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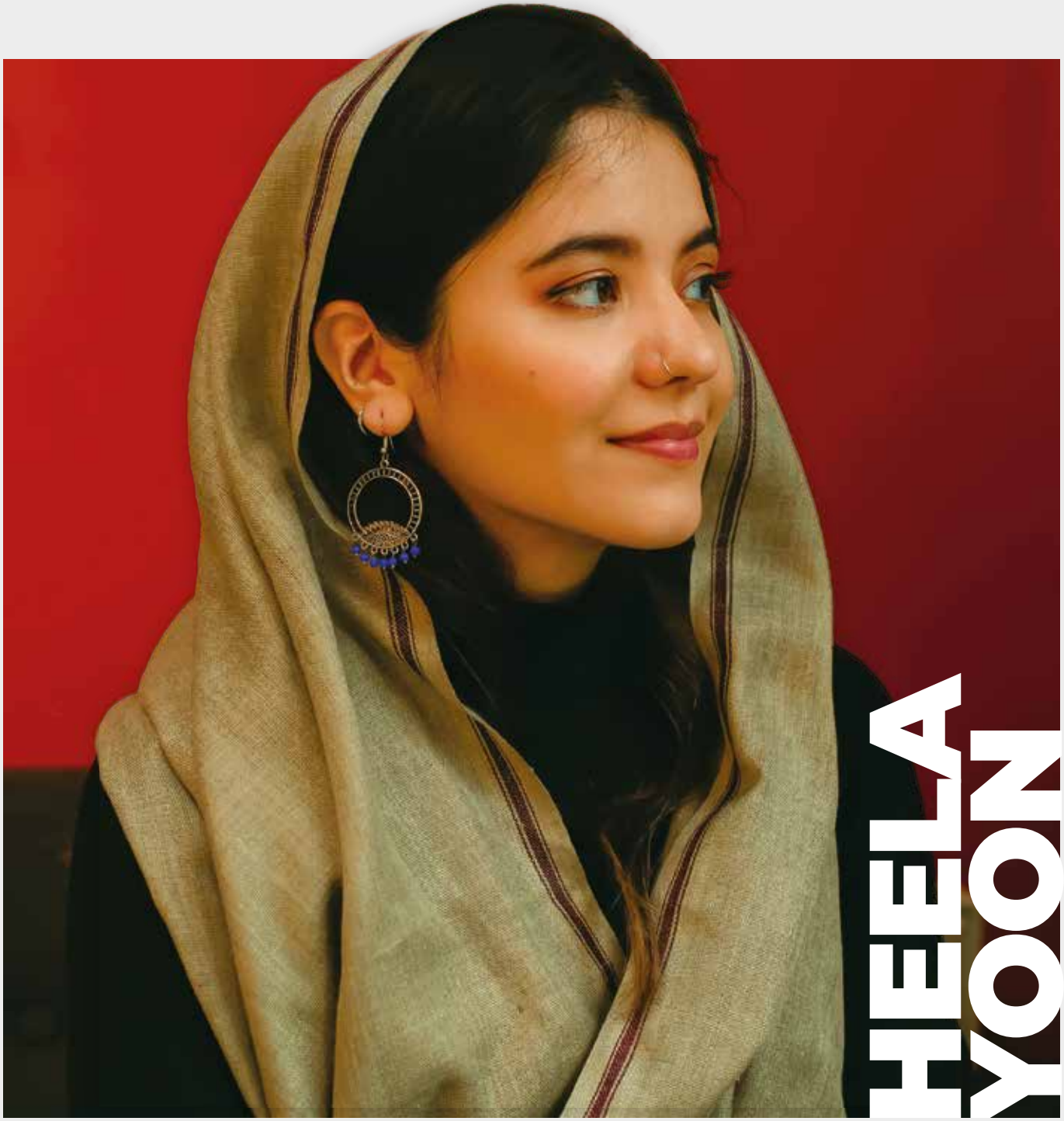

HEELA YOON

"SOCIAL CHANGE TAKES TIME"

Heela Yoon, Afghan Youth Ambassadors for Peace Organization (AYAPO)

"THE HEROES ARE THE WOMEN"

Sue Stevenson, Barefoot College International

FROM POVERTY TO EMPOWERMENT

Barefoot College International, Guatemala

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WELCOME

ISSUE 20
Sharing voices

For every issue of Futurum magazine, we have the huge privilege of working with a diverse range of researchers, representing a wide variety of fields, from around the world. We learn about their backgrounds, ambitions, hard work and commitment, and the incredible successes they achieve. We also learn about the importance of diversity and representation – how the world is all the better for different voices driving the conversation of progress forward.

Futurum works with a multitude of inspirational people striving to make academic research and its impacts on society as diverse and universally beneficial as possible. However, we know that many people in the world struggle to live their lives, let alone share their voices. Many things are heading in the right direction, but there is still much progress to be made. It is vital for us to highlight where there is work to be done and cheer on those who are making it happen, often in incredibly difficult circumstances.

One such force for change is Heela Yoon (p. 4), founder and CEO of the Afghan Youth Ambassadors for Peace Organization (AYAPO). She explains, "Social change takes time, especially when tackling big issues like violent extremism and gender inequality in countries like Afghanistan." Focused and determined, she keeps optimistic in the face of the Taliban's deliberate affront to women's and girls' human rights.

Director of Strategic Partnerships and International Development at Barefoot College International, Sue Stevenson (p. 56) tells us how the organisation, which trains women in some of the world's poorest communities to become solar engineers, is able to "reach hearts and minds and change people's attitudes about what women can do". With a wide scope of ambition, Barefoot College International also focuses on water accessibility and land management.

All the contributors in this issue have progress in their sights – for their work, wider society and the next generation who will take the mantel forward. And we will be with them – applauding people's efforts, celebrating their successes, and amplifying a diversity of voices to ensure we all remember why the work is needed.

THE FUTURUM TEAM

Karen Lindsay
Director and Editor-in-Chief

Erica Morgan
Editor

Isla Foffa
Assistant Editor

Sophia Kerby
Senior Graphic Designer

Brett Langenberg
Director

Chris Dowell
Project Manager

OUR WRITERS

Jacob Ashton, MA

Joe Aslett, MSc

Harry Carstairs, MPhys

Isla Foffa, PhD

Kate Wilkinson, MA

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CONTACT

+44 117 9099150
info@futurumcareers.com
www.futurumcareers.com

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HEELA YOON

> **Social change takes time, especially when tackling big issues like violent extremism and gender inequality in countries like Afghanistan.**

In December 2022, the Taliban banned Afghan women from universities. **Heela Yoon**, founder and CEO of the **Afghan Youth Ambassadors for Peace Organization (AYAPO),** tells us how she keeps optimistic in the face of this deliberate affront to women's and girls' human rights.

Why did you set up the AYAPO?

My mum used to work with non-governmental organisations (NGOs) in the eastern provinces of Afghanistan, and I used to travel around with her. A lot of the programmes she worked on were for young women. When I went to villages in the eastern provinces, I discovered that young women weren't being listened to, even though they were directly affected by many of the challenges the villages faced. This planted the seed for AYAPO.

In 2016, when I was studying at the American University of Afghanistan, we experienced a terrorist attack. My classmates and I were stuck in the building until 4 am. We later found out that 11 students and one professor had lost their lives. That is when my classmates and I decided to set up an NGO which focused on grassroots activism and preventing violent extremism through education.

What sets AYAPO apart from other NGOs?

Many of the programmes initiated by NGOs in Afghanistan – whether to do with peace, education, gender equality or leadership – don't involve youth. And if they are specifically aimed at youth, they don't involve young women.

Often, when you go to local communities and speak to young people, they've never been given a platform, or a chance to speak about their concerns, or asked how they might be involved in decision-making. Our goal is to place these young people at the centre of bigger programmes, such as UN resolutions or laws related to young people, and to place these programmes in a local context so that the young people who are affected by them can be a part of the change.

Food distribution in Afghanistan
© AYAPO member

How old were you when you set up AYAPO?

I was 19, so quite young, and I was working with peace-building organisations. This meant I was able to implement all the things I was learning in my own organisation. It was a struggle in the beginning. When you're young, you're overly ambitious and you want change to happen very quickly. This is something I've learned while working with NGOs; social change takes time, especially when tackling big issues like violent extremism and gender inequality in countries like Afghanistan.

Why is it important to you to empower young Afghans?

In Afghanistan, 60% of the population is under 30 and yet they're not included in decision-making. This is why the current peace process is a failure. It's also why AYAPO works from the bottom up. We want to bring about sustainable change in local communities. Another reason is that young women in Afghanistan experience war, violence and poverty differently, and are the most affected. We want to empower young women so that they can create change and build peace within their own communities.

How do you train youth and young women to be peace-builders?

We have a programme called the Peace-builder Club. We start by inviting young women and men from different districts to focus group discussions. This is where we find out what their needs are. Is it leadership training, for example, or training in technology, communications and public speaking? Once we've understood their needs, we develop bespoke training materials.

