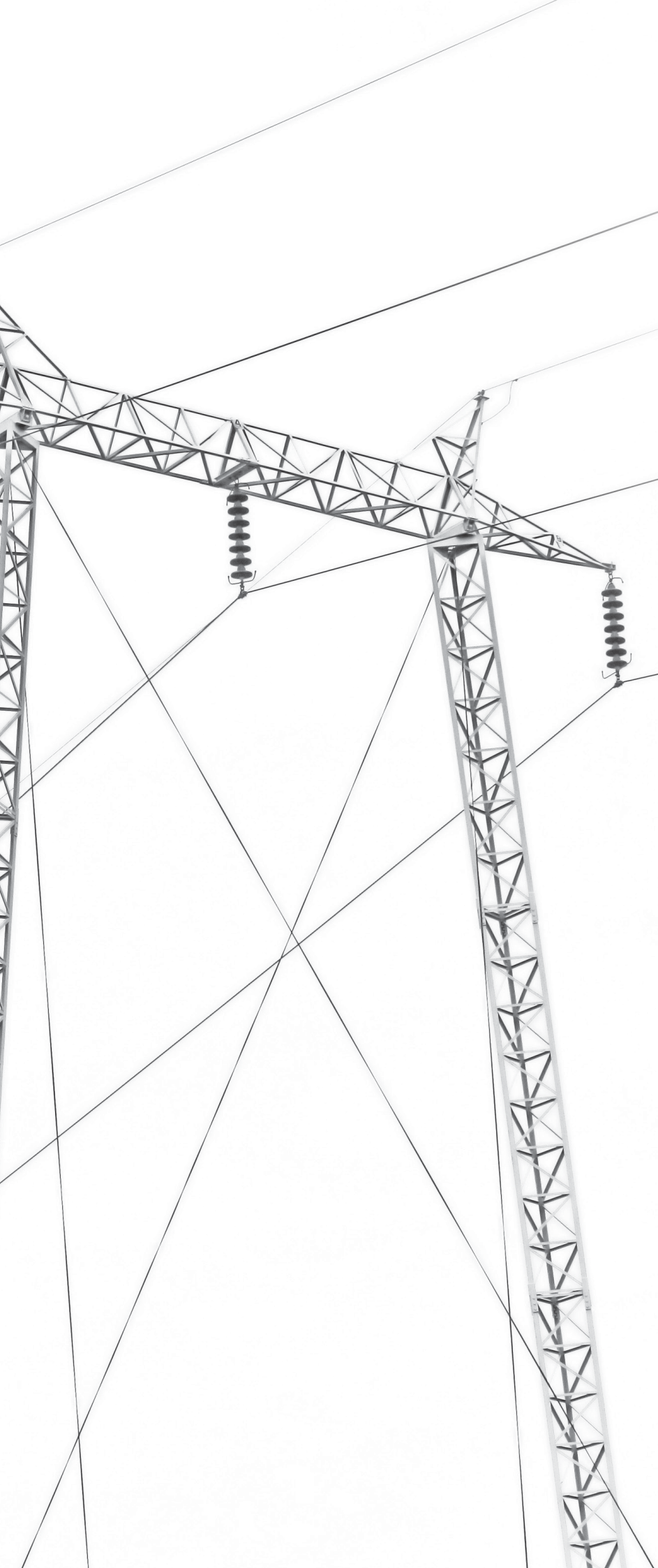
Unfortunately, the tone was set when one of the keynote speakers on the first night was a representative from British Petroleum (BP), the biggest sponsor of the event. This was followed by a chain of oil and gas companies, all attempting to persuade the delegates that they were doing as much as they possibly could to be sustainable. It was frequently brought to our attention that the problem energy companies face is to provide energy to the masses while reducing carbon emissions. To me, even allowing companies such as BP and Shell to speak at an event supporting sustainable energy was a farce. It is as despicable as allowing a victim's murderer to talk at their funeral. Why should we listen to the troublesome gas and oil companies who built our current energy economy by fuelling a climate crisis? I find it is important to emphasise that, ultimately, companies are not moral entities. Above all, they exist for profit.

> "Even allowing companies such as BP and Shell to speak at an event supporting sustainable energy was a **farce**."

It appeared that students, an often outspoken demographic, were scared to confront these companies at the conference. It is well known that they hold a monopoly over the energy sector, and this is a field in which many students hope to work in the future. This was highlighted by the way most people chose to remain anonymous when submitting online questions to the panels held throughout the conference. People should not have to moderate their protests at such an event in fear of being blacklisted.

Aside from these glaring issues, there was one other key point that bothered me about this conference. SES held multiple panel discussions on the importance of youth and diversity throughout the event. The organisers of the conference seemed to suggest that by pandering to the liberal youth, we would quieten our raucous cries for a more wholesome, sustainable approach to bettering the current world we inhabit. Although I completely agree that both diversity and the role of young people are essential as we move forward in this battle, I couldn't help but feel that these talks were less about diversity and more about diversion. There is a peculiarly large emphasis placed on the importance of 'the youth' preventing climate change. This passing of the buck down the ancestral line, rather than admitting to despicable decision-making, is a display of ignorance and hubris from the generations who have failed us and the planet. We are all responsible for the changes that must take place to grab humanity as we know it back from the brink of extinction.

Every time I heard a representative from any company talk at SES, I sensed that every word and action was carefully designed to mislead us into a false sense of security. By entertaining these fossil fuel companies and their dirty money, we are gobbling their lies and granting them amnesty – despite the fact that they have been the biggest contributors to increased CO2 emissions for decades. Since 1965, the top 20 fossil fuel companies, with BP in sixth place, have released 480 billion tonnes of CO2. This is 35% of global CO2 emissions from human activity. Even now, with our tipping point



deadline set to eleven years, many major oil and gas companies, again, including BP, shamelessly have not set goals in line with the 2015 Paris Agreement.

I do not see these facts in the news. I do not hear a call loud enough to boycott these companies. If anything, the only sounds are 'greenwashing' campaigns, pushed down our throats by these very same companies.

At SES, I heard how BP is moving 'Beyond Petroleum'. Meanwhile, Shell is introducing their hypothetical 'Sky Scenarios', a collection of ideas that may lead you to believe that they are the pioneers of a new, green utopia with carbon neutral aeroplanes and an Earth primarily populated by trees and solar panels.

> "We are **past the point** of allowing smooth, gradual transitions into a greener world."

Do not be fooled. Their dreams are unlikely to materialise considering that Shell has a budget of around $25 billion/year and their renewables spend sits at a measly $1-2 billion/year. So, what do we do now?

I propose that we emphasise how no one is doing enough. Any time a company announces a new green initiative we should celebrate that, but also ask what else they are doing. We are past the point of allowing smooth, gradual transitions into a greener world. We must jump right into the post-carbon age and drag any company that won't follow us willingly, even if they are kicking and screaming.

On a personal level this involves making the changes that have already been discussed extensively - adopting a largely vegan diet, reducing flying, and no longer purchasing single-use plastics. We can also choose renewable energy suppliers instead of fossil fuel companies, such as Bulb or Octopus Energy.

The message is simple. Fossil fuel companies are not, and never have been, doing enough while they still invest in fossil fuels. In reality, no one is doing enough until we reach at least net zero global emissions. We need clubs, institutions such as Imperial College London, and events such as SES to stop accepting sponsorships from fossil fuel companies so that they cannot have a social license to operate. It is essential that we all accept this responsibility and direct the climate change narrative ourselves from now on, before it really is too late. ■

ANAEROBIC ASTRONAUTS + BIONIC BACTERIA

Harvey Dolton looks at how bacteria could power sustainable energy-systems.

Bacteria are one of the oldest groups of organisms on Earth, however, there seems to be a lack of appreciation for these evolutionary veterans in today's society. When we think of about bacteria, most people picture the illness-inducing villains found on the underside of fingernails, which make them want to keep military grade antibacterial gels holstered on either hip in case someone coughs in their general vicinity. Whatever happened to respecting our elders? Fortunately for the microscopic organisms, their reputation may soon be on the mend thanks to the rapidly advancing field of biotechnology which has begun to unlock their potential to power our planet.

