Technology Networks

The Scientific Observer

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Navigating Eco-Anxiety in Children

Mariana Gil, PhD

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EDITORS' NOTE

Dear Readers,

Welcome to the 35th issue of *The Scientific Observer.*

As we grapple with the urgent realities of climate change, exploring the human dimensions of these challenges is increasingly important. In this issue, Dr. Mariana Gil's feature article delves deep into the hearts and minds of our youngest generation, confronting the acute and long-term impact of climate anxiety on children. Through expert insights and compassionate advice, this profound article sheds light on how we can support young people through these tumultuous times, fostering resilience and hope in the face of uncertainty.

We're also examining how research scientists, faced with the monumental task of understanding climate change and devising approaches to mitigate it, are often burdened with feelings of guilt and pressure. In an exclusive interview with Dr. Natalie Cooper, ecologist and senior researcher at the National History Museum in London, Rebecca Dawes asks: how can scientists persevere amidst global crises?

In 2009, Kathryn Ramirez-Aguilar established the University of Colorado Boulder (CU Boulders)'s CU Green Labs Program. Her goal was to address the resource-intensive nature of the institute's research laboratories. In this issue of *The Scientific Observer,* Ramirez-Aguilar outlines the key strategies that have engaged scientists in sustainable practices and details the critical role that research funding bodies play in shaping sustainable practices within laboratory environments.

Also in issue 35, we tread the evolving landscape of agricultural biotechnology, where emerging gene-editing technologies offer hope for revolutionizing food security and alleviating the impacts of climate change on crop sustainability.

We hope you enjoy our exploration into these pertinent topics – and many more – in issue 35 of *The Scientific Observer.*

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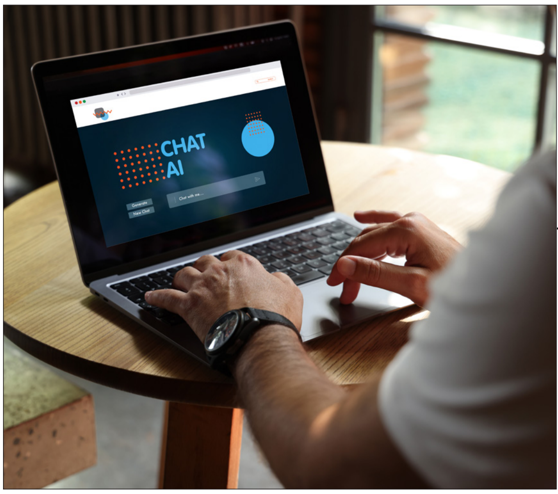
If you would like to contribute to *The Scientific Observer,* please feel free to email our friendly editorial team.

From the Newsroom

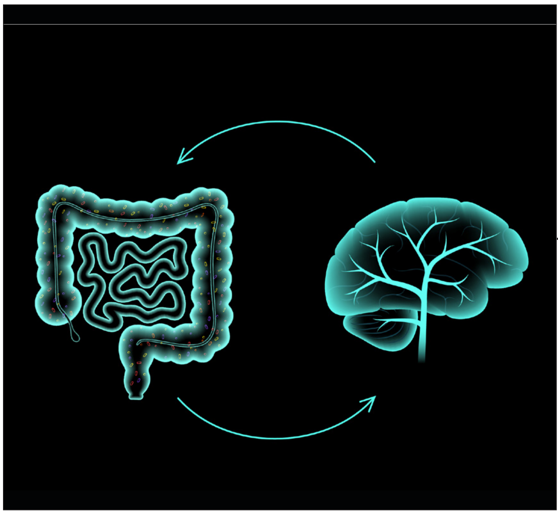


Scientific Journal Publishes Paper With AI-Generated Introduction

MOLLY CAMPBELL

A peer-reviewed scientific paper has gathered significant attention on the social media platform X (formerly Twitter), albeit for unfavorable reasons. The first line of said paper's introduction appears to have been written by a large language model.

JOURNAL: *Elsevier*



The Gut–Brain Axis May Not Operate as Previously Thought

SARAH WHELAN

New information on how the gut and brain communicate has been uncovered by Flinders University researchers in a development that could influence how we make and use certain drugs, such as antidepressants.

JOURNAL: *Cell and Tissue Research*

Concerned About Microplastics in Your Water? Consider Boiling It First

ALEX BEADLE

Boiling tap water may be an effective way to reduce exposure to nano- and microplastics, a new study suggests, after observing tiny plastic particles appearing to get trapped within the limescale deposits formed when hard water is boiled.

JOURNAL: *Environmental Science & Technology Letters*

Want to learn more?
Check out the *Technology Networks newsroom.*

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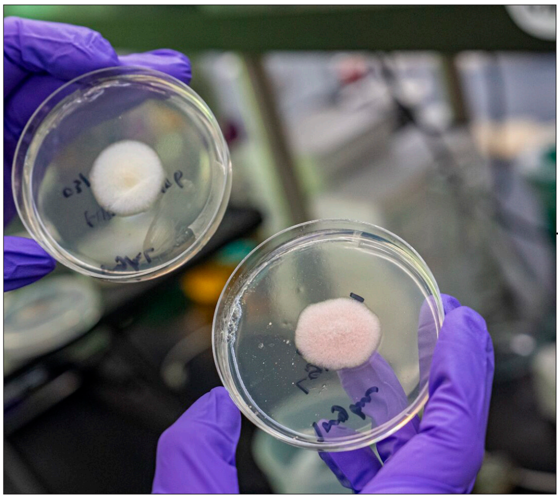

Scientists Engineer a New Mold-Burger

LEO BEAR-MCGUINNESS

Despite the unappealing origins of the fake meat, burgers derived from different fungi species have become supermarket staples in recent years thanks to rising consumer interest in environmental sustainability and meat-free lifestyles.

JOURNAL: *Nature Communications*

Imaging Study Details the Menstrual Cycle's Effects on the Brain

RHIANNA-LILY SMITH

A new study, published in *Nature Mental Health*, investigated how rhythmic oscillations in hormones shape brain structure during the reproductive years.

JOURNAL: *Nature Mental Health*

Phage Therapies for Multidrug-Resistant Infections Should Consider Host Response

BLAKE FORMAN

Scientists at the Geisel School of Medicine at Dartmouth have shown that therapeutic phages can be detected by epithelial cells of the human respiratory tract, eliciting proinflammatory responses that depend on specific phage properties and the airway microenvironment.

JOURNAL: *PLOS Biology.*

Marilyn Sargent/B erkeley Lab, Natracare/Unsplash, iStock

Want to learn more?
Check out the *Technology Networks newsroom*.

Fighting For Truth in a Burning World

REBECCA DAWES

How to remain a good scientist amidst the climate crisis

As humanity faces a growing climate and biodiversity crisis, the scientific community finds itself on the frontlines. Scientists, tasked with understanding and mitigating these issues, can often feel burdened by such responsibilities, resulting in feelings of guilt and pressure.

In this article, Dr. Natalie Cooper, an ecologist and senior researcher at the Natural History Museum in London, shares her insights on how to persevere as a scientist amidst global crises.

THE IMPORTANCE OF THE SCIENTIFIC VOICE

INTERDISCIPLINARY COLLABORATION

The climate crisis is a multi-faceted challenge requiring interdisciplinary solutions from experts across a variety of fields such as ecology, sociology, economics and policy-making. Collaboration between scientists, the public and government is vital to save our planet.

Cooper emphasizes the need for scientists to be mindful of their communication, explaining how public engagement has changed how she does her research. “I think carefully about what I'm doing and how that information might be transmitted to the public,” she says.

She explains that her role in the museum enables her to interact with donors and government departments: “Even if I'm not working directly on those climate solutions, I can be working with people who might control policy or the funding of work on climate solutions," she says. The role of the scientist extends well beyond pipetting and writing research papers; the scien-

"There are some scientists who feel that science should be kept separate from politics and emotion," she adds. "I would encourage those people to realize that nothing is without context, including science. They need to get involved."

support. Cooper emphasizes the importance of community for coping with difficult emotions surrounding major crises such as the climate crisis: "Some people manage to put it into a little box in their head, but most people have been really open about say-

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tific voice is powerful and significant in the public sphere – and we must use it wisely.

ADVOCACY AND ACTIVISM

Scientists have a unique position of authority and credibility, which can be used to raise awareness, influence policy and advocate for sustainable practices.

Are scientists doing enough to advocate for the planet, and, if not, what more they could be doing?

"Scientists are doing a pretty good job of getting the word out about the climate crisis," Cooper says. "Everyone could be doing a good job; I'm not a climate scientist, but I will shout about it ... if I give a presentation with a funny animal fact, I will ensure we also talk about how those animals are facing extinction."

Individual actions that scientists can take beyond the laboratory environment to lead by example include joining a charity, working in a nature reserve or getting involved with local campaigning groups, for example.

Empowering young people is particularly important, Cooper highlights: "Working with young activists who come from around the world is very inspiring; it does make me feel better about the future. As people who have gone through their whole lives with [knowledge of the climate crisis] underlying their childhood, they will, hopefully, make great change when they get to positions of power."

THE IMPORTANCE OF COMMUNITY

Collaboration across scientific networks allows for not only the exchange of ideas, but also emotional

ing [the climate crisis] is something that upsets them," she says.

"For some [scientists] it's especially difficult; they're working with species that are really close to extinction ... coral reefs they may have worked on are dead and don't exist anymore. Having a community to chat with has been really important," she adds.