One example is the training we did in Jalalabad. A lot of girls in this district don't have access to higher education. Even before the Taliban banned women from universities, local traditions meant that, after graduating from 12th grade, girls were not allowed to attend university.

So, we developed training materials aimed at religious and tribal leaders that focused on Sharia law (the religious law of Islam), explaining how Islam actually promotes women's education. We also conducted workshops in leadership, advocacy, social media and budgeting. We then organised a dialogue between all the stakeholders, including religious and tribal leaders and representatives from the government and NGOs. The young women we'd trained acted as moderators in this dialogue and were


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able to ask religious and tribal leaders questions about their rights to an education. Many people's mindsets were changed, thanks to this experience.

Can you share other examples of the work AYAPO does?

We often face humanitarian crises in Afghanistan, such as earthquakes and floods, and yet humanitarian responders are men. Afghan culture and gender restrictions mean that women don't feel comfortable talking about their needs to male responders. We train female responders to work with women in times of crises and teach them how to prioritise their needs.

Another project we've been working on is the provision of computer science and English as a foreign language (TOEFL) courses for women in the eastern provinces, which we'll hopefully implement in 2023.

What successes has AYAPO had?

The training we've provided to so many young women and the peace-building dialogues we have organised with communities and religious leaders are success stories. We are the first youth- and women-led NGO to have created a safe space for engagement with religious and tribal leaders in the eastern provinces, a region of Afghanistan where change doesn't come easily.

Another success story is our young peace-builders programme, which connects young people with donors and scholarships so that they can continue their education in Afghanistan.

We're also proud to have provided humanitarian support for young people and survivors of the 2022 earthquake in Paktika province, where more than 600 people died.

Then there's the international advocacy work we do to remove the current ban on girls' education. We have been working with Human Rights Watch as well as other organisations to provide educational opportunities for girls who don't have access to education on the ground.

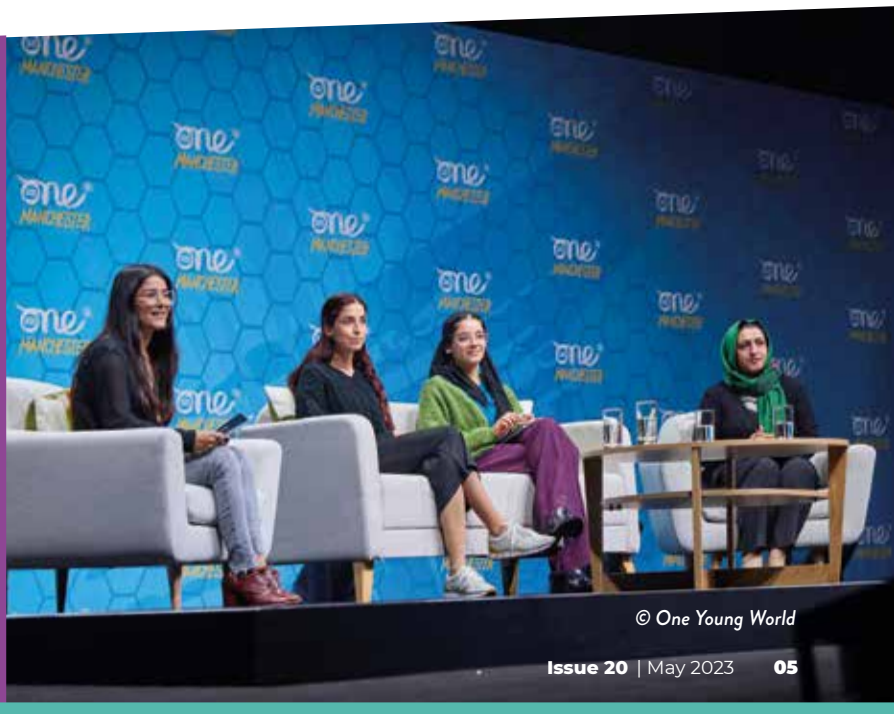
How do you work around restrictions on girls' education?

If the courses aren't university-related and there are only girls and a female teacher, and no men are in the classroom, then there aren't any restrictions. We have also partnered with an educational institute that educates girls to deliver our training, but that doesn't mean we don't experience barriers.

We wanted to start a programme called Peace Goes to School, which aims to train high school girls in peace-building and advocacy, as well as provide them with career coaching classes, but the recent ban on girls' secondary education has meant that we can't implement this project.

Another issue is security and safety. Most of our peace-builder members are female volunteers, and the restriction on women's movements within Afghanistan is affecting their work. The Taliban has also said that women can't work with NGOs. If we do any advocacy work in the country, we're putting our members at risk, and we don't have the resources to evacuate them if anything happens.

> **"WHEN YOU'RE YOUNG, YOU'RE OVERLY AMBITIOUS AND YOU WANT CHANGE TO HAPPEN VERY QUICKLY."**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How do you stay optimistic?

I have my ups and downs. When you start a project to solve one problem, another problem comes up, or the government implements a new restriction or policy. There are moments when I don't feel like being optimistic at all, but there are moments when I need to be optimistic. Young women and girls are banned from education; they don't have any basic human rights. I'm motivated because I've been privileged to continue my education and work without restrictions and outside of Afghanistan. I can use these opportunities to help others achieve the same things.

What can the international community do?

I'm always in support of peace-building dialogues. Afghans are tired of war, and I think the right way for the international community to help is to have meaningful engagement with the Taliban. The Taliban thinks the international community doesn't care about Afghan women anymore, so it can do whatever it wants. That's where we need to prove it wrong.

Neighbouring countries can also have an influence on the Taliban, so the international community could work with countries that border Afghanistan to start engaging meaningfully with the Taliban. When I say 'meaningful engagement', I mean including the people of Afghanistan, as well as women and young people. It shouldn't be men sitting at the table talking about Afghan women's rights. The international community should act as our ally, not our representative, and stop seeing Afghans or Afghan women as victims.

I also think there could be more restrictions put in place, such as travels restrictions for Taliban leaders. And there needs to be safe spaces for activists in Afghanistan, who are standing up against the Taliban's restrictive policies.

Lastly, I think the international community should take responsibility for what is happening in Afghanistan and acknowledge the mistakes it has made.

© Human Rights Watch

> **"AFGHAN WOMEN MAKE UP HALF OF SOCIETY IN AFGHANISTAN, AND IF THEY DON'T HAVE AN EDUCATION, OUR COUNTRY WON'T PROSPER."**

What can we do as individuals?

Making yourself aware of what's happening in Afghanistan is the first thing you can do. A lot of people I've met in the UK have seen a few news headlines, but they don't really know what's happening to women in Afghanistan; for example, there are no health facilities available to women or pregnant women in local communities. Their movements are restricted, and there won't be enough female doctors because the Taliban has put restrictions on girls going to university. There's also a widening illiteracy gap, especially among young women, and a lot of young women are unemployed. There are also many widows in Afghanistan, who are unable to provide for their families. How is that going to affect Afghan households in the long run?

You can help by connecting with international and local NGOs who are providing humanitarian support to Afghanistan. Learn about the different NGOs and make a donation. Even a small donation can bring about a lot of change for one family.

Holding your government to account is another thing you can do. The British government, for example, can influence what's happening in Afghanistan right now.

Then there are the Afghan refugees who come to your country. Go to your local refugee centre, help out, provide any support you can. This might be a donation, or helping refugees to learn how to make use of the services that are available such as doctors and transportation.

© AYAPO member

What are your experiences of growing up as a girl in Afghanistan?

I definitely consider myself to be one of the lucky ones. Not many families encourage their daughters to go to school in Afghanistan, or go abroad to study and work. But my mum and dad have always encouraged me. I'm also inspired by my mum who has worked with different NGOs and had a political career, as well. My dad is a professor at Kabul University and he's very keen for his children to study. I have three siblings – two brothers and one sister – and they're all studying master's and undergrad degrees abroad.

Having an educated family is certainly a blessing. I

didn't know what gender discrimination really meant until I started studying and working with NGOs. A lot of people think I'm working with NGOs because there were no other career options for women in Afghanistan, but this isn't true.

What did you want to be when you were growing up?

My first career choice was to work in the foreign service and become the first young female ambassador. That's why I studied International Relations and Diplomacy for my first undergraduate degree. Later on, through working with NGOs and starting up my own NGO, I focused more on peace-building and humanitarian work. Now, I would like to work with a UN peace-keeping mission and refugees.

I also have a bachelor's degree in finance and a master's in international trade and finance because there aren't enough women working in this area. When I was working at the Ministry of Foreign Affairs, it was only men working in economics, trade and finance.

What's your philosophy in life?

For me, every opportunity is a blessing. My philosophy is to be grateful for whatever comes. I always try to see the silver lining because I've realised that things happen for a good reason. I've also learned to be a more proactive rather than reactive, and think that using whatever opportunities and privileges I have, and sharing them with others, will keep me moving forwards and help others to move forwards, too.