Bacteria were first used to produce electricity in the form of microbial fuel cells (MFCs), which transform chemical energy into electrical energy by utilising the process of respiration in bacteria found in anaerobic (oxygen-free) conditions. These bacteria undergo a process called direct extracellular electron transfer. This involves excess electrons, produced in regular cellular respiration, being transported out of the cell through wires on its surface, allowing a current to be transmitted to the environment. Although MFCs are widely accessible to the public, their primary issue is that the voltage produced is insufficient to power daily appliances. Thankfully, research is being carried out to increase the electron transfer rate, which could result in voltages suitable for commercial use.

Whilst electricity derived from respiring bacteria has huge power-generating potential, research at the Stevens Institute of Technology in 2018 highlighted the possibility of using photosynthetic cyanobacteria to generate electricity. In the past, the primary problem faced by researchers working with cyanobacteria was that they couldn't keep them alive for long enough to produce a significant amount of energy. To solve this, they combined biology with technological advances to create an energy producing cyborg. The bacteria, contained in a substance called bio-ink, were 3D-printed onto a mushroom cap, which provided favourable environmental conditions. This allowed the cyanobacteria to survive several days longer than on previous host materials.

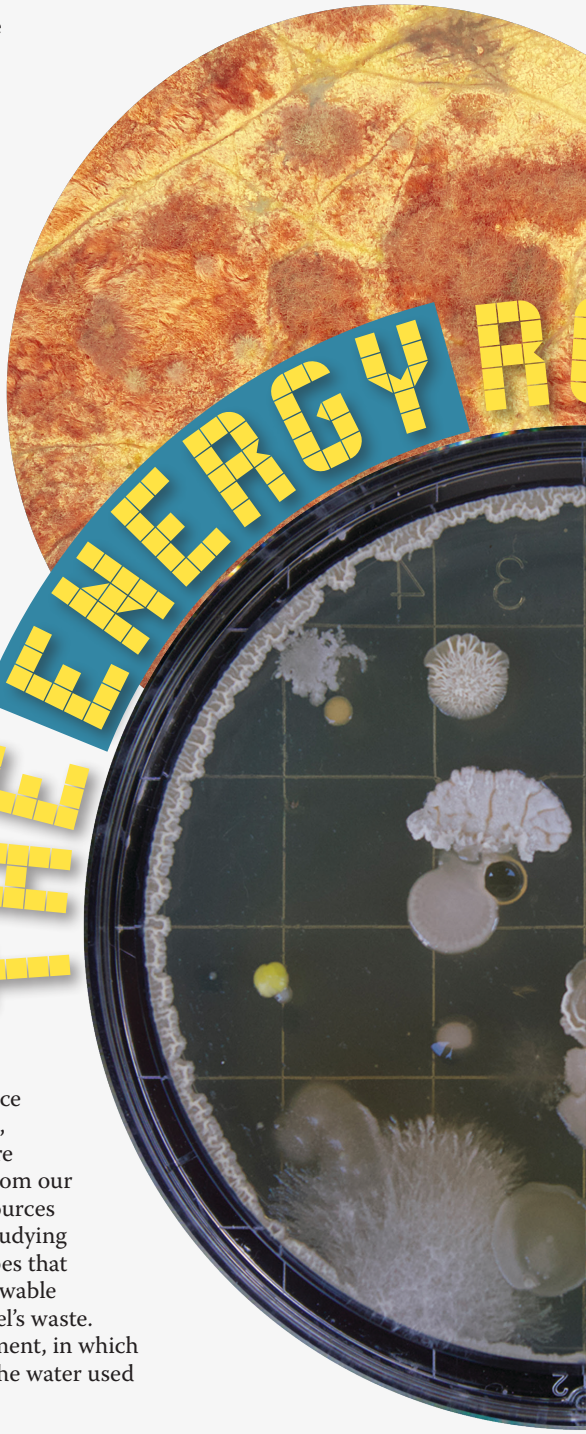
To gather electricity, an ink containing nanoscale materials capable of collecting the current, was also 3D-printed onto the cap. Light was utilised to trigger photosynthesis and the excess electrons produced were transferred through the bacterial membranes and into the electronic ink, generating a current. If we can employ the electricity-generating potential of these bacteria on a large scale, they would not only be a renewable alternative to fossil fuels, but also absorb atmospheric carbon dioxide during photosynthesis. While the process is still in its early stages, the technological leaps made over the past few decades indicate that it is entirely possible that the field of biotechnology can further harness the capability of these microorganisms in future.

> "Utilising bacteria to produce carbon-free energy would be **invaluable** in the fight against climate change"

Utilising bacteria to produce carbon-free energy would be invaluable in the fight against climate change. However, an equally concerning cost of our rapidly developing, resource hungry world is the sheer volume of waste that we are producing. In the UK alone, 222.9 million tonnes of waste were produced in 2016. 27.3 million tonnes of this waste came from households (about 1 tonne of waste per household). Luckily, bacteria may be able to aid the battle for our planet's health on both fronts thanks to their potential to be sustained by waste. This has been demonstrated by an Australian brewery, which used bacteria to generate electricity from its wastewater.

In case the thought of using bacteria to simultaneously produce electricity and reduce waste doesn't already seem out of this world, NASA also hopes to deploy bacteria in future space missions. As humans travel further from our atmosphere, they will need to produce resources over lengthier periods. NASA has begun studying electricity-producing bacteria with the hopes that they will provide future missions with renewable energy, while being maintained by the vessel's waste. One application involves wastewater treatment, in which bacteria would consume organic waste in the water used for shuttle operations and produce clean water as a by-product - all while generating electricity in a self-sustained system.

Ultimately, the full potential of bacteria to help combat the environmental crisis is still unclear. However, rapid advances in biotechnology are harnessing their abilities, which may finally grant these microorganisms the respect that they so rightfully deserve. ■



thorium: CLEAN ENERGY OF THE FUTURE?

Florian Bohr explores the merits and pitfalls of a potential new nuclear fuel.

Considering the growing threat of climate change, along with an ever-increasing global energy consumption and resultant carbon emissions, it appears fairly easy to split the different energy sources into good and bad, right? Solar: good. Coal: bad. Wind: good. Nuclear? Well…

At first, nuclear power seems easily defined within the moral energy dichotomy when we consider the disasters at Chernobyl and Fukushima, as well as the problems concerning storage of radioactive waste. Yet, nuclear energy production is carbon neutral and new types of reactors and materials could make it a viable option in our collective fight against climate change. In particular, thorium, an element aptly named after the Germanic god of thunder (and recent Marvel superhero), may have the potential to supply energy more safely and efficiently, all while resulting in less radioactive waste.

Thorium-powered nuclear energy was first explored in the 1960s, but the US government decided to discontinue its research in favour of uranium. Uranium-fueled reactors became operable at the time and generated plutonium – a much desired side product that the US used for nuclear weapons. This decision was made despite evidence that thorium, a material three to four times more abundant than uranium, could result in reactors which would make a nuclear meltdown practically impossible.

Recently, interest in thorium has grown again, particularly in liquid fluoride thorium reactor – or LFTRs for short. These next-generation nuclear reactors would mix thorium-based fuel with molten salt, a type of salt that is liquid at the high operating temperatures of nuclear reactors. The fact that the fuel is fluid has several advantages. In a standard reactor, a nuclear meltdown occurs when the solid fuel becomes too hot, for example due to a disruption of the cooling system. In an LFTR, however, the liquid fuel is cooled by the molten salt itself, which has a very high boiling point, meaning spikes in heat are unlikely to be a problem. As a last safety resort, there is a frozen plug of salt which is kept cold by an external cooling fan. In the case of a power cut, the fan stops working and the frozen plug melts, allowing the radioactive fuel to drain into a secure catch basin and preventing a nuclear catastrophe.