Now more than ever, scientists must come together. With the help of social media platforms, connection to a supportive network can be a mere click away, whether you fancy joining a network such as this LinkedIn group for women in STEM, or joining an online community via one of the myriad science associations.

FOSTERING HOPE

In the face of seemingly insurmountable challenges, Cooper reminds us that small successes can make a difference, recalling examples of people coming together to solve major environmental problems. She describes the remarkable resurgence of osprey and bald eagle populations in the US, and peregrine falcon and red kite populations in the UK, following the 1972 ban on the once routinely used pesticide dichlorodiphenyltrichloroethane (DDT) after it was found to cause eggshell thinning for birds of prey. Recounting the recovery of blue whale populations from the brink of extinction, Cooper reiterates, "It's not all bad. There's definitely hope."

Even when it may feel like our accomplishments are just a drop in the ocean, progress is progress. Amidst significant challenges, it's vital that we take the time to celebrate our successes, however small they may seem.

PRIORITIZING MENTAL HEALTH

A career in science can be noble, but often carries an emotional toll and significant self-sacrifice, with scientists finding themselves unable to "switch off". With over 20 years of research experience, Cooper recounts the challenges she faces as an ecologist amidst the climate and biodiversity crisis. "I go through cycles of feeling very guilty [about not working more], but I have my own life. I can be worried about climate change, but I still need to do the washing," she says. Her comments highlight the almost comical challenge many scientists face, juggling their personal lives – picking up the kids, taking out the bins – with the weighty responsibility of helping to solve humanitarian and environmental crises through the humble tools of research.

Cooper reminds us of the importance of balance between personal life and concern about the climate crisis, urging us to prioritize our mental well-being: "If I can't do something [about the climate crisis] right now, what else do I need to be doing to make sure that my life continues running? [Eco-anxiety] is a constant undercurrent. Maybe that's a good thing, maybe it motivates researchers – but it's important to make sure that the undercurrent doesn't overwhelm you."

Despite pressure to remain current and impassioned regarding every problem world-over, the daily barrage of distressing news we are exposed to can become overwhelming. Cooper advises: "It's okay to have a social media detox... self-care is really important. If you're feeling bad, sitting down and ruminating isn't going to help. Try to do nice things, hang out with your friends, engage in hobbies."

Balancing a personal life with the struggles of the research environment can be a challenge, both for the burnt-out post-grad student and the esteemed senior researcher. Having spent time working as a researcher in the US, Cooper highlights the differences between UK and US work culture, emphasizing the importance of a work-life balance. "The US system is at an extreme where it's not unusual for people to be working 60 to 70 hours a week... that's really unhealthy," she says. "I strongly encourage my students to take breaks, holidays and work a standard nine-to-five so they don't feel they have to be working constantly."

In a culture where success is increasingly defined by the arbitrary metrics of career progression or monetary wealth, it's crucial that we focus on real successes – creating a better world, supporting our loved ones and living a fulfilling life. Achieving these goals, and doing good science, can only happen if we are mentally well enough to do so. So, how do you remain a good scientist while the world burns? Step one: look after yourself.●

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Universal Microbial Network Breaks Down Human Flesh

MOLLY CAMPBELL

The breakdown of biological material by microbes is an integral process to life on Earth. While some genetic studies have probed the microbial communities that decompose plant matter, surprisingly, we know very little about the decomposition of vertebrates such as humans.

That was until a recent study by scientists from Colorado State University (CSU) identified a network of microbes that appear to "universally" drive the decomposition of animal flesh, regardless of environmental variables.

The research team, led by Dr. Jessica Metcalf, associate professor in the Department of Animal Sciences, tracked the decomposition of 36 human cadavers across 3 willed-body donation sites: the University of Tennessee, Sam Houston State University and Colorado Mesa University.

Over the multi-year study, cadavers were placed in cages and exposed to the elements across all four seasons. After 21 days of exposure, Metcalf and colleagues collected skin and soil samples from each cadaver, which were then subject to various molecular and genomics studies including genetic sequencing and metabolite analyses.

Strikingly, the same 20 microbes were identified across all 36 bodies, regardless of the climate or type of soil to which they had been exposed. The network, including characters such as *Oblitimonas alkaliphila, Ignatzschineria, Wohlfahrtiimonas, Bacteroides* and *Vagococcus lutrae*, represented a "unique phylogenetic diversity" that was rare or undetected in host–association or soil microbial communities in the American Gut Project or the Earth Microbiome Project data sets, two large studies characterizing microbial communities in humans. The microbes are found on insects, however, suggesting that insects act as "vectors", delivering microbes to the cadavers for decomposition.

Uncovering the makeup and timing of the microbes that decompose human flesh carries important implications for the field of forensic science. Met-

“We see similar microbes arrive at similar times during decomposition, regardless of any number of outdoor variables you can think of,” Metcalf said.

calf and collaborators applied machine learning approaches to the data and built a tool that is capable of predicting – with high accuracy – the time that has passed since a body’s death. This period, also known as the postmortem interval, can be difficult to decipher when remains have been exposed to harsh environmental conditions.

Technology Networks spoke with the research team to understand how the study – which builds on over 10 years of work – was conducted, and the how the data could help in modulating decomposition processes in human death industries.

Q: Can you explain why little was known about the ecology of vertebrate decomposition, prior to this study?

A: Microbes have been known to be one of the major players when it comes to decomposing vertebrate remains, including humans. However, some of the intricacies of how the decomposer microbial community members respond and interact with each other isn’t well known, particularly comparisons of these activities across climates. The reason for this lack of knowledge is that most prior research in the decomposition field has focused on the decomposition of plant material due to its vastly larger global biomass.

Q: Why did you choose a 21-day observation period?

A: The 21-day period was chosen because this is when vertebrate decomposition is most dynamic. We see the largest changes to the body, surrounding environment and the microbial communities. So, by choosing this timeframe we capture how the microbes are responding to these dynamic changes.

Q: The study generated a significant amount of molecular and genomic information from the samples. Can you summarize the different methods that you used to analyze this data, and why?

A: We sequenced an essential gene for all prokaryotes called the 16S rRNA gene. Sequencing this gene allows us to identify the microbial members in the system and get a relative measurement of their prevalence at each time point. We also sequenced a eukaryotic gene, 18S rRNA, that has the same role in eukaryotes to look at the microscopic eukaryotes in the system.

Further, we performed metagenomic sequencing to study the functional genes of bacteria, such as the ability to create or use specific nutrients. We were also able to assemble genomes of some key bacteria with the metagenomic data, which provides the first microbial decomposer database to our field. Lastly, we generated metabolomics data which is a profile of some of the nutrients and resource types within the environment.

Q: Can you tell us a bit more about the universal decomposers? What are some of the key microorganisms in that community? Were there any that surprised you?

A: These universal decomposers are organisms we found to be associated with active and advanced stages of decomposition at all our climate locations. Some of these organisms include bacteria known to be associated with blow flies that feed on remains, such as *Ignatzschineria*. None of them were particularly surprising, but there are some which we don’t know a lot about, such as *Oblitimonas*.

Q: You found the universal decomposers on insects, which implies that insects “bring them in” to cadavers. Can you talk more about these insects – are they found all over the world, and do they face any environmental pressures?

A: Yes, insects serve as vectors both to and from the cadavers. They bring their microbes in and deposit them via feeding and defecating. In the case of flies, they also lay eggs that hatch to maggots and deposit/pick up their own microbes. Then, once the flies/maggots leave, they take some of these microbes with them to the next location. These insects include a broad subset including flies, beetles and ants.

There are studies in which decomposition has controlled settings to exclude insects, and some of the same microbes we detect do occur, but the insect specific microbes are missing. The decomposition process still occurs, but the lack of insects can lead to slower progression and even tissue remaining on the cadaver longer.

Q: The setup of the experiment – human bodies exposed to the elements in cages across research sites – might be interpreted as quite grim by some. I appreciate that this is the only way to gather data such that it reflects real life scenarios of human decomposition, but can

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you explain how you, as a research team, felt during the experience of the study?

A: The ultimate goal for studying human decomposition specifically is to better improve society. This can be through discovering greener ways to handle the deceased, improving our understanding of essential ecological processes so we can mediate them, and for forensic investigations to ensure justice is upheld.

As a researcher, it is important to keep these benefits in mind when performing these studies. It is also extremely important that these donors, and the samples from them, are treated with the utmost respect as they willingly donated themselves to better our society.

Q: Can you talk about the cadaver donation process for your study?

A: The three facilities we worked with in this study are what we consider "willed-body donation" facilities. Because of this, the donors in this study willingly signed up to donate their body to their specific facility during life. This request was approved by the facility and the donor's next of kin, attorney or physician ensured that the donor's wishes were known and granted.

"I feel like we're opening a whole lot of avenues in basic ecology and nutrient cycling," Metcalf said.

Q: The discussion of the paper states that the data might help in modulating decomposition processes in human death industries – can you explain what you mean by this?

A: The human death industry has issues with things such as space availability in cemeteries for burials and the generation of volatiles and greenhouse gases from cremation. Because of this, other more green methods of handling the deceased have been researched. For example, human composting works to convert the human remains into nutrient-rich soil in a completely natural way that can be used to support growth of plants or recover damaged habitats.