> ***"I THINK IT'S VERY IMPORTANT TO TELL YOURSELF THAT YOU'RE PROUD OF WHAT YOU'VE ACHIEVED SO FAR AND TO TAKE EVERYTHING STEP BY STEP. YOU'RE NOT RESPONSIBLE FOR THE WORLD'S PROBLEMS BUT IF YOU CAN MAKE A SMALL IMPACT ON PEOPLE'S LIVES, THAT'S SOMETHING."***

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© UN staff

But I'm still in my early twenties. I'm also exploring and learning about how life should be, so I can't say I have a definite philosophy.

Do you think you're making an impact?

I hope so because if I thought I wasn't making an impact I wouldn't continue. I usually give myself a pep talk at the end of the day when life becomes overwhelming. I think self-care and telling yourself that you're proud of what you are doing is something that young women should be doing. We often undermine ourselves. We downplay our problems and the things we've achieved in life. Most of the time, we put it down to luck. We don't appreciate our skills and talents. I think it's very important to tell yourself that you're proud of what you've achieved so far and to take everything step by step. Things happen gradually. You're not responsible for the world's problems but if you can make a small impact on people's lives, that's something.

About Heela

ABOUT

In addition to her role as founder and CEO of AYAPO, Heela Yoon is Youth Leader at the Global Partnership for Education. She has worked for Oxfam, Amnesty International and RESULTS UK, among other NGOs. In 2022, she was part of the United Nations cohort of Young Leaders for the Sustainable Development Goals. Heela has a master's in International Business, Trade and Commerce from Leeds Beckett University, a bachelor's in Business Administration from the American University of Afghanistan and a bachelor's in International Relations and Affairs from Kabul University, Afghanistan. Heela is currently based in Leeds, UK.

About AYAPO

CONNECT

AYAPO empowers young Afghan youth and women to become active peace-builders. It aims to amplify their voices at the local, national and international levels, with the ultimate goal of fostering sustainable and just peace.

Connect with AYAPO

twitter.com/Ayapoinfo1
www.linkedin.com/company/ayap
www.youtube.com/watch?v=e7Oi5JK6Sz8

An educational journey through cell biology

Dr Kristina Ames is the Assistant Director for **Cancer Research Training and Education Coordination (CRTEC)** of the **Montefiore Einstein Cancer Center** at the **Albert Einstein College of Medicine** in New York, USA. As a biomedical scientist and passionate educator, Kristina talks us through key concepts of cell biology and how understanding of them shapes scientific research and impacts society.

Kristina Ames PhD

Assistant Director for Cancer Research Training and Education Coordination (CRTEC) of the Montefiore Einstein Cancer Center, Albert Einstein College of Medicine, New York, USA

PROFILE

Fields of research
Cell Biology, Stem Cells

Funders
US National Institutes of Health (NIH); National Cancer Institute (NCI); National Heart, Lung and Blood Institute (NHLBI); Montefiore Einstein Cancer Center

TALK LIKE A ... CELL BIOLOGIST

Autophagy — the process of cellular recycling and self-cleaning of unnecessary cellular components, such as non-functional organelles and proteins

DNA — the molecule that stores genetic information in living cells

Gene expression — the process of using genetic information stored within DNA to synthesise functional proteins, enabling the cell and organism to perform specific functions

Genome — the complete set of genetic material in an organism

Haematopoietic stem cells (HSCs) — cells found in bone marrow from which all blood cells are produced

Mouse model — a genetically engineered lab mouse used to study human disease

Myelodysplastic syndrome (MDS) — a group of disorders resulting in dysfunctional blood cell production which can lead to blood cancer

PI3K — a signalling pathway that regulates a wide variety of cellular functions including cell survival and growth

Protein — a complex biological molecule, playing a variety of essential roles in living organisms

RNA — the molecule produced during gene expression that contains copies of a gene

"As a scientist, you always find something new, something that you didn't know yesterday," says Dr Kristina Ames, whose passion for learning and education has led her to her current role as the Assistant Director for Cancer Research Training and Education Coordination (CRTEC) at the Albert Einstein College of Medicine. "My fascination with the world around me drives me to keep learning new things and exploring different perspectives, which broadens my understanding of the complexities and wonders of the world," she says.

With a background in stem cell research, Kristina's recent study focuses on the human blood production system, investigating why blood cancer develops and working towards a potential treatment that could restore the function of blood production cells. "This work combined my knowledge of and expertise in the cellular recycling process (autophagy), cellular proliferation, and genetic interactions between signalling pathways," she explains. "In my research, I used a mouse model system to understand the role of a specific signalling pathway – PI3K – in haematopoietic stem cells (HSCs)."

Because the PI3K pathway regulates multiple cellular processes, and Kristina only wanted to study its influence on HSCs, she used a mouse model that allowed her to delete three redundant isoforms of PI3K in the mouse's haematopoietic system. Kristina used this Triple Knock Out (TKO) mouse model to investigate whether the TKO mice had normal blood production. She discovered that removing the three isoforms from mouse bone marrow cells led to a significant decrease in the populations of all types of blood cells.

"We showed the important protective role of PI3K in maintaining the cellular recycling process that preserves the balance between HSC self-renewal and differentiation, that, in turn, prevents a certain type of cancer," she explains.

Kristina's research is fascinating – and you can learn more about it by reading her Futurum research article (futurumcareers.com/what-happens-when-our-blood-production-system-fails) and watching her animation (futurumcareers.com/Kristina-Ames-Animation.mp4). Her work also highlights the huge impact cell biologists can have on people's lives.

Through her CRTEC role, Kristina is working to bridge the existing educational gap in research training for students, especially for those from underserved communities and backgrounds that are underrepresented in STEM. She is passionate about mentoring a new generation of researchers needed for the evolving STEM landscape and reminds us that future achievement starts with small steps.

"If you pause each day and pay attention to small victories of learning and your growing knowledge, your life becomes fascinating and rewarding," Kristina says. "In this day and age, where everything is so fast paced, we need to remember to be patient and appreciate the process of everything we do in our lives, perhaps even more than the final destination. When we learn to appreciate what we do every day, our life becomes more interesting and reaching a goal becomes more enjoyable. Then, we can really savour the victory."

Kristina explains *the 'central dogma'*

What is the 'central dogma' of biology?

The central dogma of molecular biology was formulated by Dr Francis Crick, a British scientist, in 1958. It has been viewed as a fundamental principle of biology and explains the flow of genetic information: DNA specifies RNA and RNA specifies protein.

Why does the dogma matter?

The central dogma describes the flow of genetic information from DNA to RNA to proteins and is a powerful, fundamental concept to help your learning. It provides a solid foundation for life sciences; it is the starting principle for understanding the basic information flow in biological organisms, from DNA to protein.

By understanding this concept, you can gain a deeper appreciation of molecular biology and how cellular processes are interconnected. The central dogma can be used to understand DNA structure and function, transcription and translation, gene expression, and molecular genetics. It is a starting point to learning about molecular biology; I see it as a powerful tool to understand the processes of life.

How has understanding of the dogma changed in recent years?

The central dogma proves that, in most cases, genetic information is transferred in the direction from DNA to RNA to protein. However, like with anything else in life, there are exceptions. There seem to be factors other than DNA that specify proteins, and the flow of the information does not necessarily always go in the direction from DNA to proteins.

Since the central dogma was first formulated, scientists have learnt that DNA specification of RNA can be reversed. There is a group of viruses called retroviruses, including the human T-cell lymphotropic virus type 1 (HTLV-1) and the human immunodeficiency virus (HIV), that reverse transcribing strands of RNA to DNA using an enzyme called reverse transcriptase. A newly made segment of DNA is then incorporated by the enzyme integrase into the organism's DNA, causing a frameshift mutation and resulting in the expression of different DNA or RNA sequences in the amino-acid sequence. Moreover, this example highlights how series of proteins are responsible for modifying the DNA segment – reverse transcriptase transcribes RNA into DNA, and integrase incorporates the new DNA segment into the existing DNA, thus demonstrating how proteins can specify DNA.

Another interesting exception to Crick's central dogma is the unique prion example. Prion diseases are rare, degenerative and fatal neurological disorders such as Creutzfeldt-Jakob disease (CJD) and fatal familial insomnia (FFI). Prions are abnormal agents that are infectious and produce atypical folding of normal cellular proteins. In the case of prions, abnormal proteins infect and change normal proteins, rather than reproduce. Prions do not contain genetic material in the form of nucleic acids and they do not multiply, but they affect similar proteins – often in the brain – by behaving as templates to convert other naturally occurring proteins into their abnormal shape.

"To be a scientist is to continuously engagein exploration without ever stopping," says Kristina
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Exceptions to the rules, like these exceptions to the central dogma, are one of the reasons why I love exploring cell biology. To be a scientist is to continuously engage in exploration without ever stopping.

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Kristina recommends...

A selection of videos that use animation to reveal the fascinating world of cell biology.