> "**Thorium-powered nuclear energy** was first explored in the 1960s, but the US government decided to discontinue its research in favour of uranium."

In addition, unlike conventional reactors, LFTRs do not need to be shut down for refueling. While LFTRs still require some highly enriched uranium to start, thereafter, the liquid thorium fuel can simply be refilled and cleaned while the reactor is running. Lastly, and perhaps most importantly, thorium-based reactors use up almost all of the fuel, while conventional reactors use less than 5%. The rest of the fuel becomes radioactive waste which must be stored away safely to avoid irradiation: in the case of uranium for tens of thousands of years, and in the case of thorium supposedly for merely 300 years.

So why aren't we using Thorium reactors right now? The simple answer is because they don't exist – or at least, not yet. Despite the fact that the first molten salt reactors were built in the 1960s, there are no energy-generating salt reactors running today. There have been efforts in Japan, China, India, the Netherlands, the US, and Australia, but thus far to no success. The remaining technical challenges have simply been too hard to overcome. Turns out, the online cleaning of fuel while the reactor is running is difficult to accomplish. To initiate the thorium fuel cycle, the reactors require highly enriched uranium as a start-up fuel, which is hard to produce. The molten salt liquid is not only extremely hot, but highly corrosive and thus can damage the reactor itself.

The big question is how long it will take until thorium reactors will become commercially viable – and whether the promise of green and clean nuclear energy will hold up after they do. It is easy to paint a rosy future when a technology is still theoretical. On the other hand, climate change catastrophes are just around the corner and all cards should be on the table. Do we really have the time to outright dismiss nuclear technology advancements? ■

AGLECTRIC FARMING: CASTING LIGHT ON THE POST-CARBON ERA

Ruben Colindres-Zuehlke investigates how new technologies could diffuse the tension between renewable energy and food production.

The competition for land between food and energy production is a substantial hurdle for a fossil fuel phase-out. A team of cross-disciplinary experts at the centre for Sustainable Food, Energy and Water Systems (SFEWS) at Purdue University, Indiana lays its focus on innovative photovoltaic (PV) designs.

As 72% of greenhouse gas emissions caused by humans are due to the production and consumption of energy, the transition to renewable energies constitute an essential step to avert a climate crisis to ensure global warming is limited to 1.5°C.

At this juncture, a recent drop in the costs of producing PV panels supports the viability of solar energy becoming the world's new primary energy source. The SFEWS have even provided a detailed calculation model for a complete transition from fossil fuel to solar energy. However, the feasibility of a solar economy is firstly dependent on the availability of land for solar energy production. PV plants supply less energy per unit of land area than their fossil fuel counterparts, meaning a solar economy will require a larger portion of land than existing fossil fuel plants currently do.

On the other hand, land is largely used for agricultural purposes, especially in densely populated areas of the world. This land competition between food and energy production is further accelerated by a rising global population. Numbers are estimated to approach 10 billion by 2050 so land constraints due to the consequential rise in global food and energy demands will present a major challenge for sustainability.

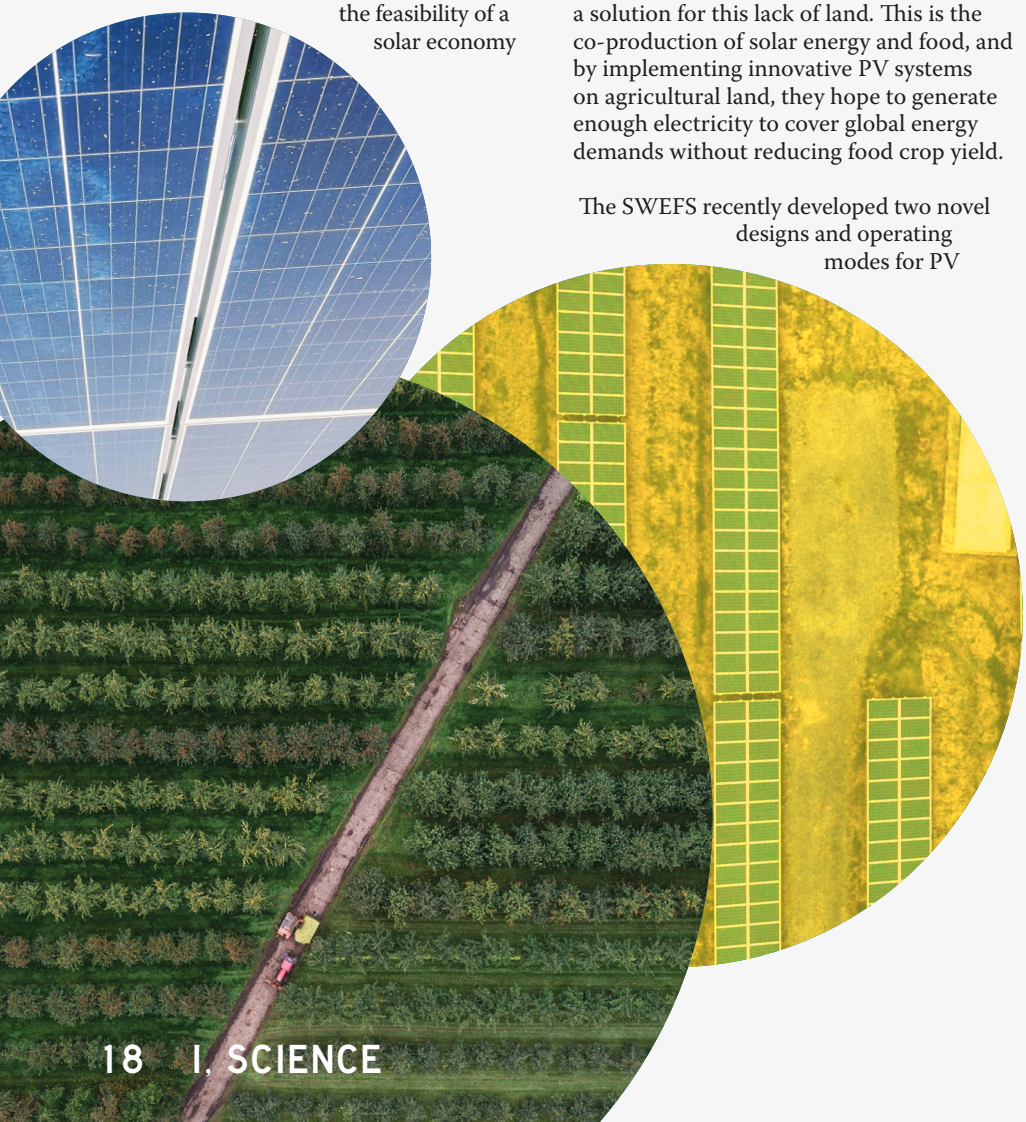
> A "rise in global food and energy demands will present a **major challenge** for sustainability."

The proposed concept offered by SWEFS of 'aglectric farming' could help provide a solution for this lack of land. This is the co-production of solar energy and food, and by implementing innovative PV systems on agricultural land, they hope to generate enough electricity to cover global energy demands without reducing food crop yield.

The SWEFS recently developed two novel designs and operating modes for PV modules to minimise any negative effects on the agricultural output as, earlier, when the PV panels were installed above the crops, they cast shadows which deprived the plants of sunlight for normal growth and photosynthesis, reducing crop yield.

The first design involves modelling shadows. By rotating the PV modules throughout the day, it is possible, at least in theory, to minimise the time any plant spends under a shadow, eliminating some of the negative impact on crop yield. This threshold does vary from plant to plant, though. Therefore, crop-specific PV systems will have to be created from pre-existing PV materials.