Through the study of the microorganisms associated with decomposition, we can work towards increasing our understanding of these processes in a way that we can hopefully increase their efficiency. ●

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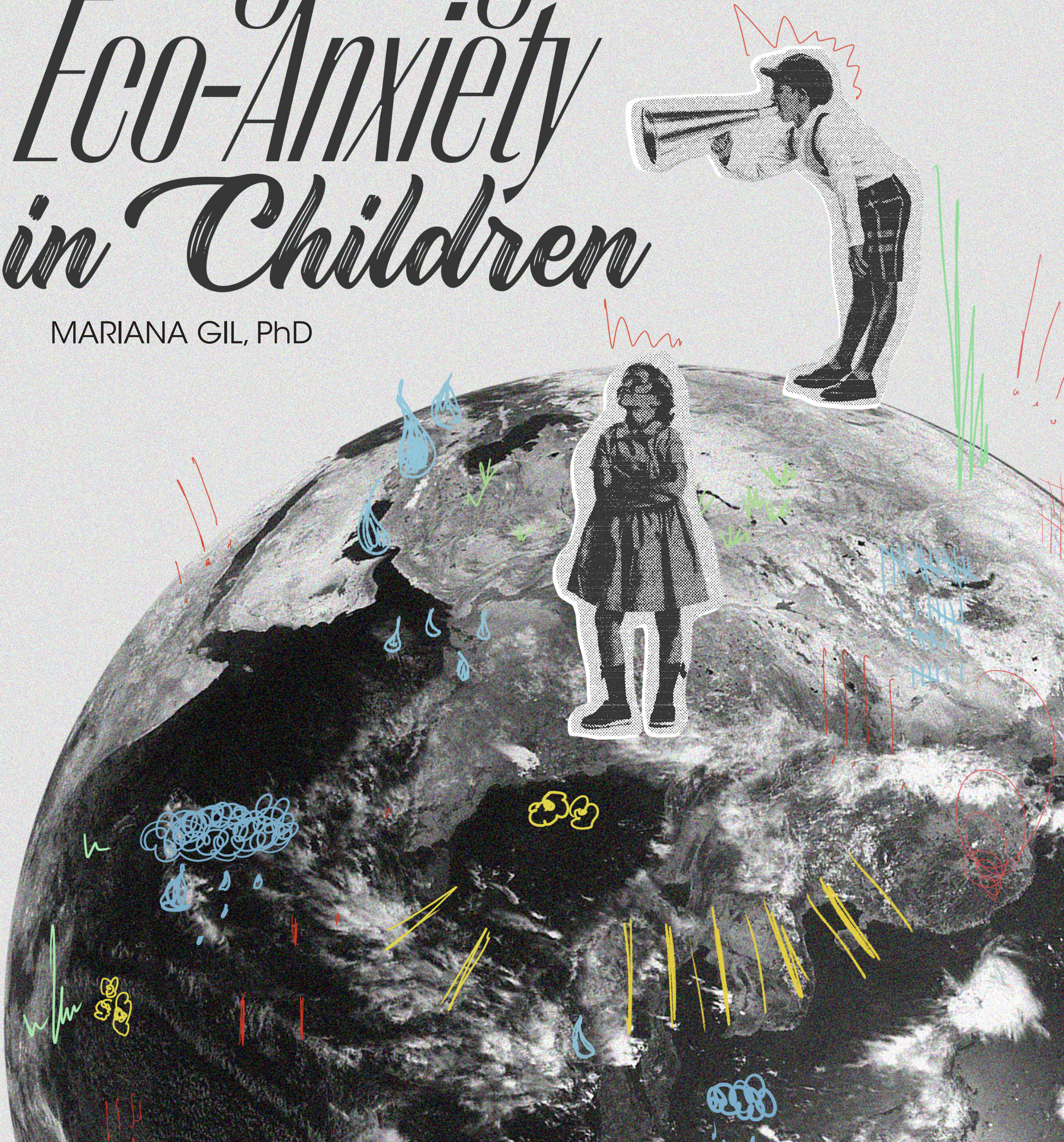
Navigating Eco-Anxiety in Children

MARIANA GIL, PhD



It's late and I'm trying to get my boy to sleep. That's when the deepest meaningful questions arise.

"Does pollution harm the planet?" he asks. "Yes, it does," I reply.

"Can the planet defend itself?" he continues. "No, it can't," I say.

"But then, people are harming themselves; why do they do that?" and without waiting for an answer, he irately says, "I'm starting to hate people because they throw garbage, and the animals eat it and they die. That's so stupid!"

He just turned six, and it's not the first time he has made questions and statements revealing his concern about environmental issues. He cares about it, and failing to understand why all this happens makes him truly upset. I wonder if this is part of the so-called "eco-anxiety" phenomenon.

This new and complex concept has diverse definitions across the literature. Dr. Susan Clayton, professor of psychology and environmental studies at the College of Wooster in the USA, defines eco-anxiety as "a pattern of negative emotional responses, especially anxiety but also possibly mixed with grief or guilt, associated with a perception of environmental degradation."

We all are susceptible to suffering eco-anxiety to some degree. "A common predictor of negative emotions triggered by climate change is to embrace universal and biospheric values – such as animals' right to exist, global justice and peace. Since climate change threatens these values, a very rational and normal reaction is to worry," explains Dr. Maria Ojala, associate professor in psychology at Örebro University in Sweden.

"Everybody on the planet, as far as I'm concerned, has mild climate anxiety; how could you not? It's a healthy response. But it affects children differently as they have an empathic connection with nature and are completely tuned into things being fair or unfair. As adults, we're able to rationalize the problem and accommodate it by our recognition that life is not always fair. But children have not learned about injustice yet," adds Caroline Hickman, psychotherapist and lecturer at the University of Bath in the UK.

Learning about environmental degradation can trigger a plethora of emotions – such as worry, stress, hopelessness, irritability, despair, anger, frustration, confusion, grief and guilt – that children (and adults) need to learn to navigate.

MEASURING THE PROBLEM

The largest global survey on eco-anxiety in children and young people was conducted in 2021. It collected data from 10,000 young people aged 16–25 years old living in 10 countries across the world. The results showed that nearly 60% of young people are very or extremely worried about environmental problems.

Between 50% and 67% said climate change makes them feel sad, scared, anxious, angry, powerless, helpless and guilty. Remarkably, 45% reported a negative impact of these emotions on daily functioning such as eating, concentrating, sleeping and playing. An overwhelming 83% of the young people surveyed think adults have failed to take care of the planet, and 75% believe that the future is frightening. Moreover, 48% reported they have been dismissed or ignored when trying to talk about the environmental crisis.

The survey also offers insight into young people's perceptions of governmental responses to climate change. Participants tended to rate government responses negatively; around 64% think governments are not taking their concerns seriously, are not doing enough to avoid a climate catastrophe and are failing young people around the world. Thus, the source of eco-anxiety seems to be twofold; one part is the actual ecological problem, and the other is the realization that our leaders are not doing enough to change it. "Climate anxiety, particularly in children, is a moral injury caused by the people who are supposed to be looking after us but are failing us. A big portion of the children's distress comes from realizing that we live in a world that doesn't care about their future," highlights Hickman.

Although responses varied across countries, strong negative feelings were present in all populations, despite differential access to resources and exposure to the physical effects of climate change. "The overall responses are the same among young people from different cultures that have different experiences in terms of poverty and climate impact; this is a shared generational phenomenon," explains Hickman.

Several scales have been developed and validated to measure eco-anxiety in adults over recent years, such as the Clayton & Karazsia's Climate Change Anxiety Scale (CCAS) and the Hogg Eco-Anxiety Scale (HEAS). But, unfortunately, measuring eco-anxiety in young children is quite complex. "The CCAS has been used with children as young as 11–14 years old but would probably not be appropriate for younger children. I don't know of [any] attempts to assess eco-anxiety in younger children," explains Clayton.

That is because studies on younger children are very difficult to perform, explains Ojala: "I have worked with 11–12 years old; it is possible to do interviews as well as let them write and paint pictures about their worries and anxieties, but you need a lot of assistants present in the classroom." Interestingly, her data showed that 11–12 years old are more hopeful than older children. "Hope can reside side by side with worry and can help people feel well, confront their worry and do something constructive with it," she concludes.

More work needs to be done to overcome the challenges of measuring eco-anxiety in younger children. Until then, our understanding of their emotional well-being will be limited to personal experiences and sparse qualitative data.

"Everybody on the planet, as far as I'm concerned, has mild climate anxiety; how could you not?" said Hickman.

THE MENTAL HEALTH IMPACT

There is overwhelming evidence that climate change is having a negative effect on the mental health and emotional wellbeing of people around the world. The experts agree that eco-anxiety is a rational, rather than a pathological response. "However, it may lead to diminished mental health, especially clinical anxiety or depression if it becomes extreme and people don't have good coping skills," explains Clayton.

Eco-distress constitutes a chronic and long-term stressor that can increase the risk of developing mental health problems in vulnerable individuals, and exacerbate pre-existing mental health problems in some children. Maybe the best-known example of the latter is the case of Greta Thunberg. She was eight years old when she first heard about climate change and felt extremely distressed because she could not understand why so little was being done about it. The distress was followed by depression. At the age of 11, she stopped talking and eating. The same year, she was diagnosed with Asperger syndrome, obsessive compulsive disorder and selective mutism. Thunberg struggled with depression for almost four years before beginning her school strike campaign when she was 15. This is certainly an extreme case, but a very enlightening one.

"Eco-anxiety is a normal emotion to a very serious and difficult problem. The question is not to get rid of worry but to promote constructive ways of coping with these feelings. To transform it into active citizenship without lower mental wellbeing in general. And to prevent a feeling of hopelessness," emphasizes Ojala.