- From the DNA Learning Center (**dnalc.cshl.edu/view/15876-The-Central-Dogma.html**) at the Cold Spring Harbor Laboratory:
  www.youtube.com/watch?v=9kOGOY7vthk&ab_channel=DNALearningCenter-molecular-biology-2
- From the National Center for Case Study Teaching in Science:
  www.youtube.comwatch?v=0VA275plaQE&t=8s&ab_channel=NationalCenterforCaseStudyTeachinginScience
- An explanation of 'DNA to protein' from yourgenome:
  www.youtube.comwatch?v=gG7uCskUOrA&t=7s&ab_channel=yourgenome
- Drew Berry's 'Animations of Unseeable Biology' from TED:
  www.youtube.comwatch?v=WFCvkkDSfIU&ab_channel=TED

Activities:

- Mutate a DNA sequence: **teach.genetics.utah.edu/content/dna**
- A central dogma card sorting activity from the Howard Hughes Medical Institute (HHMI):
  www.biointeractive.org/sites/default/files/CentralDogma-Educator-act.pdf

Kristina explains *the structure of DNA & DNA replication*

KEY TERMINOLOGY

Adenine (A), cytosine (C), guanine (G) and thymine (T) — the four 'bases' found in DNA. They combine in pairs, always A with T, and G with C

Chromosome — the structure containing DNA in a cell's nucleus

Genome — the complete set of genetic material in an organism

What is DNA, and what does it do?

These are important, fundamental questions! DNA is the molecule inside cells that contains the genetic instructions for the cells' development and function. DNA has a language of nucleotides that it uses to 'write' an organism's instruction manual.

The language of DNA is composed of only four chemical bases: adenine (A), cytosine (C), guanine (G) and thymine (T). DNA is structured in the form of a double helix, consisting of two intertwined strands resembling a twisted ladder. Each of the DNA strands has a 'backbone' made of alternating sugar (deoxyribose) and phosphate groups with one of the four bases (A, C, T, or G) attached to each sugar. The bases on the two strands link together, connecting the two strands of DNA. These four bases arrange themselves in different sequences to create genes that carry different instructions for the organism.

In a human body, there are approximately 3 billion DNA bases packed into the chromosomes in the nuclei of the cells. What is fascinating is that about 99% of those bases are the same in every person; the remaining 1% is what makes you unique!

Why is the structure of DNA significant?

The structure of DNA enables genetic information storage, replication and transmission, as well as genetic mutations and diversity. DNA's double-helix structure allows it to store and transmit genetic information, replicate (make a copy of itself) during cell division and provide the basis for evolution. The sequence of nucleotides in DNA determines the genetic code that directs protein synthesis, which is essential for cellular function. Thus, DNA's structure is crucial for understanding the basis of heredity, evolution and biology.

What is the process of DNA replication?

DNA replication is the process by which a cell creates an identical copy of its DNA before cell division. The process begins with the unwinding of the double helix structure, creating a replication 'fork'. DNA polymerase then adds complementary nucleotides to each strand, creating two new double-stranded DNA molecules. This ensures that each daughter cell (resulting from the division of a single cell) receives an accurate copy of the genetic material.

How has the understanding of DNA impacted science?

The Human Genome Project (1990-2003; **www.genome.gov/human-genome-project**) generated the first sequence of the human genome. This project provided fundamental information about human genetic makeup and accelerated the study of human biology, drastically improving the practice of medicine. The Human Genome Project provided three surprising findings:

1. Most of the genome is non-protein coding. Out of 3.2 billion bases, only 1.5% code for specific proteins.
2. Humans have a small number of protein coding genes compared to other species. For example, 46 human chromosomes carry 21,000 protein coding genes, while 12 chromosomes of the rice plant carry 37,000 protein coding genes.
3. Humans and chimpanzees share 98% of their DNA sequence, and each human on the planet is 99.5% similar to every other human!

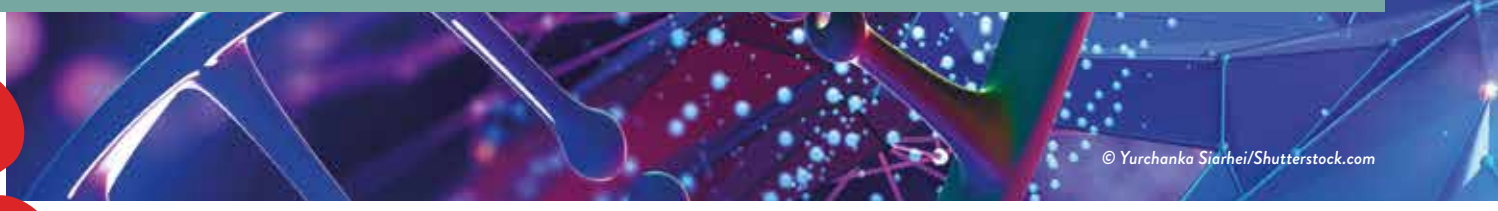
DNA is central to our knowledge of biological processes. Errors or mutations in DNA can lead to genetic disorders and evolutionary changes. DNA, replication allows timely repair of damaged DNA which is critical for the maintenance and transmission of genetic information. Not only does DNA serve as the fundamental blueprint for all living organisms, but it also dictates the functioning of our body under normal circumstances, as well as the development and progression of diseases. The more details scientists understand about the structure and function of DNA, the more they can investigate disease pathways, evaluate genetic predisposition to specific diseases, diagnose genetic disorders, formulate new drugs and bring them to the clinic to treat patients.

How has this understanding impacted society?

In so many ways! DNA is critical to the identification of pathogens. Since detection of DNA presence does not require a viable organism, it provides a vital advantage in the use of molecular techniques for microbial identification.

In addition to medical uses, the uniqueness of DNA to each individual makes it a vital tool for forensic science in criminal investigations, where forensic analysis is used to identify criminals. It can also answer other questions, such as identifying the remains of a missing person and determining the biological parent of a child. Moreover, DNA forensics is used to track food-borne epidemics, identify endangered species in shipments of smuggled material, and trace the history of humans around the world, among other things.

Within agriculture, DNA is used to help improve livestock and plants, as the development of DNA-based technologies opened up possibilities for improving the quality and yields of agricultural products. In addition, genetic engineering has enabled reduced costs of food production, enhanced nutrient composition, and decreased use of pesticides, providing greater food security and protecting the environment.



Kristina explains *transcription*

KEY TERMINOLOGY

Amino acid — molecules that form proteins

Cytoplasm — gelatinous liquid inside a cell, surrounding the nucleus

Mammalian — the group of vertebrate animals whose young are nourished with milk

Ribosome — a structure made of both RNA and protein

RNA — the molecule produced during gene expression that contains copies of a gene

What is transcription, and what does the process involve?

Transcription is the crucial process of synthesising RNA molecules from the DNA template. It is the initial step in the flow of genetic information according to the central dogma, where the genetic code from DNA is transferred to messenger RNA, which carries the instructions for protein synthesis. This process occurs inside the nucleus of the cell and involves the creation of an accurate RNA copy of a gene's DNA sequence, which contains the code for the corresponding protein. The RNA copy, known as messenger RNA or mRNA, carries this information to the ribosomes, where it is used to assemble the amino acids and synthesise the protein.

All of the RNA in a cell is made by DNA transcription. At a basic level, DNA transcription is similar to DNA replication. Transcription starts with the opening and unwinding of a DNA double helix to expose the bases on each DNA strand. Unlike in replication however, only one of two strands of the DNA double helix serves as a template for the synthesis of an RNA molecule. Similar to replication, the sequence of nucleotides in the RNA is determined by the DNA template. The complementarity of RNA nucleotides to the DNA template is essential for the accurate transcription of genetic information, wherein the base pairing rules dictate that adenine (A) pairs with thymine (T) and guanine (G) pairs with cytosine (C). However, the difference is that adenine (A) on DNA molecule pairs up with uracil (U) on the RNA molecule. The incoming ribonucleotides on the newly forming RNA are linked one by one to each other on the growing RNA chain during the transcription.

Why does RNA matter?

Most genes carried in a cell's DNA specify the amino acid sequence of proteins. However, there are other genes that code for the final product, that is, the RNA itself. Although these genes are the minority compared to the protein coding genes, they are no less important for cells. For example, the complete DNA sequence analysis of the genome of the yeast *S. cerevisiae* revealed that more than 10% of the total number of yeast genes produce RNA as their final product. Similar to the proteins, these RNAs are major components in the biochemical reactions and structural components of important processes in the cell.

Scientists don't know all of the functions of the RNAs, but here are some examples:
snRNA – small nuclear RNA molecules that play a major role in the splicing of pre-mRNA to form mRNA;
rRNA – ribosomal RNA molecules that form the core of ribosomes (including the large and small ribosomal subunits);
tRNA – transfer RNA molecules that play a key role in the translation process of making protein from RNA, where they act as adaptors to select amino acids and hold them in place on a ribosome for incorporation into protein.

> TRANSCRIPTION IS THE CRUCIAL PROCESS OF SYNTHESISING RNA MOLECULES FROM THE DNA TEMPLATE.