In their second approach, the SWEFS created new PV materials. Using a variety of innovative designs and materials, they manipulated the spectral distribution of light within the shadow to help the plant receive active photons of light, required for photosynthesis, allowing the rest of the light spectrum to generate electricity. While this second approach will initially lead to high costs, with low commercial viability in the short-term, it is thought that the new materials could be used for any crop species, making the modules more cost-efficient in the long run.



If aglectric farming is implemented, it will also present a major challenge to engineering agricultural machinery, as the commonly used farming equipment will not be able to operate between the PV modules. In addition to bettering the material for the PV modules, the development of smaller, automatic agricultural machines will also prove necessary for the feasibility of a post-carbon era.

The SFEWS is currently testing the two PV modules at Purdue University's Agriculture Centre for Research and Education (ACRE) Farm, to demonstrate the value of aglectric farming for major food crop production. The efficiency of each of the proposed PV modules will need to be further investigated to show which has the more promise to pair with the food crop industry. As these modules are highly specific to geographical location and crop species, studies are needed using several different major crops in different parts of the world as these will be essential in developing a commercially viable option for PV aglectric farming. ■

IT IS WHAT IT IS. OR IS IT?

Alana Cullen discusses the phenomenon of 'Millennial burnout' and advises on how to conserve our own energy.

If the Millennial generation could be summarised by a TV show, it would be Love Island: concerned largely with image, fortune and how to look good on paper (or strictly speaking, on social media). We have almost given up on trying to change the daily struggles faced by our entire generation, embodied by the phrase "it is what it is". Translating from Love Island speak, this phrase suggests the feeling of a lack of control over events in your life, a hallmark symptom of Millennial burnout. Previously considered a fad ailment embodied by lazy students, in 2020 a 'burnout' will be recognised by the World Health Organisation (WHO) as a chronic condition. This is serious.

Have you ever found yourself casually lying in bed, waiting for sleep to come when an uninvited, endless to-do list formulates in your head? If this is a familiar scenario, you may be suffering from a soon-to-be medical burnout. Defined by the WHO, burnout is a syndrome resulting from chronic workplace stress that has not been successfully managed.

The physiological symptoms include headaches, insomnia, gastrointestinal disorders and even heart disease. These are akin to those of chronic (prolonged, long-lasting) stress. Research has shown an increased risk of heart disease can be characterised by high levels of the inflammatory marker, c-reactive inflammatory biomarker, and of a protein called fibrinogen. These have a positive correlation in females with symptoms of burnout but, for reasons scientists don't yet understand, a negative correlation within males.

In the UK alone over 595,000 people identified as suffering with the condition in 2018. The list of burnout symptoms is, ironically, both exhaustive and exhausting. The psychological symptoms include depression and anxiety. Sufferers also exhibit emotional exhaustion from 'errand paralysis' – the feeling of always needing to be doing something more productive with your time. This ominous and overwhelming sensation has become our background noise, playing incessantly, no matter where we are.

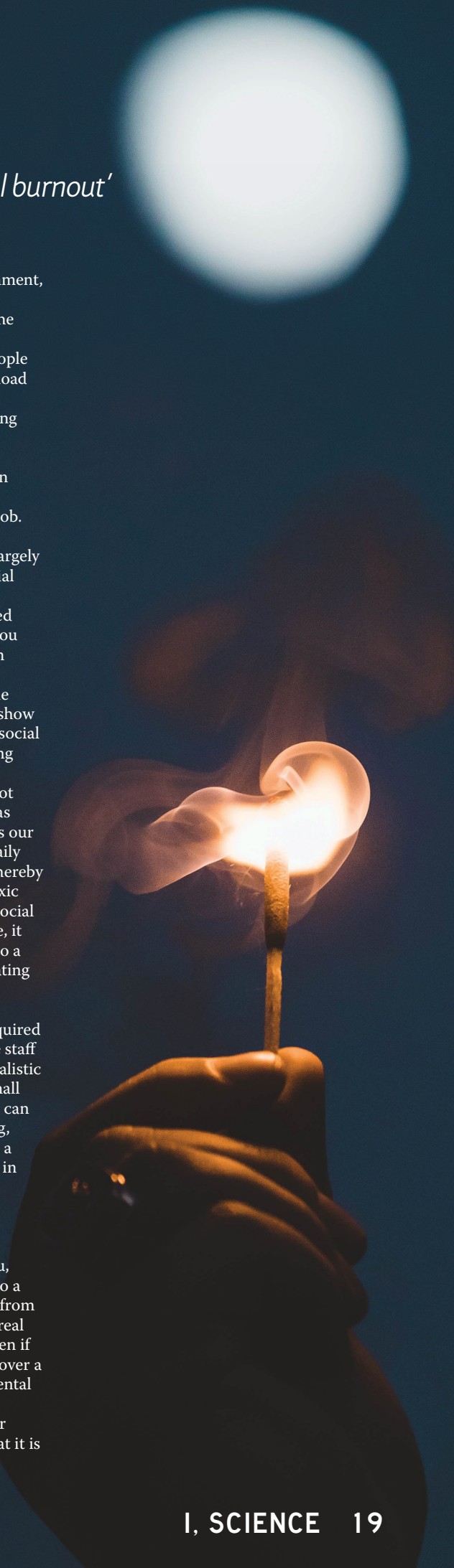
So, who is most at risk? Idolised for providing constant emotional support to others in a high-pressure work environment, healthcare professionals are the most likely people to suffer from burnout. The overarching theme seems to show the highest correlation of burnout with people in jobs which have an unrealistic workload and long working hours, together with idealised visions of themselves stretching their own needs to fit this demand. Decreased performance at work may also result from a lack of control, driven by exhaustion and causing consequent detachment of importance from their job.

> "This ominous and overwhelming sensation has become our **background noise**."

Social media is also largely to blame for Millennial burnout. When our technology is switched on, we are too. Can you even remember when you last turned your mobile phone off? The competitive drive to show our 'perfect' lives on social media means that we are always striving for the unachievable. We must remind ourselves that social media is simply not reality. Mindfulness techniques, such as group meditation, can be used to focus our thoughts on what we do have in our daily lives rather than what we see online, thereby helping to increase our tolerance to toxic social media. It's not all bad news for social media though, as, when used with care, it is an excellent way to connect people to a support network, often by communicating with friends and family.

Stronger action in the workplace is required by better trained managers to improve staff ratios and to ensure enforcement of realistic working hours. There are, however, small and progressive individual changes we can make: alongside the essentials of eating, sleeping and exercising well, including a disciplined work/life balance, working in a job you enjoy and talking about your concerns can be extremely beneficial.

Take the time to delve deeper into understanding what works best for you, as it will be a long term investment into a much healthier future. Taking a break from social media and connecting with the real world around you is a healthy start, even if it is as simple as taking some fresh air over a lunch break. Adapting now is fundamental to preventing Gen Z from suffering as Millennials have. Most importantly, for everyone's sake, let's stop accepting that it is what it is. ■



EXTREME ENERGIES

Guest writer, Sumeet Kulkarni writes about his involvement at the Laser Interferometer Gravitational-Wave Observatory, searching for signs of gravitational waves.

In the dreary desert of eastern Washington State, USA, one can find two giant, adjacent facilities, which both serve as signposts to how Einstein changed our ideas of energy, space, and time forever. One helped develop the most energetic man-made explosion of its time, while the other helped detect one of the most energetic events we have seen in the universe.

On my visit there last summer, I saw the scenery change abruptly as I drove towards the old abandoned hamlet of Hanford. The large irrigated fields fueled by the Columbia river morphed into a barren emptiness, save for the stray rolling tumbleweeds. My destination: a pair of huge concrete pipes extending two and a half miles each way in an L-shape. This is one of the two Laser Interferometer Gravitational-Wave Observatories (LIGO). Nearly 10 miles further, along the same route lies the Hanford B-reactor, a giant building resembling stacked cubes of different sizes, as if it had been designed with LEGO.

"Any object with mass, however miniscule, harbours **a tremendous amount of energy**."