COPING STRATEGIES

Climate anxiety is a correlate of care and empathy for our planet. Nonetheless, the scale of its emotional and psychological effects on children and young people is disturbing. Exploring how to cope with these emotions seems paramount in this context.

Ojala's research focuses on how children and young people cope with global environmental problems. She identifies three main coping strategies: emotion-, problem- and meaning-focused coping. During emotion-focused coping, people usually take distance from the problem to avoid the negative emotions associated with it. "This can be done by doing something else than to worry or avoiding information about the topic, but it could also involve de-em-

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phasizing the problem by denying it," she explains.

Problem-focused coping, in turn, involves taking action and trying to find solutions. "Often these are small actions in everyday life, like eating less beef, asking your parents not to drive you to school but take the bicycle instead or to talk to your friends and parents about the importance of the problem," she says. Although this strategy is associated with a feeling of empowerment, it can also have negative effects on young people. This is because there is no individual action that can solve the problem. "It is important to balance external activism with internal activism; that is, building emotional intelligence and resilience to tolerate these complex emotions. Because you're not going to save the planet by taking the streets; and chasing after something impossible to achieve, can massively damage your mental health," stresses Hickman.

When, as in the case of climate change, the stressor cannot be removed, a meaning-focused coping strategy seems to be the best approach. "This involves promoting constructive hope by acknowledging the seriousness of the problem but also being able to switch perspectives and see positive aspects. Constructive hope can be facilitated by trusting in other more powerful actors such as the climate change movement, the young generation or technological progress. Meaning-focused coping can buffer worries and anxiety from turning into low wellbeing," explains Ojala. This strategy is positively correlated with both active engagement and wellbeing. Thus, the more meaning-focused coping the children use, the more they experience life satisfaction, purpose and optimism. Constructing meaning requires navigating (not controlling, nor managing) all the emotions triggered by the problem. "This allows the children to reframe the problem and turn eco-anxiety into something positive such as eco-empathy, eco-compassion, eco-awareness or eco-community. It's all about learning to be okay with not being okay," concludes Hickman.

HOW CAN WE HELP OUR CHILDREN?

All adults – parents, teachers and policymakers – have the responsibility to help children and young people deal with the emotions triggered by the environmental crisis.

We might recognize that confronting the truth is the first step towards hope, yet it is not always easy knowing what to do and how. "I do think parents of young children need more support and advice with this," explains Hickman. "Because a natural thing for a parent is to protect your child from scary things. But we're trying to turn parenting on its head today with the climate crisis. Instead of protecting your child from scary things, you now need to introduce them to scary things. Otherwise, they will find out by themselves from school, the internet or their friends, and then they will often misunderstand some of it. So, my advice to parents is to start talking to the children as soon

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as possible and normalize these conversations."

"Do not be afraid of negative emotions but listen, be empathic and help children put words to their worries. This will give a sense of control and worry will not be transformed into free-floating anxiety. Also, talk about how a sustainable society could look like and how can we work together to promote it," adds Ojala.

When talking with children around the world, Hickman asked an eight-year-old about how we should talk to kids about the climate crisis without frightening them. "You have to tell us the truth because if you don't tell us the truth, you're lying to us. And if you lie to us, we can't trust you. And if we can't trust you, we can't tell you how we feel. And then we're alone," she replied.

The role of teachers is also fundamental. But they need help. A recent survey in the UK showed that 70% of teachers feel they haven't received adequate training to educate students about climate change, and 79% believe they are not teaching about the ecological crisis in a meaningful and relevant way. Climate change education should be an integral part of school curriculums. For this, teachers need to be trained in how to teach about the ecological crisis and also how to deal with the emotions triggered by this knowledge. "Meaning-focused coping can (and should) be promoted in school," says Ojala.

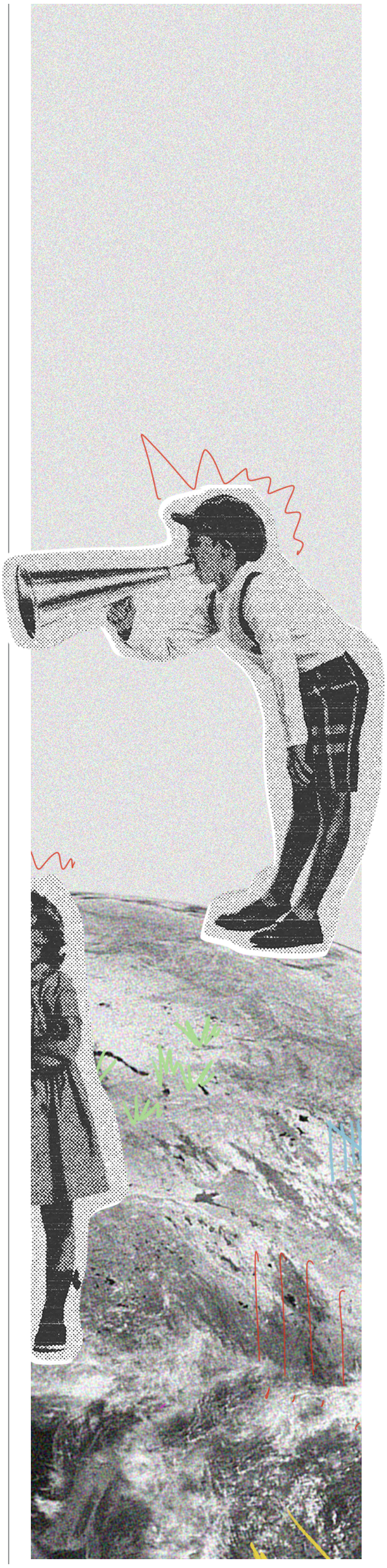
Validation is crucial for children and young people. "Children would be less anxious if they felt confident that those in charge were paying attention. We can support our children by providing them with accurate information about the climate crisis and by listening to their concerns, not dismissing them," says Clayton. "We can show young people that there are adults who do take climate change seriously by for example inviting climate scientists and politicians to the classrooms," adds Ojala.

Finally, government representatives and legislators can act to reduce eco-distress by validating the emotions of young people and prioritizing their rights when making decisions. Promisingly, international legal bodies are starting to recognize the negative effects of climate crisis on physical and mental health as a human right issue. In a unique and inspiring case, 6 Portuguese children and young people (aged between 11 and 24) filed a complaint with the European Court of Human Rights against 33 countries in 2020. They argue that climate change impacts their physical and mental health, their right to life and their right to non-discrimination (because children disproportionately suffer these effects during their lifetime). The complaint alleges that by failing to take sufficient action on climate change, these countries have violated their human rights and seeks an order requiring them to take more ambitious action.

In an address to the British Parliament in 2019, Thunberg said: "You lied to us. You gave us false hope. You told us that the future was something to look forward to. And the saddest thing is that most children are not even aware of the fate that awaits us. We will not understand it until it's too late. And yet we are the lucky ones. Those who will be affected the hardest are already suffering the consequences. But their voices are not heard." She was only 16.

"I always apologize to children; I always say I'm sorry that you're having to deal with this because previous generations didn't deal with this quickly enough. And I'm sorry that this is now going to make life harder for you and your generation. We have to say sorry. Children respond brilliantly to this because they know they can then trust you," concludes Hickman.

My boy is sleeping now. His future might be daunting, but I am committed to nurturing constructive hope and amplifying his voice. That might hopefully help. ●



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Strategies for Sustainable Science at CU Boulder and Beyond

LAURA ELIZABETH LANSDOWNE

The CU Green Labs Program plays a pivotal role at the University of Colorado Boulder (CU Boulder) by helping to tackle the resource-intensive and expensive nature of its research laboratories. It achieves this by engaging scientists in sustainable practices and encouraging cultural changes to improve the efficiency of research processes. This initiative is not only transforming laboratory operations at CU Boulder but is also setting a precedent for sustainable research practices globally. Kathryn Ramirez-Aguilar, who established the program in 2009 and is an expert in sustainable laboratory practices, sheds light on some key strategies that have significantly influenced the way the university's scientists and laboratory personnel approach environmental responsibility in their daily routines.

In the interview, Ramirez-Aguilar also elaborated on her involvement with the International Institute for Sustainable Laboratories and discussed the role of research funders in furthering sustainability within a lab environment.

Laura Lansdowne (LL): Could you share the key strategies or initiatives that have been most effective in engaging scientists and lab personnel in sustainable practices at CU Boulder?

Kathryn Ramirez-Aguilar (KR-A): Our program has had great success with utilizing posters. We created these to share information on specific lab sustainability topics, raise awareness of the CU Boulder Green Labs Program and inform researchers about how to contact us (via information displayed at the bottom of every poster). At research universities, there is a turnover of students working in campus labs as they graduate. Our goal is to establish a culture of sustainability in research while these individuals are still on campus before they transition to their next roles. The posters are strategically positioned in laboratory buildings where scientists will likely have time to engage with them, such as in lavatories and near microwaves in kitchenettes.

Other initiatives that have been particularly effective at engaging lab members include our lab-specific material recycling program and contests such as "Just Shut It" for fume hood sashes and the International Laboratory Freezer Challenge.

Over the years, scientists have repeatedly expressed interest in diverting their waste streams from the landfill. The diversion streams established by CU Boulder Green Labs have effectively engaged scientists in our program and facilitated discussions on various efficiency-related topics, including energy and water conservation. For example, by setting ultra-low temperature (ULT) freezers to -70 ºC instead of -80 ºC scientists can not only save energy but also extend the life of their freezers in some cases. By sharing research equipment (preferably where a manager oversees the resources) it's possible to provide more researchers with better and more inclusive access to equipment while also avoiding repeat equipment purchases. Unnecessary equipment duplication not only results in increased electricity use but also requires more laboratory space to house the equipment. Given that lab space is energy-intensive due to its ventilation needs, optimized use of laboratory space is of utmost importance for energy efficiency in scientific research.