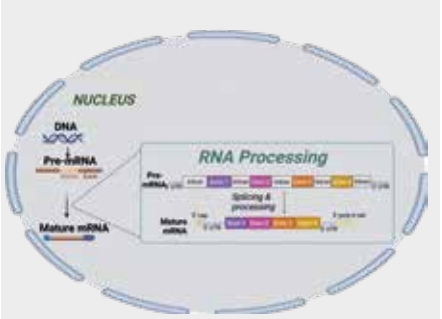
In a typical mammalian cell, total RNA makes up a few percent of the cell's dry weight, where the majority of the cell's RNA is rRNA, and mRNA comprises only 3–5% of the total RNA. Intriguingly, at any given point, the mRNA population of the cell is made up of tens of thousands of different species of mRNA, but only about 10 to 15 molecules of each species of mRNA are present in each cell. RNA is a versatile and indispensable molecule that underpins many fundamental biological processes such as catalysing chemical reactions, regulating gene expression, and participating in various signalling pathways in the cell, and it has numerous applications in medicine and biotechnology.

What are new discoveries adding to this area of scientific knowledge?

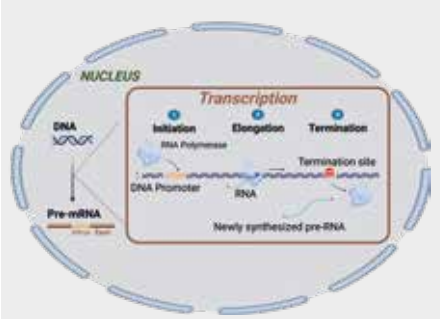
In recent years, scientists at Massachusetts Institute of Technology (MIT) in the US proposed the existence of the cellular machinery that transcribes DNA into RNA in the form of specialised droplets called condensates (scitechdaily.com/radical-new-view-of-gene-control). These droplets occur only at certain sites on the genome. They require an 'on-demand biochemical factory' at specific locations on a gene that is being expressed, allowing the droplet to concentrate all the necessary molecules for transcription, then disassemble them once the 'job' is done.

Similarly to the condensates, it was shown that cells have a 'replication timing programme' that is thought to be an ideal timing for the cell that determines the DNA replication process (scitechdaily.com/60-year-scientific-mystery-about-dna-replication-solved). These concentrations of cellular resources in time and space offer a new way to understand cellular organisation. Instead of randomly floating through the cytoplasm and bumping into other molecules, proteins involved in processes, such as relaying molecular signals, may form specific droplets at specific times, allowing them to interact with the right partners.

Many other recent discoveries highlight new roles for RNA, including editing, splicing and regulation of gene expression. RNA-based technologies, such as CRISPR/Cas9, are revolutionising gene editing and therapeutics.



RNA processing (created by Biorender.com)



Transcription (created with Biorender.com)

Kristina explains *translation*

KEY TERMINOLOGY

Cytoplasm — the gel-like substance that fills a cell and surrounds the nucleus

Differentiated cell — specialised cell with unique functions and characteristics

Homeostasis — the process of maintaining stable internal conditions for optimal cell function

Stem cells — unspecialised cells with potential to develop into specialised cells

Nucleus — the organelle within a cell that contains the chromosomes

Progenitor cells — cells produced from HSCs that have not fully differentiated into mature blood cells

What is translation, and what does the process involve?

The second part of the central dogma of molecular biology is the translation of RNA to protein. Once mRNA is produced, it leaves the nucleus and enters the cytoplasm. In the cytoplasm, mRNA can be translated to protein immediately, stored for later translation, or degraded. Translation is the process during which the genetic code that was transcribed to mRNA is read one codon (three nucleotides) at a time. Groups of the transfer RNA molecules, tRNA, bring amino acids one by one to the ribosome and match them to the correct mRNA sequence, binding them to one another within the ribosome to produce the growing amino acid chain of the protein.

Why does translation matter?

Proper regulation of protein synthesis is very important for normal cell function, since it is indispensable in the gene expression process for the multitude of proteins in the cell for every cellular process. In general, the rate of protein synthesis is proportional to the concentration and translational efficiency of its mRNA.

Regulation of translation also plays an important role in controlling the expression of many genes that respond to nutrient supply, hormones or stress. Furthermore, protein synthesis takes a lot of energy from the rapidly growing or biosynthetically active cell, and therefore requires tight regulation. Any abnormalities in protein synthesis of normal cell function can contribute to the development of disease. Therefore, understanding the mechanisms that contribute to translational control is essential for understanding cell homeostasis and disease.

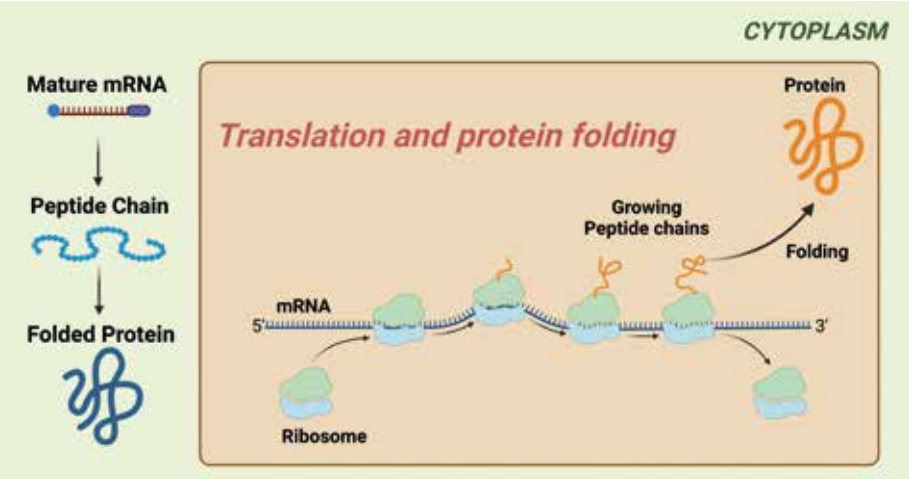
Although much research has been done on understanding the regulation of translation in metabolically active cells, less is known about translation in stem cells. Recent data show that there is a significant difference between protein synthesis in stem cells and more metabolically active differentiated progenitor cells. Increasing evidence suggests that keeping a low level of translation in stem cells is important for controlling stem cell fate, and increased translation is associated with differentiated cells. Moreover, during normal development, when stem or progenitor cells differentiate, protein synthesis is altered, which determines the cell's fate. Understanding how translation regulates cell fate will provide insights for how stem cells can generate desired cell types and prevent or treat cancer.

Translational control is critical for the development and survival of cancer cells. Cancer cells frequently rely on the translation phase of gene expression, though it is not fully understood why translation is targeted. Several major signalling pathways can reprogram the genome via translation. Cancer cells also can use translation to adapt to cellular stress by translating mRNAs that can alleviate stress and promote survival. To oppose the effects of cancer, future cancer therapies may target disruption of the translation machinery of the cell.

What are new technologies adding to this area of scientific knowledge?

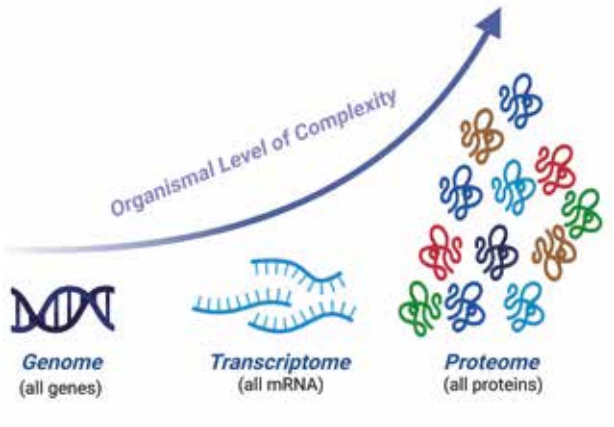
For several disorders, such as diabetes, cancer and arthritis, proteins are useful as drugs as they can ease the disease. Scientists have learnt to synthesise artificial versions of these proteins. However, this process is very time-consuming and requires genetically engineering microbes or other cells to produce the desired protein. Recently, chemists at Massachusetts Institute of Technology (MIT) have devised an automated flow synthesis machine that can string together hundreds of individual amino acids to make proteins within hours (news.mit.edu/2020/faster-protein-synthesis-0528).

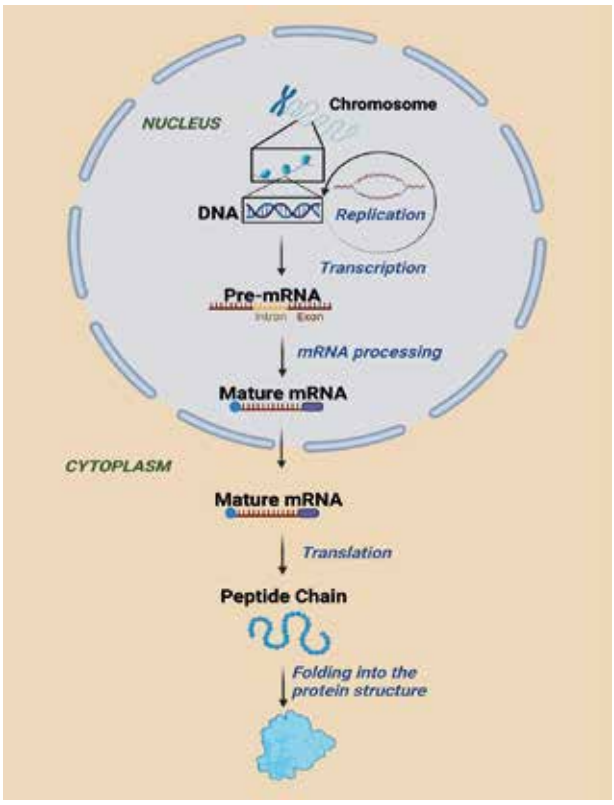
Scientists have also created an artificial intelligence system that can generate artificial enzymes from scratch! (www.sciencedaily.com/releases/2023/01/230126124330.htm). What is even more amazing is that some of these enzymes have been shown to work as well as natural enzymes, even when their artificially generated amino acid sequences were not exactly the same as in the natural protein. These new technologies can dramatically reduce the amount of time and resources required to generate synthetic proteins and could speed up the manufacturing of on-demand therapies and the development of new drugs. It's an exciting prospect!