The image of Albert Einstein is almost always accompanied by the equation, $E = mc^2$. An outcome of his Special Theory of Relativity, it states that any object with mass, however minuscule, harbors a tremendous amount of energy. The world saw a disastrous consequence of this concept when an atomic bomb obliterated Nagasaki, Japan, on August 9th, 1945. A mere gram of plutonium, about the weight of a paperclip, was converted into energy in this catastrophic explosion. The same plutonium was enriched at Hanford's B-reactor.

Fast-forward 60 years to more peaceful times. In 2015, the same equation confirmed that LIGO's first detection of gravitational waves came from a cataclysmic collision that released a burst of energy unparalleled by any single cosmic phenomenon we had seen. Gravitational waves are a prediction of Einstein's General Theory of Relativity, which states that all bodies are embedded inside the so-called 'fabric of spacetime', causing the fabric to curve and bend. The motion of matter at extreme densities, as seen in neutron stars and black holes, sends out ripples in spacetime called gravitational waves.

What LIGO detected on September 15th 2015 were gravitational waves coming from two black holes spiraling into each other. The two black holes had similar masses: the first one weighed 29 times the mass of the sun (solar mass), while the second weighed 36 solar masses. At the end of their merger was born another black hole, which had a total mass of 62 solar masses, 3 less than the sum of the masses of the two black holes that created it. What happened to this mass deficit? The entirety of it was converted into energy released as gravitational waves.

"The motion of matter at extreme densities sends out ripples in spacetime called **gravitational waves**."

The energy corresponding to a mass of 3 solar masses is incomprehensible. In grams, the sun weighs about 1033 grams, or a trillion trillion billion. Recall that a single gram of mass-energy was enough to destroy an entire city. In fact, the gravitational-wave power radiated by this event was more than ten times greater than the combined power of every star and galaxy in the observable Universe!

If you still find it hard to wrap your head around this, LIGO physicist Christopher Berry notes that in terms of food energy, this is about as many calories as you'd get from eating 8 billion suns made of butter.

Today, LIGO and its European counterpart, Virgo, have recorded over 30 such mergers involving black holes and neutron stars. Each of these has released humongous amounts of energy in the form of gravitational waves. The rate of detecting such events in our cosmic neighbourhood is now around one per week. Opening a new

window to study it, LIGO-Virgo have told us that the universe is a place more violent than we had imagined.

Intuitively, all forms of energy we know of involve the motion of objects in space, or the potential to do work by making objects move in space. On the other hand, energy released as gravitational waves involves the stretching and squeezing of space itself. How, then, can one feel the effect of this energy or exploit it to do work?

It was a delightfully simple thought experiment by Richard Feynman that cleared the dust. He imagined a pair of beads free to slide on a rigid rod, with some friction. If a gravitational wave passed by, it would stretch and squeeze both the rod and the beads. Strong molecular forces within the rod and bead material would prevent them from expanding and contracting. However, the motion of beads along the rod itself cannot be prevented. The beads would be free to rub to and fro, generating heat due to friction. Gravitational wave energy would thus get converted into heat in this process.

> "For an instrument that observes some of **the most energetic events in the universe**, we spend all our time worrying about the earthliest matters."

Given this possibility and the enormous amounts of energy, can we ever harness it?

It is almost certainly impossible. My job at Hanford last summer was to help with 'detector characterisation', the task of understanding the background noise to distinguish it from astrophysical signals. For an instrument that observes some of the most energetic events in the universe, we spend all our time worrying about the earthliest matters - high winds, noise from the air-conditioning system in a neighbouring building, trucks driving along the highway, and even thirsty ravens pecking on ice formed outside the cooling system!

This is because the events seen by LIGO-Virgo are billions of light-years away. By the time gravitational waves reach us, they become so feeble that the vibrations of space are a thousand times smaller than a proton. Even if they were larger, it would not be possible to devise something like Feynman's sticky bead apparatus to harness this energy. The 'beads' would then need to have an astrophysical size and mass similar to the objects that create these waves, a task beyond our wildest capabilities. But it is also true that Einstein himself deemed it impossible to even detect gravitational waves. We have only just begun to experimentally probe this fundamental aspect of gravity. Who knows what the future holds? ■

BON APPÉTIT!

A LOOK AT NATURE'S WEIRDEST MEALS

From mud to mosquito gonads, Jacqui Wakefield compiles some of the strangest food sources in nature.

Life on earth is all about transfers of energy from one organism to another through the food web. We all fill our own ecological niche, carving out a unique place in this transfer. We humans got lucky – we get our energy from things like chocolate and chips, but some living organisms weren't so fortunate...

RABBITS

Isn't poo such a waste? Surely there's so much more we can get from it. This is the thought process of rabbits. **Rabbits** have two types of poop, the dry pellets you usually see, and soft, vitamin-rich goodness. These critters are all about waste reduction and want to get every last bit of energy. This is not about eating poop for the taste. As rabbits eat mostly grasses, their cellulose-rich diet takes longer to digest, getting through their system before they've had a chance to squeeze out all of the nutrients. They beat this issue through hindgut fermentation, essentially digesting their food a second time, which means eating their poo. Their soft poo is eaten immediately after excretion, and they swallow it straight down. The poo sits in their stomach for five to six hours while they leech every last nutrient from it. This is where rabbits get 22% of their daily protein, so they really wouldn't be able to get by without doing it. This also replenishes the microbes from their gut, which maintains a nice healthy microbiome!

VAMPIRE BATS

Vampire bats are (shockingly) very vampiric, drinking up to half of their bodyweight in blood from mammals or birds in one sitting. It turns out that blood is actually a pretty good source of nutrients. Blood is rich in proteins and fats and it can be digested very quickly, meaning the bat can use all that bloody energy almost immediately. The bats eat by piercing the animal's skin with their razor-sharp teeth, and dribble on the wound. This isn't just hunger drool; their saliva is an anti-coagulant, which means the animal will continue to bleed without clotting, giving the bats a constant stream of blood. Brutal, I know. But, although they treat their prey with a fair amount of barbarity, vampire bats are actually very caring of one another. When one bat hasn't managed to find food, these guys are known to regurgitate blood and help others through rough patches. Very altruistic!

> "Isn't poo such a waste? Surely there's **so much more** we can get from it."

NEPENTHES – PITCHER PLANTS

The ***Nepenthes*** **pitcher plant** is a tropical carnivorous plant. Sometimes their pitchers can be so big that frogs can get accidentally trapped inside. But we can't be fooled by their size. Although they are carnivorous, these plants don't actively kill anything. The slippery rim of the plant causes insects to fall into the pitcher; they are then unable to climb out of the top due to the leaf 'lid'. However, these prisoners might not want to leave, as the ideal conditions inside the plant perfectly protect them from harsh outside conditions. They are also given a whole food web of other insects, as well as a sugar-rich liquid to eat. *Nepenthes* are actually a self-contained ecosystem, supporting the lives of hundreds of insects. In return, the *Nepenthes* is paid back for all its hard work through delicious faeces and insect carcasses.

WOLBACHIA

ORANGUTANS

So, we've explored some plants and animals, but bacteria can also have strange eating practices. Some of these have even been harnessed to benefit humans! ***Wolbachia***, a type of bacteria that infects mosquitoes, have a habit of chowing down on mosquito gonads. This might sound awful, but the species of mosquito which they infect is *Aedes aegypti* – the same species that transmits dengue fever. *Wolbachia* don't just eat this particular body part. They actually invade the cells of the mosquito, completely changing the way they reproduce. *Wolbachia* can only be transmitted through females, so they get into reproductive cells and change them to ensure the female only produces female offspring! Over time, a population made up entirely of females cannot reproduce, so would die out. This might sound dire for these mosquitos, but *Wolbachia* are a great tool for controlling the spread of *Aedes*-borne diseases.

> "Wolbachia have a habit of chowing down on **mosquito gonads**."