Leadership by researchers (on behalf of CU Boulder Green Labs) who are passionate about sustainability in research practices has helped to engage lab members through peer-to-peer interaction. It has also led to the creation of efforts such as the solvent recycling and reuse program, which was established and led by a chemistry graduate student. Lab members can volunteer to be eco-leaders for their labs or team leaders for their lab buildings.

LL: Can you tell me about the International Institute for Sustainable Laboratories (I2SL) and your responsibilities as a board member?

KR-A: I2SL is the first and largest international organization where professionals involved in the design, building and operation of labs come together to promote efficiency, safety and sustainability in research facilities. I2SL had its start as a US federal program by the US Environmental Protection Agency and Department of Energy to address the large energy consumption of laboratory facilities. It is now a non-profit organization, with an educational mission and participation from non-profit institutions/groups, federal agencies and companies that interact with laboratory research in various capacities. I will highlight several I2SL initiatives that could be particularly relevant to those focused on green lab efforts:

1. Last year the I2SL Annual Conference and Technology Fair featured a Green Labs track from start to finish over multiple days and we expect to have the same again at the 2024 conference.

2. In April each year, I2SL Education Week takes place. Attendees have the opportunity to participate in live virtual sessions or watch pre-recorded sessions on topics such as sustainable lab design, lab decarbonization strategies, efficient ventilation systems and green lab leadership. My Green Lab, another nonprofit with whom I frequently partner, also hosts a virtual summit each year in May or June.

3. The Circular Economy for Laboratories (CEL) Community of Practice webpage was recently launched. This is designed to encourage communication and collaboration between lab and campus sustainability experts, and their suppliers on topics such as the diversion of materials from landfills through reuse, recycling and reduction of materials.

4. There are also several different I2SL working groups focused on specific technical topics and common sustainability issues that you can get involved in.

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In addition to serving as a board member for I2SL, where I have the opportunity to give input on the direction that that the organization is headed and contribute as time allows to ongoing efforts of I2SL, I also chair the I2SL University Alliance Group (UAG) which is primarily composed of individuals interested in greening labs from universities but also from federal roles/campuses and nonprofit research institutions as well.

The I2SL UAG focuses on green lab topics and emphasizes the importance of connecting efficiency and sustainability expectations in the way research is conducted to the funding of research.

LL: What have been the most significant challenges you've encountered while promoting sustainability in labs and how have you tackled them?

KR-A: While certainly there are those labs that are more engaged in greening their lab operations than others, it is our experience that there are many scientists and labs that want to work with us on efforts for efficiency and sustainability in their labs. So much so that we have trouble keeping up.

Our most significant challenge is the constraints on our time as staff members of the CU Boulder Green Labs Program – we are not limited by finding engaged laboratory scientists who want to do more. We are tackling our time limitations in various ways. Where possible, we empower interested researchers to take the lead in their laboratory buildings. Over time, we are chipping away at individual topics, one at a time, as well as focusing on systematic change and establishing processes that simplify the ongoing effort to achieve our goals. For example, many of our laboratory departments at CU Boulder are now proactively inviting us to their new graduate student recruitment events and orientations each year, whereas historically we had to initiate contact to ask if CU Boulder Green Labs could be included. We also are currently piloting the My Green Lab certification as a way to have greater implementation of best practices in our campus labs.

LL: What emerging trends or technologies do you see playing a pivotal role in furthering sustainability within the lab environment?

KR-A: Two key areas of focus come to mind – the influence of research funders and the resulting advancement of equipment and supplies in response to sustainability expectations by funders.

1. **Research funders:** Increasingly it is being recognized that there is a need for granting bodies to encourage or expect efficiency and sustainability in the way research is conducted in connection with receiving grant funding. Research is contingent on funding, thus if those funding the science make it clear they are prioritizing environmental sustainability in research practices, it will lead to large-scale, widespread adoption of environmental sustainability in research.

The I2SL UAG and My Green Lab have led the Million Advocates for Sustainable Science (MASS) effort, which is a call to action for science funders around the world to encourage sustainability in research.

Also, some granting bodies are beginning to show signs of taking action, for example:

- **UK Research & Innovation (UKRI):** The UKRI Environmental Sustainability Strategy has a goal to "embed environmental sustainability across all our investment decisions" by 2025. The UKRI is also finalizing a Concordat for Environmental Sustainability of Research and Innovation Practice that "aims to gain agreement from all organizations involved in research or innovation activities on immediate and consistent long-term action to reduce and eliminate environmental impacts and emissions associated with R&I."

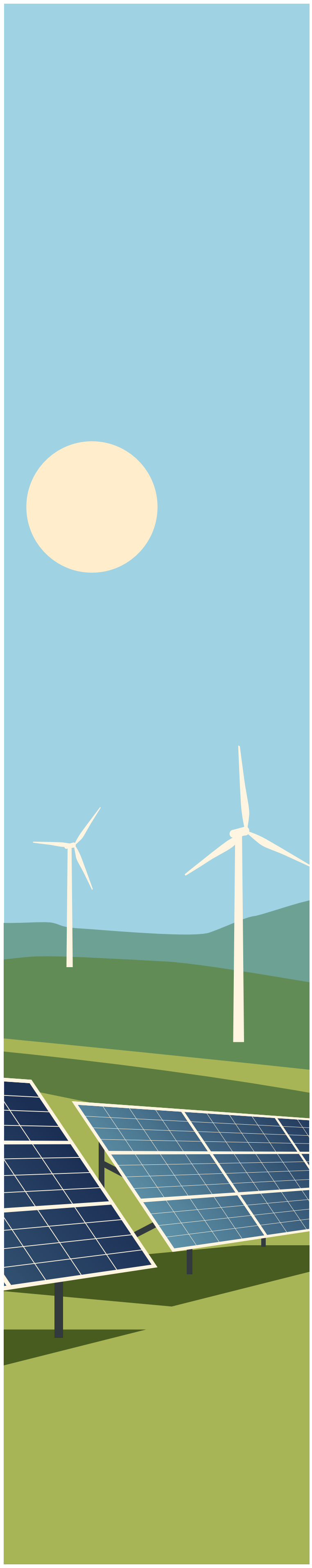
- **Science Foundation Ireland** initiated a Sustainable Laboratory Certification Pilot Programme in October 2023.

- **The German Research Foundation (DFG)** issued a press release in June 2023 stating that "applicants for DFG grants must provide a concise account of sustainability aspects in their research process, including a succinct and comprehensible outline of any potential for reduction of emissions and use of resources as part of the materials submitted along with the project proposal." DFG has also created a webpage of "Guiding Questions" which DFG says are to serve "as a source of inspiration". Among many others, the site includes questions such as "Can providers be found that sell more energy-efficient products?" and "Is it necessary to purchase new equipment if existing or repairable equipment is available (e.g., in a neighboring working group)?"

- **The Wellcome Trust** published a report by RAND Europe that provides an overview of the current initiatives focused on minimizing the environmental footprint of health research. "Progress on sustainable health research has been reliant on the goodwill of individual researchers. Wider research system actors, like funders, need to match the efforts of these individuals by providing resources and impetus for action. Without this, progress towards more sustainable health research will be stunted." — RAND Europe.

- **US Health and Human Services'** climate action plan priority action #3 is to "develop language across the range of HHS grant-making programs and funding announcements to advance federal sustainability and climate resilience goals."

2. **Advances in equipment/supplies:** Funder expectations for efficiency and sustainability described above will drive more sustainable solutions from companies developing/manufacturing research equipment and supplies. Already advances have been made to develop highly efficient ultra-low temperature (ULT) freezers that use half or less than half of the electricity they used to use (see Energy Star for the top efficient ULT freezers), but there are so many other types of equipment utilized in research that require advancements in efficiency. Additionally, there is a significant use of single-use materials in research that necessitates truly green/sustainable solutions for waste diversion. ●



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The Landscape of Agricultural Biotechnology

MOLLY CAMPBELL

Nourishing our growing population in the face of climate change and diminishing resources will not be an easy feat.

By 2049, our global population will reach ~9 billion people. Pests, diseases and adverse environmental conditions are impacting crops across the globe, compounding the issue of feeding a growing population.

Traditional breeding techniques have enabled scientists and farmers to develop many varieties of plants and livestock tailored for specific agricultural or commercial purposes. Technologies such as genomic sequencing are helping to enhance these methods further. However, traditional breeding techniques can still take years to produce results.

Genetic engineering and gene-editing tools are by no means a panacea for the time-sensitive agricultural and food-related challenges we face – but they could help, if given the opportunity.

GENETIC ENGINEERING

The invention of recombinant-DNA technology in the 1970s provided a new method for introducing desirable traits into a crop plant using genetic engineering. "A transgenic organism contains one or more genes that have been incorporated from another species, or across (trans) species, hence 'trans-gene'," Dr. Kevin Pixley, Dryland Crops Program director and Wheat Program director at the International Maize and Wheat Improvement Center, describes.

Genetically-modified organism – or GMO – has become the common term used to refer to transgenic organisms. GMO is not generally used to refer to organisms developed using selective breeding. Instead, it "refers to crops where DNA that does not originate from that species remains in the final product," explains Professor Giles Oldroyd, director of the Crop Science Centre at the University of Cambridge.