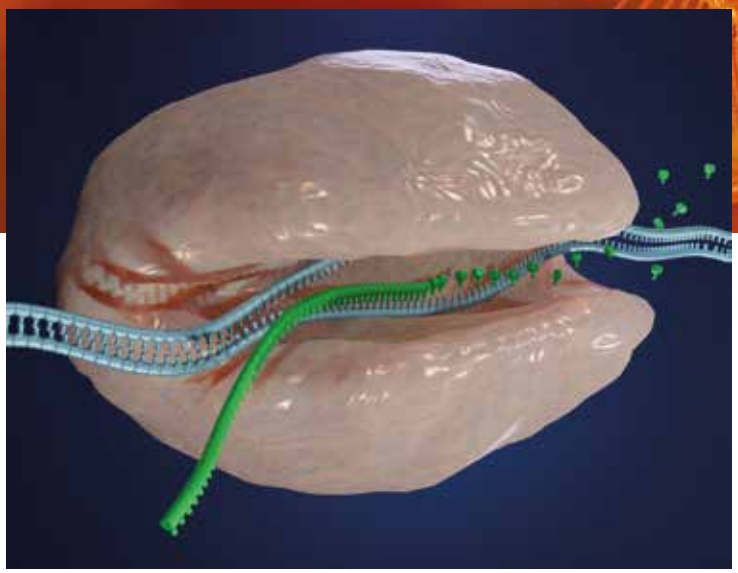


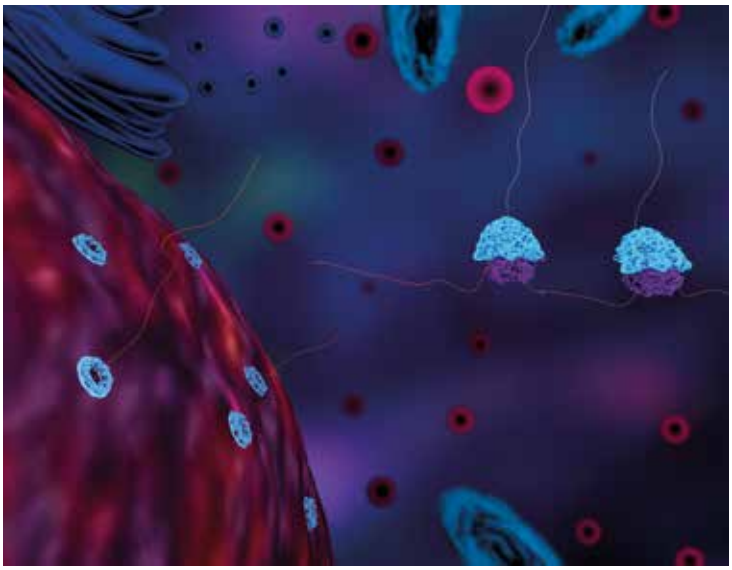
Translation and protein folding (created with Biorender.com)

Photo *montage*









Top left: *DNA to protein complexity in the organism (created with Biorender.com)*

Bottom left: *The 'Central Dogma' – from DNA to protein (created with Biorender.com)*

Top right: *Kristina explains,"Transcription is the crucial process of synthesising RNA molecules from the DNA template." © Love Employee/Shutterstock.com*

Bottom right: *3D illustration of protein translation in a cell (credit: Shutterstock/ Meletios Verras) © Meletios Verras/Shutterstock.com*

What do we know about the ovary?

Ovarian cancer ranks fifth in cancer deaths amongst women, with a woman's risk of getting it during her lifetime being about 1 in 78. Polycystic ovary syndrome (PCOS) is the most common endocrine and ovulation disorder in women that severely alters fertility. At **Baylor College of Medicine** in Texas in the US, **Professor JoAnne S. Richards** has dedicated her career to improving our knowledge and understanding of the ovaries, with the ultimate hope of improving women's health worldwide.

Professor Joanne S. Richards

Department of Molecular and Cellular Biology, Baylor College of Medicine, Houston, Texas, USA

PROFILE

Field of research
Molecular and Cellular Biology

Research project
Studying ovarian function and related dysfunctions, such as polycystic ovary syndrome and ovarian cancer

Funder
US National Institutes of Health (NIH)

TALK LIKE A ...

MOLECULAR AND CELLULAR BIOLOGIST

Embryo — an unborn, developing offspring. In humans, the embryonic stage lasts from approximately the second to eighth week after fertilisation

Gamete cell — the reproductive female or male germ cell

Membrane — a thin sheet of extracellular matrix protein or layer of cells that act as a boundary or lining between specific cell types

Metastatic cancer — a dangerous, late stage of cancer where it spreads to distant parts of the body

Omentum — fatty tissue in the peritoneal cavity

Ovary — an endocrine gland at the upper end of the uterus that contains follicles and corpora lutea, the sources of steroid hormones, and releases mature oocytes (eggs) at the time of ovulation

Ovulation — the process during which an egg surrounded by specialised cumulus cells is released from the surface of the ovary for fertilisation to occur

Peptides — compounds consisting of two or more amino acids linked in a chain, which can bind to specific receptors to alter cell functions

Pituitary gland — a pea-sized gland at the base of the brain that produces several protein hormones, including FSH and LH

Somatic cells — any cell in the body other than the gamete cells (sperm and egg cells)

Uterine — relating to the uterus

The ovary is an essential organ that plays a crucial role in the reproductive system of females. Professor JoAnne S. Richards, a molecular and cellular biologist at Baylor College of Medicine, has been studying the ovary for decades, learning about its various critical functions, as well as the causes of female infertility and ovarian cancer.

Females have two ovaries each, which are about the size of a thumb and are attached to the uterus located in the pelvic cavity. Ovaries contain the female reproductive cells, oocytes (eggs), which, once fertilised by a male sperm, can develop into a living embryo. Individual oocytes are one of the largest cells in the human body, measuring around 0.1 mm in size. Once grown, they are even visible to the naked eye.

"The primary functions of the ovary are to promote the maturation, ovulation and fertilisation of the oocyte and to regulate embryo implantation and uterine maintenance during pregnancy," says JoAnne.