When it comes to detoxes, I think we've heard it all. Juice cleanses, saltwater, laxatives – the list goes on. **Orangutans**, however, might be ahead of us for the next big detox trend; eating dirt! As orangutans have a vegetarian diet, they end up ingesting high quantities of toxic tannins and acids. You might know tannins as the ingredient in red wine which makes your mouth feel slightly rubbery. Tannins are a plant defence mechanism which makes their leaves bitter and negatively affects digestion. Tannins keep some nutrients from being absorbed, so if orangutans are eating a lot of these, they won't be able to get the full nutritional value from their food. Luckily, the minerals in soil neutralise the toxic effects of tannins. This detox claim may actually be accurate in the case of these apes! ■

THE LONG ROAD AHEAD FOR SUSTAINABLE FASHION

Cristina Coman discusses the need for plastic recycling and the challenges it faces.

Finding renewable, clean methods of recycling polyethylene terephthalate (PET) bottle waste seems to be the frontier of the fight for energy efficient recycling. A recent study by researchers from the Birla Institute of Technology and Science in India revealed that use of solar electricity limits the environment and economic impacts of PET recycling.

In their assessment, the team compared three different methods of recycling PET: the use of virgin PET as a raw material with conventional electricity (generated from fossil fuels), use of PET waste with conventional electricity, and use of PET waste with solar energy. The third scenario was found to be the most sustainable solution from combined economic (solar electricity is three times cheaper than conventional electricity) and environmental perspectives (less damage to natural resources).

PET is the most commonly used plastic in the world, but also amongst the most highly recycled (48.3% of Europe's PET is recycled). The recycling of PET is not only essential to reduce the depletion of natural resources, such as crude oil, but also to diminish the energy demand required for its manufacture. It requires 80 MJ/kG (calorific value, which is the total energy released as heat) for virgin material — twice the daily amount of energy usage in a household — versus 10 MJ/kG for recycled plastic. Economic growth and concomitant changes in consumer behaviour constantly increase the global energy demand. Societies could tackle this issue by shifting to renewable energy sources, such as solar, wind, and biomass. In fact, Christiana Figueres, former secretary general of the United Nations Framework Convention on Climate Change, attested that "the energy transformation is one that is currently already under way, it is unstoppable, it is irreversible."

An area where sustainable recycling could make a huge impact is the fashion industry. Synthetic garments have long dominated the fashion market, owing to the fast and cheap nature of their production. The output of the fashion industry is currently made up of around 60% polyester material – twice the amount used for plastic bottles. According to Professor Steve Evans of the University of Cambridge, "the clothing industry is recognised as the second most polluting industry globally". There is little doubt about the issue here — action must be taken. In the move towards a more circular fashion system, recycling remains the best end-of-life option for managing plastic waste. The incorporation of recycled-PET filaments into clothing fabrics, home textile fabrics, and other materials presents itself as a fresh development trend.

One major problem we are facing is the widely varying plastic recycling rates across countries (for example, 60% in India, versus only 30% in the European Union), which remain critically low in particular regions (only 9% in the United States). This is due to significant disparities between the states of recycling infrastructures, financial resources available to modernise them, as well as potential environmental and health problems which must be addressed first. Nevertheless, large retail companies, like Adidas, appear ready to tackle these issues, as they have resolved to increase their uptake of recycled polyester by 25% by 2020.

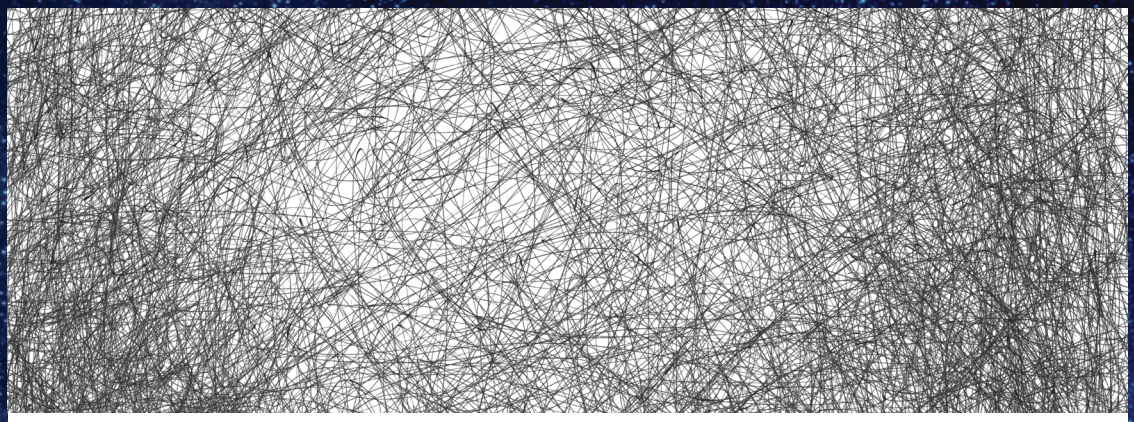
Over 300 brands around the world, including Fossil, Patagonia or Quicksilver, are already using REPREVE, the world's number one brand of recycled fibre, to make a difference. Through the recycling of plastic bottles, REPREVE has generated enough energy to supply 133,000 homes for a whole year.

With ethical and sustainable practices as their core mission, slow fashion brands from around the globe are taking a stand against the fast fashion trend. In Dubai, British expat Kris Barber has started the world's first bottle-to-yarn recycling plant: DGRADE takes plastic bottles from local businesses and transforms them into eco-friendly clothing and fashion accessories. In Denmark, Organic Basics has saved 1991GJ of energy so far — enough to power 569,000 households per year. UK companies such as ADKN and Thought are also tackling the same issues by solely relying on natural, organic and recycled fabrics.

Ultimately, sustainable fashion is a developing trend whose progress will not only depend on society's shift to cleaner energies, but also on the will of single individuals to reduce their own footprint on the planet. ■

> "With ethical and sustainable practices as their core mission, slow fashion brands are **taking a stand** against the fast fashion trend."

Plastics
by Yan Gi Cheng



Energy
by Mariana Heilmann

ON THE SPIRIT OF THE COSMOS

By Stefano Veroni

Energy, omni-diffused, from the outer space
to the galaxies' clusters,
from the novas which were, to the bright stars,
everything It spins, everything flusters,
up to the tiny edge of ours,
traversed by the comets' and meteors' race.
From the ardent sun to us It advances,
while keen seizes its dear earth,
and gracefully leads their gliding dances,
as it rays and beams its girth.

Energy, in the scorching heat of the day,
barren sweeps heavily quakes,
and rolls the rocks and mighty boulders moves,
the ground itself, so vast, the lands it breaks,
when the infernal depths it grooves:
escapes naught, of such force the tightened sway.
Thus, the hills, so mild, and the colossal peaks
which high scrape the azure skies,
the whole continents too, leisurely tweaks
as Its command and device.

Energy, over the immense marine stretches,
when has drawn the night its veils,
and sweet and smooth the candid moon reflects
over the spumescent wakes of the sails,
the waves, their power erects,
and diverted, whirling currents sketches.
Thus, the sinuous path of the dancing floods,
where blissful the critters sip:
their clear, fresh and sweet lymph It gently scuds
to life rousing every drip.

Energy, awakes Its breath the gusty air,
the happy breeze, clear and soft,
where gracious the sparrows twirl, and the swifts,
as their symphonies daint'ly fuse and waft:
thus, fly their harmonious gifts
to the pearly clouds and to the sky, azure 'nd fair.

Tender leaves It sustains, timid spores,
a carbon atom floating
all alone, in their journey to unknown shores,
the sparks of the dawn toting.

Energy, It's our Earth's sincere core:
ignites its hub and departs
to the world's embroidered vestment and drapes,
as the gasp, the start, the pulse of its heart
high to the exterior traipse,
rising and gliding, gro'ing Its fiery roar.
So intense, powerful, superb is the show
as It flares its unveiled forms;
so great, so noble, Its deep blazing flow
as our hearts kindles and warms.