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EXAMPLES OF GENETIC ENGINEERING IN AGRICULTURE

The first genetically engineered food product to be made available commercially was Calgene's FLAVR SAVR™ tomato in 1994. The FLAVR SAVR™ was engineered to possess reduced polygalacturonase activity, an enzyme that dissolves pectin in the cell walls and causes the fruit to soften.

Over the last 25 years, transgenic crop production has undergone an over 100-fold increase; by 2013, over 4 billion acres of crops had been grown across 27 countries. These crops are typically classified by generation, where first-generation traits offer herbicide tolerance, resistance to pests or environmental conditions, and second-generation traits improve nutritional quality. Third-generation qualities are for which the applications "extend beyond those of traditional food items."

The first genetically engineered food product to be made available commercially was Calgene's FLAVR SAVR™ tomato in 1994.

Over 90% of US corn – the most commonly grown crop in the country – is transgenic, and an example of a first-generation trait. Corn growers are confronted by numerous pests, with lepidopteran larvae considered one of the most damaging. Bt corn is engineered to express genes from the soil bacterium *Bacillus thuringiensis* to produce Bt delta endotoxin, which kills the larvae. The selectivity of the protein against lepidoptera means that it is generally not harmful to other insects and is regarded as safe for humans and other mammal species.

Ninety five percent of canola crops – a staple ingredient in many cooking oils or margarines, and a commonly used animal feed – are transgenic in Canada. The crop is engineered to possess tolerance against ingredients found in widely used herbicides, which ensures that the plant can be sprayed and protected against weeds without experiencing damage itself.

Vitamin A deficiency, which can cause blindness or even death, is a major public health issue that affects 250 million people worldwide. Scientists engineered a combination of transgenes into rice that results in an increased production of beta-carotene, a precursor to vitamin A. "Golden rice" (GR) has been approved for cultivation in the Philippines, where a recent study found it could provide 57%–99% of the average vitamin A requirement for preschool children.

Transgenic crops could also support climate change mitigation. A 2022 study suggests that growing transgenic crops in the European Union (EU) could reduce greenhouse gas emissions by 33 million tons of CO_2 equivalents per year, equivalent to 7.5% of the total agricultural greenhouse gas emissions produced in the EU in 2017.

A variety of laboratory techniques can be utilized to create transgenic crops. A simplistic overview of the process is as follows:

1. Scientists decide which trait they want to insert into a plant and identify an organism that possesses the gene encoding that trait.
2. The gene is isolated and copied, typically using polymerase chain reaction (PCR).
3. To insert the gene into the organism's cells, a vector is required that can carry the gene into the plant's cells, such as a plasmid.
4. The plasmid is introduced to the host plant's cells, either using agrobacterium-based methods or biolistics.
5. Once the gene is inserted, the cells are cultured in a laboratory and those that have successfully incorporated the gene are utilized to grow plants.

REGULATION OF TRANSGENIC CROPS AROUND THE WORLD

Many transgenic crops with diverse traits have been produced in laboratory settings, but ultimately the number of new, commercially available crops has been limited by a complex interplay of factors.

Transgenic crops cannot be grown or commercialized without approval from an appropriate regulatory agency, processes that ensure their safety both for human consumption and the environment. Legislation protocols vary across the world, with some regulations focusing on the *product* and others on the *process*, creating disparity.

In the US, three federal agencies are responsible for transgenics regulation: the Environmental Protection Agency (EPA), the Food and Drug Administration (FDA) and the United States Department of Agriculture (USDA). Recently, the USDA changed its position on assessing environmental risks from transgenic crops. Developers are no longer required to invest in intensive risk assessment if there is no scientific reason to believe that the crop is likely to cause environmental harm. An anthocyanin-rich purple tomato, developed at the John Innes Centre in Norwich, was the first transgenic approved under the USDA's novel framework. Tomatoes carry the genes to produce anthocyanins, but they aren't "switched on". Researchers engineered the tomatoes to express two genes from snapdragons that work as genetic "switches", helping to ramp up production of the antioxidant. "The bittersweet thing is that the tomatoes will be on sale in America and not the UK as well," says Professor Cathie Martin, who developed the tomato in 2008.

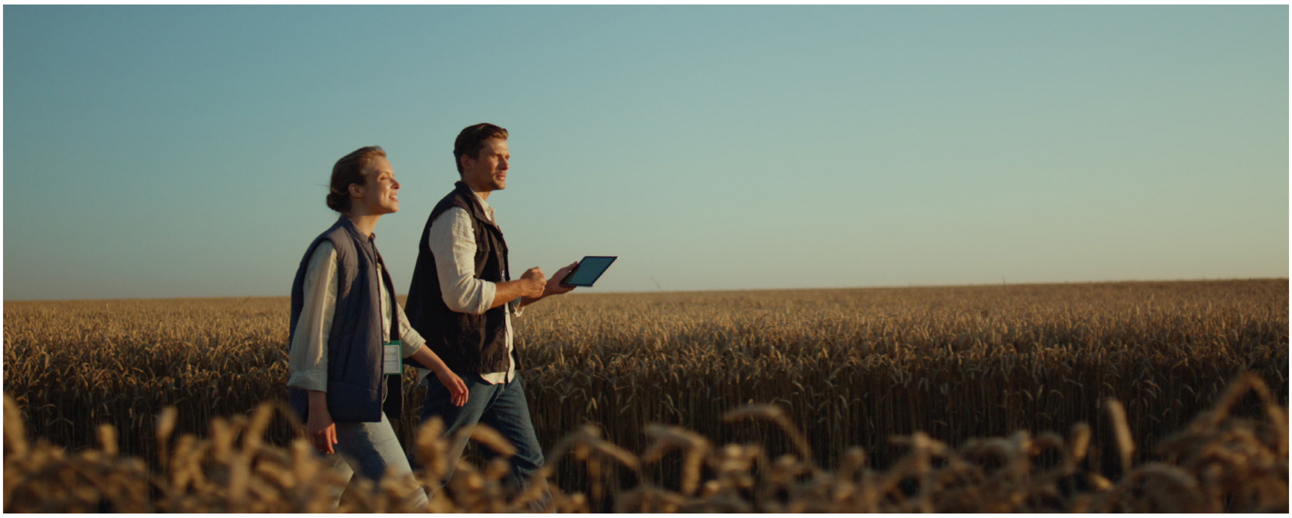
That's because the landscape is very different across the pond, and, despite leaving the EU in 2020, the UK currently adopts its regulatory regime when it comes to transgenic crops. "The EU has had a de-facto ban on almost all cultivation of transgenic crops for over 20 years," Dr. Emma Kovak, senior food and agriculture analyst at The Breakthrough Institute explains.

The EU's regulation of transgenics is considered an example of a process-orientated regulatory scheme. It adopts a precautionary approach to regulating transgenic crop cultivation and commercialization, where decisions are made on a case-by-case basis and require extensive scientific and safety trials. From 1992 to 2016, the EU had approved 2,404 experimental transgenic field trials for research, a stark contrast to the 18,381 approved in the US. Only 2 cultivation applications have been approved in the last 25 years in the EU, and critics have argued that achieving its requirements is so challenging that it likely deters researchers from trying.

Even if authorization for cultivation is made at the EU level, individual member states retain the right to ban cultivation in their territory. Cultivation of MON 810 maize, for example, has been banned by several countries including Germany.

The general public is also offered consultation on approvals, which can influence regulatory decisions. Public acceptance of transgenics has been notoriously turbulent – with a lot of skepticism deriving from "the publication of fraudulent, poorly designed and biased studies", according to a recent article by Kathleen L. Hefferon and Henry I. Miller.

Elsewhere in the world, we are continuing to witness a growing eagerness for the adoption of agricultural biotechnology and the streamlining of regulations.



In Africa – where farmers are arguably most exposed to pressing climate, pest and disease challenges – there have been significant developments, says Oldroyd: "For instance, Nigeria approved pod-borer resistant cowpea, the world's first transgenic cowpea, for commercial use in 2019. Likewise, amid historic droughts in 2022, the government of Kenya lifted a 10-year ban on the cultivation, as well as importation, of transgenic crops and animal feed, a move that is currently subject to an ongoing court case."

Thorough scientific assessment of transgenic crops is necessary, but particularly strict methods can limit the development of scientific expertise, hinder innovation and have adverse economic and environmental impacts. In a 2021 opinion piece, Wu et al. argue that delaying the uptake of transgenic products that

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demonstrate clear benefits "has and will cost numerous lives, frequently of the most vulnerable individuals."

"We need to feed people properly without destroying the planet," says Professor Jonathan Jones, group leader at The Sainsbury Laboratory in Norwich. [...] "Using GM methods, we can replace chemistry with genetics for pest and disease control."

"The lesson from countries that have used this technology for 30 years is that its potential risks can be regulated on the basis that they are predictable and specific to the change being made," Jones adds.

GENE EDITING

Gene editing allows scientists to modify gene sequences directly in an organism's genome, a process that can introduce changes much faster than conventional breeding permits. Most gene-editing processes do not result in the introduction of DNA from a different organism.

"Advantages of genome editing are that these changes are precisely targeted and can be made within already excellent plant varieties, improving one trait, such as disease resistance, without altering any other traits," says Pixley. "This contrasts with most breeding techniques, where mating a disease-resistant parent with another excellent parent produces progeny with half of the traits from each parent."