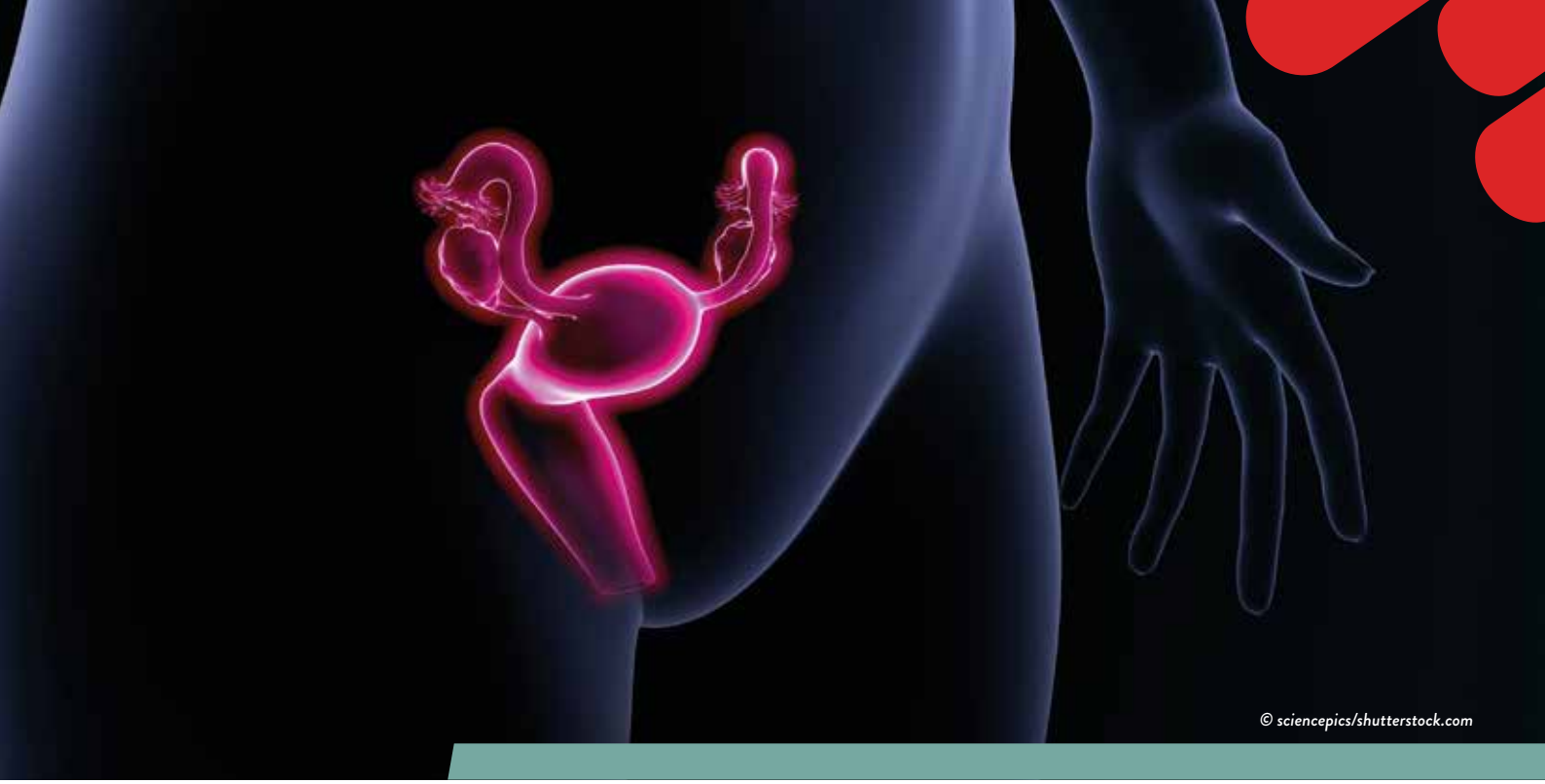
The ovary is controlled by two pituitary hormones called follicle stimulating hormone (FSH) and luteinising hormone (LH). These hormones act via receptors on specific cells to regulate the growth of ovarian follicles and the maturation of oocytes within these follicles. A surge of LH induces ovulation, during which a follicle ruptures and releases a mature, fertilisable egg.

What are follicles?

Ovaries contain thousands of follicles (all at different stages of development) that function to ensure that the oocyte is well-protected and nurtured, so it can mature and be fertilised.

"Inside a follicle, the oocyte is attached directly to special somatic cells called cumulus cells," says JoAnne. "These cells come from the surrounding granulosa cell layer. FSH-responsive granulosa cells are then separated from LH-responsive theca cells (the outer cells) by a basement membrane."

"The oocyte affects these somatic cells



by releasing specific peptides. The somatic cells (granulosa and theca cells, in turn) coordinate and promote maturation of the oocyte," JoAnne explains.

In addition, the somatic cells produce steroid hormones – oestradiol and progesterone, the major female sex hormones – that regulate embryo attachment and development during pregnancy. These steroids also control breast development and lactation, ensuring that mothers are able to breastfeed once they give birth (though other issues can make this difficult to do in practice, and not everyone chooses to breastfeed).

What do scientists know about the causes of female infertility?

"Age is a major factor in fertility," says JoAnne. This is because women are born with all the oocytes they will ever have and are not able to make any more during their lifetime. "The ovary of a human infant immediately prior to birth contains around 6 million oocytes," says JoAnne. "This number declines to around 1 million at birth; 300,000 at puberty; 25,000 at age 36 and about 1,000 at menopause. Thus, if women delay childbirth until age 40, they have difficulty conceiving."*

Women who have difficulty conceiving might consider *in vitro* fertilisation, also known as IVF. "IVF clinics can sometimes rescue ovulation," says JoAnne. However, the number of follicles present and that can be stimulated to ovulate is greatly reduced, meaning the chances of getting pregnant through IVF at age 40 or later are much lower.

There are multiple other causes of female infertility that scientists know about. Polycystic ovary syndrome (PCOS) is a common but complex cause that is associated with elevated levels of androgens, LH and obesity. "Women with PCOS can usually be stimulated to ovulate by managing levels of FSH and LH," says JoAnne.

> **"THE PRIMARY FUNCTIONS OF THE OVARY ARE TO PROMOTE THE MATURATION, OVULATION AND FERTILISATION OF THE OOCYTE AND TO REGULATE EMBRYO IMPLANTATION AND UTERINE MAINTENANCE DURING PREGNANCY."**

What do scientists know about ovarian cancer?

Unfortunately, ovarian cancer is a dangerous and deadly disease, with a survival rate of only 30% if diagnosed at an advanced stage. "The lethality of ovarian cancer is largely due to the late stage at which it is diagnosed and the extreme difficulty in removing the tumours surgically," explains JoAnne. Current anti-cancer drugs are also only effective for short durations, as cancer cells have powerful mechanisms that allow them to become drug-resistant and evade cell death.

While there are multiple cells in the ovarian follicles that are helpful for the oocyte – such as the granulosa, theca and cumulus cells – there are some outside the follicles that can be dangerous. "Ovarian surface epithelial (OSE) cells, for instance, are not part of the ovulatory follicle and can give rise to ovarian cancer," says JoAnne. Ovarian cancer can be caused by these OSE cells or by cancerous cells coming from the fallopian tubes that spread to the ovary and the omentum within the peritoneal cavity. "The initial causes of ovarian cancer, as with other types of cancer, remain largely unknown," says JoAnne. "99% of the time, ovarian cancer is associated with mutations in the tumour protein p53," says JoAnne. p53 plays a role in DNA repair mechanisms, which means that mutations in p53 can prevent DNA from repairing itself, making cells more susceptible to damage and further mutations. Unfortunately, mutations in this and other genes can be passed down from parents to children, meaning that ovarian cancer can be an inherited disease.

What research has JoAnne done on ovarian cancer?

Some of JoAnne's research has involved expressing KRAS – a gene that if mutated has been associated with cancer cell functions – in granulosa cells in mice. "When we did this, we saw that KRAS blocked follicle growth, reduced ovarian steroid production, and led to an increase in the tumour suppressor gene, PTEN," says JoAnne.

JoAnne and colleagues then disrupted expression of PTEN in the KRAS mutant mouse ovarian cells. "When we did this, follicle development remained blocked, but OSE cells (which can cause ovarian cancer) were transformed," explains JoAnne. This provided one of the first mouse models of ovarian cancer.

After this, JoAnne and colleagues decided to reduce the p53 gene in the OSE cells of mutant mice. This led to the discovery that p53 was essential for tumour growth. "Cells lacking p53 developed only small tumour lesions that were exquisitely sensitive to steroid hormones and became highly metastatic when exposed to oestradiol," JoAnne explains.**

The realisation that steroid hormones can impact some types of ovarian cancer might allow better treatments for this disease to be discovered in the future.

** Adapted from Pangas, Molecular Reproduction & Development 79: 666, 2012*

***a. Fan et al. Cancer Res. 69:6463-6472., 2009*
b. Mullany et al. Mol Endocrinol 28: 127-137 2014

About *molecular and cellular biology*

Molecular and cellular biologists study the processes and interactions of cells and molecules in animals, microorganisms and plants. They will often work in lab environments, set up experiments, teach and write scientific papers to explain their findings to others. They can have wide-ranging impacts on other researchers as their work can advance various fields such as medicine, pharmaceuticals, food and agriculture.

Molecular and cellular biologists must love discovering the unknown, as working as a researcher will lead to lots of unexpected discoveries! "Science is a mindset, and I think one either has it or not," says JoAnne. "It is not about making money. Rather, it is about people and the hope and joy of discovery. It is the ideas and puzzles of nature that provide the rewards and inspiration in science, with the ultimate hope of improving health for everyone."

How has JoAnne contributed to scientists' knowledge of ovarian function?

One of JoAnne's biggest contributions was the discovery of a second form of the enzyme cyclooxygenase, now known as prostaglandin synthase-2 (PTGS2). This form is essential for ovulation and is selectively expressed by ovulating follicles.

"Prior to 1991, the scientific community only recognised a single cyclooxygenase gene," says JoAnne. "My laboratory unexpectedly unveiled the second form, which is induced in ovulatory follicles by the luteinising hormone (LH). This was perhaps the most memorable moment in my career, because it was so unexpected, and it took us so long to figure it out!" *

What research opportunities will be open to the next generation of molecular and cellular biologists?

"The technologies available to molecular biologists are changing and expanding at a rapid pace. Analysing cells and genes at a single-cell level is the most recent approach. Microscopic technologies are also improving, becoming more powerful and being linked to computer driven images. Gene editing is now becoming routine, but this will face challenges of ethics. My hope is that we do not forget to see the big picture and understand the physiology and the beauty of the basic biology."