Energy, spreads diffused Its glowing gleams,
as to the serene sky alight,
lovely reawakens the scented blooms,
and high adorns the trees cherry and bright,
as through the day's sweet perfumes,
the smitten herds leap, lured in vital streams.
Energy, the sky we owe, the lands, the sea,
all begun things, all things done,
for without It, naught is risen to see
the shining shores of the sun.

Life, precious, is Its universal breath
to the mortal human soul,
each, alone, unique and single and one,
in It absolute and utter and whole,
as along streams, mounts, the sun,
the stars, it goes, over life, over death.
Energy, infinitely, varies its face,
its essence same and diverse,
as sempiternal stamps the cosmos' trace,
and is its spirit disperse'...

...the eternal principle of universe.

Neo Artisvir

RE-ENERGISING OUR APPROACH TO MEDICINE

Lydia Melville examines how animal hibernation could inspire medical research.

With winter approaching, it is natural for us to feel increasingly sleepy. Some animals find rest in a state of low physical and mental inactivity called torpor, mostly due to a limited food supply. When this expands over a longer timeframe, we know it as hibernation or multi-day torpor. However, hibernation is not just an extensive period of sleep on little food. Huge physiological changes occur in these well-adapted animals that could offer benefits to modern medicine.

Humans, like all mammals, are endotherms. This means we control and regulate a constant core body temperature which comes at a high energetic cost, to keep daily metabolic processes working optimally. Scientists think all mammals may, at one point, have had the ability to suppress their basal metabolic rate (BMR) to hibernate, as the gene is still present within us, though currently inactive. As our ancestors initially lived nearest the Equator, where food supplies were abundant all year round, it may be that slowly through evolution, the genes involved in hibernation (and active in animals such as brown bears, wood frogs and Arctic ground squirrels), were inactivated in humans. Not only do hibernators save energy, they can also prevent long-term damage to their bodies under excess stress when food supplies and temperatures are low. This, however, comes at the cost of a larger brain, which non-hibernators have evolved.

> "Scientists think all mammals may, at one point, have had **the ability to hibernate**."

So, if hibernation in humans is possible, could the adaptations made by these animals be adopted into our modern medicine?

By understanding the responses of hibernators to their environment, developments in modern science, health, and even space travel could be opened for us. Hibernation is complex, involving huge bodily changes to animal physiology. Non-rapid eye movement (NREM) sleep (the sleep in which we do not dream) is a rare example of a suppressed metabolic state and probably the most similar experience to torpor that we experience. Sleep is essential for us. We are aware of the health detriments caused by lack of sleep. So, as we are awakening to the importance of sleep, why stop dreaming there?

It may be surprising to know that the state of torpor is a reversible process. Even though animals occasionally arise from hibernation with serious physiological changes, including symptoms of asthmatic lungs and memory loss, they are well-adapted to reverse these symptoms once temperatures rise and food supplies increase. For example, the brains of most hibernators receive just 10% of the normal blood flow during torpor. When hibernators wake, their organs are surged with blood and recover with no or very little damage to their brain tissue. Humans, by contrast, suffer significantly upon re-infiltration after limited blood flow (ischaemia), such as during a stroke. The ability of

hibernating animals to reverse any changes in their physiology rapidly and without long-term damage could be useful when treating a patient after a stroke. Inducing an artificial state of torpor in humans could theoretically help to gradually slow brain activity, reducing the overall extent of damage to the tissue.

It is not only the brain that could be protected by mimicking a state of torpor in humans. Often, we envision hibernators gorging on fatty foods before their deep slumber. Like humans, hibernators house microbes within their intestinal tract, which are alerted through complex chemical changes when the animal enters torpor. The microbes then produce metabolites by breaking down food sources, ensuring the host hibernator maintains its health during the long periods of fasting.

"Even though animals occasionally arise from hibernation with serious physiological changes, they are **well-adapted** to reverse these symptoms."

The compilation of microbes within the body is called the microbiome. The microbiome undergoes alterations during periods of disease or a course of antibiotics, which can take months to recover. There could be potential to modify our own human gut microbiome in a similar way to the adaptations made by hibernators, allowing us to reap the health benefits. This could be achieved by adding carefully balanced probiotics to our diet or by introducing certain microbes through medical practices such as enemas. At the moment, though, these studies are very much still in their infancy.

As well as manipulating hard-working microbes during hibernation, animals can also save energy by reducing their costly immune responses. With less immune-based inflammatory signalling, less inflammation occurs in the body, which is hugely beneficial, as ongoing inflammation has been linked to long-term organ damage. In humans, this manifests itself as conditions such as cirrhosis in the liver.

Severe organ damage in humans is treated by transplantation but performing these procedures is complicated and expensive. In addition, the demand for organs is currently higher than the supply, and still rising. Wood frogs in Canada can withstand temperatures below 0°C without damage to their organs by producing DIY 'antifreeze', mostly as glycerol. Studying the process used by the wood frogs could allow huge advances in frozen tissue storage (cryopreservation) for humans. This may also improve the shelf life of donated blood samples within the NHS beyond 30 days and of donated platelets which are kept for just seven days before use.

WHAT NOW?

A better understanding of the physiological changes which occur to animals during torpor could help us to regulate much more than just our core body temperature. Mimicked on these animals' adaptations, this new knowledge may allow the introduction of a restful and recuperative method of treating patients amidst our currently chaotic lives. Studies on hibernating bears, which do not lose much bone density during their slumber, has alerted scientists to ways in which astronauts could avoid weakened bones on their space expeditions. In our increasingly busy world, taking a step back to reflect on how animals adapt to their environment could certainly help to boost our own health. Rather than just dreaming of a better quality of life as we extend our life expectancy with modern medicine, we may already hold the genetic and microbial cures for ailments, deep within us. ■

POST-APOCALYPTIC PARADISE

Charlotte Hartley investigates the extent to which ecosystems can recover from nuclear catastrophes.

WHAT DOES LIFE LOOK LIKE AFTER A NUCLEAR DISASTER?

On 26th April 1986, during a simulated power outage safety test, reactor no. 4 of the Chernobyl Nuclear Power Plant overheated, ultimately amounting to the world's worst nuclear disaster. The subsequent explosion and reactor core fire released enormous amounts of radioactive particles, called radionuclides, into the atmosphere. Over the coming days, as reports of radiation sickness proliferated, hundreds of thousands of residents from the surrounding communities were evacuated. Downwind, the contaminated pine trees of a nearby forest turned a rusted shade of red before promptly dying. Early reports concluded that the local wildlife had been decimated by radiation-induced mutations.

Over 30 years on, the Exclusion Zone's few visitors paint a very different picture. It is one of nature making an unexpected recovery. In fact, some researchers who have studied the area claim that local wildlife is thriving, even labelling the area as, in essence, a nature reserve.

Does this mean that ecosystems can bounce back from a disaster with the severity of Chernobyl? The idea feels unlikely. Radionuclides emit ionising radiation, which at high enough levels, lethally damages tissues. It was this process by which dozens of nuclear technicians and emergency workers were killed, and the Red Forest earned its nickname. But, even at lower dosages, radiation is a well-established mutagen. This means it induces changes, or mutations, in the cellular genetic material (DNA), which may manifest over longer periods as cancers or physical abnormalities.

Radiation-induced damage has certainly been reported in organisms within nuclear exclusion zones. Some bird and mammal populations around Chernobyl show increased incidence of cataracts, cancerous tumours and a smaller than average brain size – mirroring the human survivors of the Hiroshima and Nagasaki atomic bombs. Partial albinism is another easily observable consequence for exposed organisms: the same white spots which appeared on the fur and feathers of cattle and barn swallows in Chernobyl later appeared in Fukushima, after the only other International Nuclear Event Scale maximum severity disaster in 2011. Less visibly, abnormality rates for sperm morphology and swimming behaviour were observed to be higher in Chernobyl, compared to populations elsewhere in Europe.