A variety of genome-editing technologies now exist, such as zinc finger nucleases (ZFNs), homing endonucleases or meganucleases (HEs), transcriptional activator-like effector nucleases (TALENs) and the recent Nobel-prize winning CRISPR/Cas nuclease system. While their molecular components differ, these approaches all generate double-strand breaks in the DNA, activating the cell's endogenous DNA repair pathway.

There are three types of edits that can be made, referred to as site-directed nucleases: SDN1, SDN2 and SDN3. Pixley describes SDN1 as the "simplest type of edit", where DNA is cut and the natural repair mechanism results in the editing of only a few nucleotides at a precise location, altering the performance of a gene. "SDN2 is similar to SDN1, but a 'template' is provided, such that the reassembly of the DNA is not random," he explains. "SDN3 is the most complex and involves the insertion of a complete gene or genes, often resulting in a transgenic, but differing from other transgenic plants in that the transgene is precisely inserted into the DNA at a carefully chosen site."

APPLICATIONS OF GENE EDITING

The number of research studies applying gene editing to plants continues to grow. The versatility, low cost and high efficiency of CRISPR and its derivatives has led it to take center stage in this space.

CRISPR is being used to develop a wide range of products that possess beneficial agronomic traits, consumer-focused traits and traits that are favorable for improving the sustainability of agricultural practices.

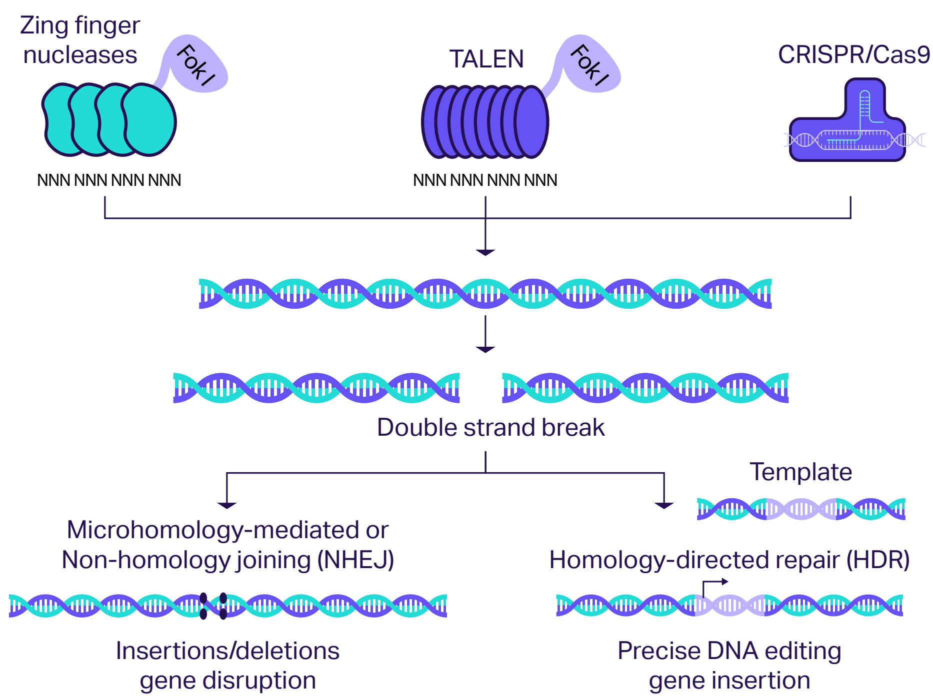

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***Figure 1:** How CRISPR/Cas9 technology works.*

Rice supplies 20% of global calories but is particularly sensitive to drought in comparison to other cereal crops. Karavolias et al. used CRISPR-Cas9 to create *stomagen* and *epidermal patterning factor-like$_{10}$ (epfl$_{10}$)* knockout rice lines to fine-tune stomatal density, as previous research had demonstrated a reduction in stomatal density contributed to drought adaptation. Modest reductions in stomatal density were observed in *epfl$_{10}$* lines, without adverse reductions in stomatal conductions, carbon assimilation or thermoregulation. "These attributes could contribute to improved climate resilience in current and future conditions where water is limiting, and temperatures are increased," the researchers say.

Rice is also susceptible to a disease known as bacterial blight, which can cause severe crop loss, particularly in Asia and Africa. Oliva et al. used CRISPR-Cas9 to introduce mutations into three *SWEET* gene promoters in rice lines. These promoters are required for the crop's susceptibility to the pathogen *Xanthomonas oryzae*, which causes bacterial blight of rice. In paddy trials, rice containing genome-edited *SWEET* promoters showed broad-spectrum and robust resistance.

Other agronomic traits introduced using CRISPR technology include fungal, viral and temperature resistance and increased crop yield. Examples of consumer-focused traits include reduced browning, improved shelf-life, reductions in allergens and traits that address broader health issues. Raffan et al. recently published the results of Europe's first CRISPR field trial, where wheat lines had been generated with the asparagine synthetase gene *TaASN2* knocked out. "The aim of knocking out *TaASN2* was to reduce the concentration of free asparagine in the grain. Free asparagine is converted to the carcinogenic processing contaminant, acrylamide, during high-temperature processing, baking and toasting," the researchers describe. The gene-edited wheat lines had approximately 50% the amount of free asparagine as unaltered plants.

"Advantages of genome editing are that these changes are precisely targeted and can be made within already excellent plant varieties, improving one trait, such as disease resistance, without altering any other traits," says Pixley.

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GENE-EDITED CROPS: THE REGULATORY LANDSCAPE

While most gene-edited plant varieties created with SDN1 or SDN2 edits do not contain genetic material from another organism, there is ongoing debate surrounding the biological, political, social and legal distinctions between gene-edited crops and transgenic crops.

A growing number of countries are updating their regulatory frameworks, making it easier to approve gene-edited crops for cultivation compared to transgenic crops. "Argentina was the first country worldwide to update regulations to make it easier, and many countries followed – including the US, Brazil, Canada, Paraguay, Ecuador, Chile, Colombia, Japan, Australia and

Israel – with others considering such regulations," Kovak explains.

These frameworks, says Pixley, largely consider SDN1 and SDN2 as "no different" from conventionally bred plants.

In 2018, the EU's Court of Justice determined that gene-edited crops are required to meet the same regulation as transgenic crops. In July, the executive body of the EU – the European Commission – proposed a revision to these restrictions, which splits new genomic technique (NGT) plants into two categories. "Those that could occur naturally by conventional breeding, including those developed from gene-editing technologies that do not introduce foreign DNA, would be exempted from transgenic legislation and labeling requirements," explains Oldroyd. "Conversely, all other NGT plants would continue to be treated as GMOs and will continue to require risk assessments and other authorizations."

In the UK, a "game-changing" Act was passed into law earlier in March, which allows for the commercial development of gene-edited plants and crops in England. "This means researchers can cut down the time it takes to supply farmers with more resilient or higher yielding crop varieties, which could be the difference between failed harvests and food shortages – or food security and continuous supply," says Oldroyd. The Act will help the plant sector mainstream genetic technologies to encourage further research by public sector institutes and start-ups.

Food and nutrition security must be a basic human right for all – forever

"It also stands to generate new varieties, products and technologies that can be adapted and used by other parts of the world, including developing countries," Oldroyd adds.

The UK government is phasing in the new framework, which does not affect the country's stance on transgenic crops. "While there are many important traits that can be delivered in food crops through gene editing, there remain some traits, such as the transfer of nitrogen-fixation, that require transgenics," Oldroyd says.

Access is a further barrier to wider use of gene editing in agriculture, says Pixley: "Some [technology] is protected by intellectual property rights, and [there are] trade barriers from potential importing countries that decide not to accept grains or plant products from genome-edited plants." A 2020 study found that 1,232 out of 7,427 patent families relating to CRISPR were specific to plant modification. Patents can hinder research progress, especially for public sector or small-scale breeders, as licensing fees charged by companies that hold them might not be affordable for smaller organizations.

INNOVATION FOR A BETTER WORLD

The current landscape of agricultural biotechnology shows us that nourishing our growing population in the face of climate change and diminishing resources will not be an easy feat. Pixley emphasizes that while navigating these issues, there will be differences of opinion about the best approaches to follow: "But most of us will agree that food and nutrition security must be a basic human right for all – forever." This, he says, is a great starting point to discuss science and innovation for a better world. ●

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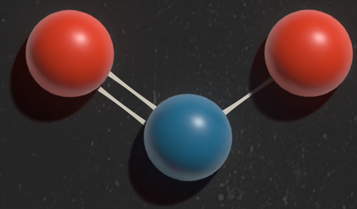
COMMON AIR POLLUTANTS

The World Health Organization (WHO) Global Air Quality Guidelines establish air quality standards for five common air pollutants, which have the strongest evidence to suggest public health concerns.

PARTICULATE MATTER

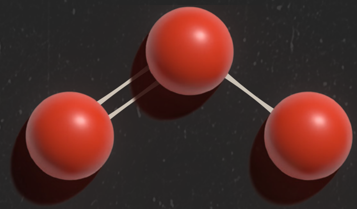
Particulate matter includes coarse particles (with a diameter between 2.5 µm and 10 µm), such as pollen, wind-blown soil particles and dust from industrial activities.

Finer particles (diameter less than 2.5 µm) such as the soot and chemicals generated from the burning of fuels are also included in this category.



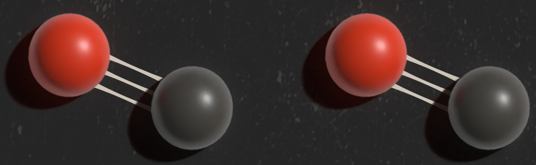
NITROGEN DIOXIDE

Nitrogen dioxide is a reddish-brown gas produced predominately through the burning of fossil fuels. It is one of the most common indoor air contaminants, due to heating systems and cooking. It also plays a key role in the formation of atmospheric ozone.



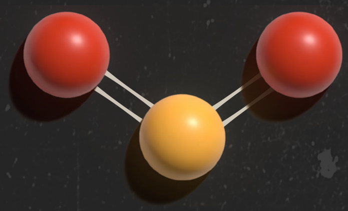
OZONE

Ozone in the upper atmosphere helps to protect the Earth from the Sun's harmful ultraviolet (UV) rays. But ground-level ozone has been linked to problems with lung health. As climate change creates favorable conditions for ozone formation, combatting global ozone production is expected to be a strong focus for the coming decades.



CARBON MONOXIDE

Carbon monoxide is a colorless, odor-less gas produced by the incomplete combustion of wood and fossil fuels. As an indoor air contaminant, carbon monoxide is difficult to detect without specialized equipment. Carbon monoxide can be potentially lethal to humans if exposed for a long period of time.



SULFUR DIOXIDE

Sulfur dioxide is another harmful gas that is produced mainly from fossil fuel combustion. Sulfur dioxide is the most important acidifying compound responsible for acid rain.

There are many other common air pollutants that are not formally included in the WHO air quality guidelines, but that are often presented as contaminants of concern. These include:

- LEAD AND LEAD COMPOUNDS
- RADIOACTIVE RADON GAS
- ULTRAFINE PARTICLES
- FORMALDEHYDE AND OTHER VOLATILE ORGANIC COMPOUNDS (VOCS)
- BACTERIAL MOLD

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Testing London's Water for PFAS

LEO BEAR-MCGUINNESS

British water is in need of some good publicity. The country's water companies have been mired in controversy in recent years following reports of mismanagement, widespread leaking pipes, sewage-saturated seas and record fines. In a recent survey, only 34% of respondents trusted their local water company to prevent sewage from entering rivers and seas.

So, the last thing these companies would want right now is a trending story about another dangerous contaminant in the country's water systems. But such a headline may just be around the corner...

LONDON TRAWLING: LOOKING FOR FOREVER CHEMICALS IN THE THAMES

Per-and polyfluoroalkyl substances (PFAS) are a growing concern around the world. The group of surfactants were first mass produced in the mid-20th century to waterproof consumer products like pans, paints and packaging. They're now known as "forever chemicals" because they have an almost-unbreakable highly-fluorinated alkyl chain backbone that makes them extremely chemically stable and difficult to degrade naturally.

This robustness has helped the chemicals reach as far the Arctic and the base camp of Mount Everest. So it's no surprise they're in British rivers, too.

What may be more shocking is the level of PFAS that might persist in the nation's drinking water, particularly as a recent wave of research has linked the compounds to health concerns like cancer and low birth weights.

A recent report from the Royal Society of Chemistry found that more than a third of tested water courses in England and Wales contained medium- or high-risk levels of PFAS. The river Thames in London was one of the most polluted sites the team sampled; the capital's waterway contained a combined PFAS concentration level of 4,931.1 nanograms per liter (ng/l) – nearly 50 times the Royal Society's proposed limit (100 ng/l) of all forever chemicals in drinking water.

So, the pertinent question is: how many of these PFAS compounds are making their way through the river's filtration network and into London's drinking water?

To work that out, researchers would need to gather tap water samples from across the city, which is exactly what one team is about to do.

"We want to quantify how much PFAS is coming out of the taps in people's homes," said Dr. Alexandra Richardson, a researcher at Imperial College London's School of Public Health. Richardson is heading up the university's Investigating the Toxicological Assessment of PFAS (ITAPS) project, which is partly funded by the Royal Society of Chemistry.

"There are guidelines for what PFAS levels are suitable once it leaves the drinking water treatment plant, but there's a lot of piping between the treatment plants and our kitchen taps," said Richardson. "In the US, that there are quite a few studies looking at what's coming out the taps in the various states in the USA, but nothing really in the UK. So that's what this project is about."

To gather the required data, Richardson and her colleagues have already recruited 40 participants, and hope to enlist more from across the city after the Easter break.

"From an experimental and scientific standpoint, a scatter [of data] across London is what we're trying to achieve – good representation from almost every from every London borough," said Richardson. "Because we genuinely do not know if the PFAS concentrations vary across the city at all, or one region, or if a region with old infrastructure is better or worse affected than a newer build area. We genuinely don't know."

MORE PFAS, MORE RESEARCH

If the team do end up detecting high levels of PFAS in one particular area, they've vowed to notify all relevant participants.

"We want to give back to the community in some ways," Richardson continues. "We are planning on giving them the concentrations of PFAS in line with the current drinking water spectra guidelines, which I've hoped would be below the lowest tier. If a house does trigger a concern, then we will investigate that further. But it's a balance, as we don't want to fear monger."

This balance between safety and excessive scrutiny is something that, according to Richardson, hasn't always been struck when it comes to recent PFAS regulation, particularly in the US.

"I think the US has gone a bit overboard in some ways with it," she said. "PFAS and PFOA [perfluorooctanoic acid] are nasty compounds. There are definitely indications there might be cancer risk caused by them. But asking labs to routinely test down to four PPT [parts per trillion], it's a very big ask, analytically."

In 2022, the US Environmental Protection Agency (EPA) issued its interim PFOA and perfluorooctanesulfonic acid [PFOS] limit of 4 ng/l for single samples. In comparison, the European Union's collective limit for 20 PFAS chemicals is 100 ng/l. While there are no firm limits for PFAS in England and Wales, there are "wholesomeness" guidelines to keep 47 individual PFAS compounds to 100 ng/l.

While the Royal Society of Chemistry isn't as ardent as the EPA, it has proposed more stringent PFAS limits for the UK (100 ng/l for all collective compounds) to bring the country's regulations in line with the continent. In its report last year, the society also called on the UK government to enforce stricter limits on PFAS industrial discharge and ensure that many hundreds of sources of PFAS are captured and documented in a national lab for record-keeping.

In principle, Richardson agrees that more PFAS research can only be a good thing for public health policies.

"I hope that research along this route will continue," she said. "It doesn't necessarily have to be the same model as the ITAP study. It's like the early days of understanding the health effects of air pollution. We know these things are in the environment. We know they can cause effects. But we don't know the human dose at the moment. Because we don't know how much we ingest in food or tap water. Therefore, it's very hard to put a toxicology value on it and to determine effect. So, I definitely hope that PFAS research into human health exposures and human health effects will definitely continue because I do think it's something that is important."

Richardson hopes the ITAP study will have produced its first round of results by the end of this year. ●

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Meet the Interviewees

Meet the interviewees whose insights featured in issue 35 of *The Scientific Observer*.

Jessica Metcalf, PhD, is an associate professor in the Department of Animal Science at Colorado State University. She is a microbiome scientist who leads highly interdisciplinary, innovative research projects that span the fields of animal science, health, and forensics by combining experimental ecology, large genomic datasets, and bioinformatics tools.

Natalie Cooper, PhD, is a senior researcher at the Natural History Museum, London. Her research sits at the interface between macroecology and macroevolution, and aims to understand broad-scale patterns of biodiversity

Kathryn Ramirez-Aguilar completed her PhD in analytical chemistry in 1999. She gained 15 years of research experience before shifting her focus away from the bench, dedicating her efforts toward enhancing the environmental sustainability of scientific research and addressing its influence on climate change more broadly. As well as managing the CU Green Labs Program at the University of Colorado Boulder, she serves on the board of the International Institute for Sustainable Laboratories (I2SL), acts as chair of the I2SL University Alliance Group (UAG), and heads the Bringing Efficiency to Research Grants initiative under the I2SL UAG, aiming to integrate efficiency and sustainability into US research funding.

Zachary Burnham, PhD, is a research assistant professor at the University of Tennessee at Knoxville, and was formerly a postdoctoral researcher at Colorado State University.

Caroline Hickman is a practicing climate-aware psychotherapist and lecturer in social work and climate psychology at the University of Bath in the UK. Her research focuses on eco-anxiety and distress about the climate and ecological crisis in children and young people globally.

Susan Clayton, PhD, is a professor of psychology and environmental studies at the College of Wooster in the USA. She studies the psychology of climate change and people's social and emotional responses to changes in the natural environment.

Maria Ojala, PhD, is a senior lecturer in psychology and one of the research directors of the Center for Environmental and Sustainability Social Science (CESSS) at Örebro University in Sweden. Her research focuses on how young people think, feel, act, learn and communicate about global environmental problems, with a specific focus on climate change.

Kevin Pixley, PhD, is the Dryland Crops Program director and Wheat Program director at the International Maize and Wheat Improvement Center. His research focuses on the use of crop biodiversity to address novel opportunities, including enhanced sustainability of farming systems, improved nutritional or health outcomes or value-addition for farmers.

Professor Giles Oldroyd is the director of the Crop Science Centre at the University of Cambridge. His research focuses on the interactions between plants and beneficial microorganisms, both bacteria and fungi, that aid in the uptake of nutrients from the environment, especially nitrogen and phosphorus.

Alexandra Richardson, PhD, is a research associate within the Epidemiology and Biostatistics (EBS) and Emerging Chemical Contaminants (ECC) groups at Imperial College London.

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