There also is evidence for similar radiation-induced consequences in invertebrates. Pale grass blue butterflies near Fukushima sometimes develop with malformed appendages and unusual colour patterns. Meanwhile, far from the comic book superheroes you might picture, Chernobyl's radioactive spiders spin erratic webs, resembling those produced under the influence of psychoactive drugs. Many of the observed effects are thought to have a genetic basis, so can be passed on to the next generation (if they don't limit lifespan enough to preclude reproduction, that is). However, the direct toxicity of radiation exposure may be at least partially responsible in some cases.

> "The implication that everyday human activity is **more damaging to wildlife** than the worst nuclear disaster is sobering."

One might expect that the prevalence of potentially damaging mutations would lower organisms' fitness, ultimately resulting in reduced abundance of species in contaminated areas. This is exactly what a series of studies in the Chernobyl Exclusion Zone by frequent collaborators, Anders Pape Møller and Timothy Mousseau, concluded, suggesting that the ecosystem is still severely damaged.

> "Chernobyl's **radioactive spiders spin erratic webs**, resembling those produced under the influence of psychoactive drugs."

But these impacts are not universal. The radiation released from Chernobyl appears to have had no ill-effects on the abundance of certain species. Weirder still, others' populations are higher now than before the accident. This lack of consensus is a source of intense debate among scientists and to say that Møller and Mousseau's views are representative of the radiobiology community would be inaccurate. Other researchers in the field have been unable to replicate their findings, leading some to question their methods and credibility (Møller was previously found to have falsified data in an unrelated experiment).

One theory is that organisms are evolving resistance to radioactivity. However, the experimental conditions required to show that evolutionary adaptation has occurred are difficult to meet, so supporting evidence is patchy. Possibly, the radiation doesn't lethally affect animals until after they have already reproduced, meaning populations wouldn't decline. Or, in species with naturally low juvenile survival, most will die from normal processes before radiation-induced mutations can kill them. Of course, this doesn't mean that individual organisms don't suffer because of the radiation; cataracts may not kill them, but will probably reduce their quality of life.

Another reason why the wildlife in Chernobyl is doing better than expected could be the fact that radiation levels dropped drastically shortly after the accident. Furthermore, the initial pattern of nuclear fallout was largely driven by the weather at the time, leaving some areas close to Chernobyl with relatively few radioactive particles. Ultimately, across much of the Exclusion Zone, the radioactivity simply isn't high enough to cause severe reproductive damage to animal populations.

Additionally, animals can hugely benefit from the lack of humans. Wolves, elk, deer and wild boar are among those whose populations in Chernobyl have not suffered. Even brown bears have since colonised the area. Enormous changes in land-use after the mass evacuation removed many of the threats previously facing these animals: agriculture, hunting and forestry. Lower populations of competitors or predators probably also played a role, but the implication that everyday human activity is more damaging to wildlife than the worst nuclear disaster in history is sobering.

Chernobyl is evidently not the post-nuclear wasteland one might expect. And yet, the reports of physiological and behavioural abnormalities are difficult to ignore. If nuclear power is to become a larger component of the global energy mix, we must be better prepared to deal with the possibility of future nuclear disasters. In addition to the human cost, ecological damage is a hugely important consideration, but, for now, Chernobyl and Fukushima provide scientists with a unique experimental setting. ■

INDIGENOUS PEOPLES ARE AT THE FOREFRONT OF GLOBAL WARMING

S Reid-Collins sheds light on the struggles faced by the Arctic's indigenous communities.

People around the world are talking. They are desperately looking for answers, for solutions. The planet has warmed at an alarming rate (nearly 1°C over the past century, according to NASA) and activist groups, such as Extinction Rebellion, are taking to the streets to make their voices heard.

But the voices least heard are of those most affected. Indigenous people across the globe rely on their close relationship with the land for their livelihood. Climate change is seriously affecting that.

One such people are the Sámi, the indigenous people of Norway, Sweden, Finland, and the Kola Peninsula in Russia. They have been herding reindeer for thousands of years and are reliant on their symbiotic relationship with their reindeer and the land. This way of life is being threatened. These communities are particularly vulnerable to climate change, and temperatures in the Arctic have risen at over double the global average rate.

Carl-Johan Utsi is a reindeer herder and photographer based in Jokkmokk, Sweden. His family has been herding reindeer for countless generations. After realising the devastating effects of "green energies", such as hydropower, on the people living along the rivers, he went to university, determined to find a solution. He studied for a Master's degree in Engineering and Modern Physics at Uppsala University, Sweden, hoping to solve the issues associated with nuclear fusion energy and find a better "green energy" source for everyone. While studying this course, he realised that it wasn't for him, and in 2006 he returned to his family and started looking after his own reindeer herd.

That was the year that the Sámi noticed everything change.

"I told my fiancée, '2006, this will be the year that we'll remember as the start of climate change,'" Utsi says. "You could see the impact so clear and at once. It was [a] really bad winter for the reindeer, for all of Sápmi [the region inhabited by the Sámi]."

Since 2006, he says, the Sámi have not had two similar winters in a row. "I could compare to my father who had a stretch of 30 years that were basically the same when you look at the reindeer herding. They herded the same way. They used the same lands."

One of the effects of this warming is the change of snow conditions. Warmer winters are causing "rain on snow". This phenomenon was extremely rare prior to the year 2000, but now happens every year. After the initial snowfall, rain returns and melts the snow, causing it to freeze. This creates hard-packed snow and sheets of ice.

> "They have no interest in us. **We are on the losing side.**"

Reindeer's main food source, lichen, is buried beneath the layers of snow. Using their sense of smell, they locate it and dig to find it. But now, hidden beneath the layers of ice, they can't smell it anymore. Or, if they can smell it, Utsi says, "they do the calculation that it's not worth the effort to dig it up." This means that the reindeer will start wondering off in search of scarce food, spreading out and creating extra work for the herders who then struggle to keep track of their herd. Herders are consequently being forced to supplement their reindeers' diets with pellets, just to ensure that they have enough food to survive.

But it's not just Arctic warming that is causing devastation for the Sámi and their reindeer. Utsi explains the worrying impact of deforestation. If reindeer weren't able to find ground food in previous generations, they would survive on tree lichen. But deforestation has cut down these old trees. "Even if the forest grows up again," he says, "there's no tree lichen."

As the country, and the rest of the world, shifts towards biofuel, this is something which he predicts is going to get even worse. Trees do not need to grow as quickly to produce oils as they do for timber. This is leading to a lack of biodiversity. Almost all the forests in Sweden are very young, Utsi says: "Actually, I don't call it forest anymore, because forest is a big diversity of species and tree ages." Now, the forests are just growing pine and birch. "We have been working with the forest industry in different ways for tens of years, trying to coexist. They have no interest in us. We are on the losing side."

As Sweden moves on to cleaner energy sources, more land is being stolen from the Sámi. Windfarms are being built in traditional pastures. Mining is increasing as the government tries to keep up with the resources required to build new energy sources: "The problem is that Western society doesn't want to cut down on energy usage. They want to switch it to 'green energy', but somebody has to pay for that." Again, the impact is being felt by the Sámi. "We are facing a new wave of colonialism or green capitalism that will totally destroy reindeer herding for sure."

Utsi has considered solutions to this for some time: "For me it's a question about Europe and the will of Europeans, if they're willing to protect the only indigenous livelihood in Europe. Are the Europeans willing to sacrifice it for the lifestyle that they have?"

Without reindeer herding, he worries about what the future might hold for the Sámi. "You can already see what would happen to our indigenous culture when you steal away our way of life. Just go to America, look at North America, how the societies are totally collapsed there."

Despite all their efforts to co-exist and adapt to change, he is really not hopeful for the future of the Sámi: "Reindeer herding is on the verge of collapsing. It's just a matter of years. The change in climate is too fast for us to adapt. It's just about survival now." ■

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