** Wong and Richards Mol. Endocrinol. 5: 1269-1279, 1991.*

Pathway from school to *molecular and cellular biology*

- At school and post-16, take as many science classes as you can. You will then need to complete an undergraduate degree in a scientific subject, such as biology, molecular biology, biophysics or biochemistry. After that, complete a master's degree and a PhD in molecular biology.
- JoAnne recommends you also learn computer language skills, as well as English and writing skills.
- Before you choose a university, have a thorough look at their website to get an idea of their strengths.
- "Many institutions also have outstanding summer programmes," says JoAnne. "For example, Baylor College of Medicine has a summer SMART (Summer Medical and Research Training) Program."
- Find out more: **www.bcm.edu/education/graduate-school-of-biomedical-sciences/programs/diversity/smart-program**
- "Scientists must have a love of adventure and be willing to take failure," says JoAnne. Something to keep in mind whichever route your pathway from school takes.

Explore careers in *molecular and cellular biology*

- "Working in a lab, almost any lab, is a great way to get started," says JoAnne. Try and find workplace experience as soon as possible to see if a career in molecular and cellular biology is something you are truly interested in. You can also reach out to current biologists to see if they might have opportunities for you to shadow their work.
- The University of California Berkeley has a useful webpage summarising career options for people with molecular and cell biology degrees: **mcb.berkeley.edu/undergrad/major/career**
- The American Society for Cell Biology has a wealth of information on its website (**www.ascb.org**), including its Pathways Podcast series for those interested in life sciences: **anchor.fm/ascb-pathwayspodcast**
- The British Society for Cell Biology also provides careers information: **bscb.org/learning-resources/softcell-e-learning/careers-and-courses**
- Salaries vary depending on position, employer (for example, you could work in academia or industry) and experience. **CareerExplorer.com** explains that a starting level molecular biologist can earn around $48,000 a year, while a senior molecular biologist could be earning around $133,000 a year.

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Q&A

Meet *JoAnne*

What prompted your shift from majoring in French to pursuing a career in science?

My goal to become a French major changed in my second year of college when I had difficulty using headphones to distinguish recorded French conversation (little did I know that I had a hearing problem). Luckily, I was taking all the pre-med biology courses because I was keenly interested in biology, and eventually biology became my major.

Afterwards, I went to graduate school at Brown University to become a high school biology teacher. I learned the first day of practising teaching that this was not my calling – I had absolutely no disciplinary powers whatsoever! Luckily, the programme required a research experience and that evolved into my applying for the PhD programme in physiological chemistry (biochemistry) at Brown. This was my first exposure to research. Research in the ovary, with a focus on steroidogenesis, isolating steroid hormones was a big thing in the late 1960s. It was an exciting time!*

* Richards, JS. Discovering science and the ovary: a career of joy. Reproduction 158: F69-F80, 2019.

What do you find rewarding about research in your field?

What captures me most about science is the process of discovery and the challenges to decipher the secrets of Mother Nature. Most rewarding has been the unexpected experimental results that have led me down new paths and reminded me that one should always keep an open mind. In my lab, the most rewarding moments have been identifying a new cyclooxygenase gene, generating an unexpected mouse model of ovarian cancer, identifying novel pathways regulating ovulation and documenting a novel role for androgens in theca/stromal cells. In these discoveries, I have enjoyed the enthusiasm of young students and colleagues.

Scientists are rewarded by discovering new pathways, genes and approaches to understand biological processes. I have been richly rewarded throughout my career. None of this would be possible without the support of the Society for the Study of Reproduction, the Endocrine Society and the National Institutes of Health. These organisations, and the wonderful, dedicated people who maintain these scientific and educational opportunities and the yearly NIH sponsored, Frontiers in Reproduction, course at Woods Hole, Massachusetts, are the ones who sustain our research in endocrinology and reproductive biology.

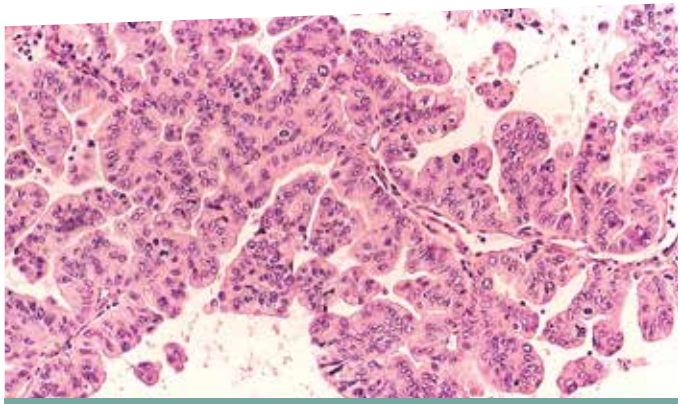
What keeps you motivated as a scientist?

The most important motivator is the research itself: the ideas, the data, tackling new approaches to understand complex biological events. It is just so exciting to see novel data begin to unravel the current puzzle. There is nothing quite like having a complex experiment work.

I have also been motivated by my colleagues, students, other scientists and the camaraderie we have shared. The scientific excellence of the facilities and faculty at the University of Michigan and Baylor College of Medicine have motivated me, as have the scientific meetings around the world, which have brought new insights at all levels. Science is a world community that is open-minded. I have collaborators that I have never met, and have been lucky to work with a bright, energetic and thoughtful group of colleagues during my career.

JoAnne's *top tips*

1. Don't be afraid to see an experiment fail, seek help, ask questions. If failure was not due to technical issues, then there is something new to learn.
2. Enjoy tackling the unknown and love what you do. Perseverance is the key. If you like what you are doing, you will be successful.
3. Don't let anyone take you for granted!



A micrograph of a cancerous tumour in the female ovary. (© David A Litman/shutterstock.com)

How does pre-birth milk expression help with breastfeeding?

The benefits of breastfeeding newborn infants are long-established. However, the idea of expressing milk while pregnant, before the baby is born, is a relatively new one. At the **University of Pittsburgh** in the US, **Dr Jill Demirci** is researching why antenatal milk expression is becoming increasingly popular and whether this technique might improve breastfeeding post-birth.

Dr Jill Demirci

School of Nursing, University of Pittsburgh, USA

PROFILE

Field of research
Nursing Science

Research project
Investigating how antenatal milk expression affects breastfeeding outcomes among women with BMI 25 and over

Funders
University of Pittsburgh, US National Institutes of Health (NIH), Association of Women's Health, Obstetric and Neonatal Nurses (AWHONN), American Nurses Foundation (ANA)

TALK LIKE A ...

NURSING SCIENTIST

Antenatal — before birth

Antibodies — proteins that protect you when an unwanted substance enters your body

Body mass index (BMI) — a measure of body fat based on height and weight

Colostrum — the first milk produced during pregnancy and the first days after birth that is low in total volume but high in antibodies

Hand expression — expressing breast milk by hand

Milk expression — removing milk from the breast by any method (e.g., electric breast pump, hand expression), so that it can be stored and fed to a baby later

Infant formula — nutrition for babies, which can be a substitute for breast milk; sold as a ready-to-feed liquid or a powder to be mixed with water

Postpartum — after childbirth

Antenatal milk expression, also known as AME, is becoming increasingly popular worldwide. It involves self-collecting early milk from the breasts, often around the 36-37th week of pregnancy (though it can be available earlier), which may then be frozen for a child to have once they are born.

"There are no major US-based maternal child health organisations recommending or not recommending AME," says Dr Jill Demirci, a nursing scientist at the University of Pittsburgh. While not everyone chooses or is able to breastfeed, Jill notes that societal pressure to succeed at breastfeeding may cause parents to jump at the chance to get a head start though AME and increase their chances of successful breastfeeding. "They might hear about AME through other breastfeeding parents, health providers who have read the early research on AME or more informal social media channels, like 'mommy' blogs, Instagram accounts and online breastfeeding groups."

Does AME have positive effects?

"There is some evidence that AME reduces infant formula supplementation in the first few days after birth and promotes more exclusive breastfeeding," says Jill. "That's good news, since longer, more exclusive breastfeeding has important health benefits for both parent and baby, and is good for the economy and environment."

AME might reduce infant formula use because it allows women/birthing people to freeze expressed milk before their baby is born. This gives them an option other than infant formula or donor human milk (which is not always available) if their baby needs a small amount of extra milk after birth. This might be necessary if breastfeeding is not going well or parent and baby are separated due to medical complications.

AME can also increase an individual's confidence and comfort with breastfeeding, leading to them feeling more prepared for their baby's arrival. "AME seems to be a catalyst to get people thinking through the mechanics and logistics of breastfeeding," says Jill. Some women/birthing people have even reported that AME seemed to contribute to having more breast milk after they give birth, too.

What is Jill's research looking at?

Until now, AME has mainly been studied in women/birthing people with diabetes. This group has a high risk of using infant formula right after birth, because the babies can have blood sugar regulation issues that require immediate feeding. In addition, those with diabetes may have hormonal issues caused by diabetes which negatively affect milk production.

However, Jill has decided to study AME among other groups at risk for sub-optimal breastfeeding outcomes. One of the groups she has focused on in her research are people whose BMI before pregnancy is 25 or higher (classified as overweight or obese). "Compared to those with pre-pregnancy BMIs less then 25, these birthing people have a higher likelihood of breastfeeding problems, too, like low milk supply and early, unintended infant formula use," says Jill.

This might be for both biological and societal reasons. "Birthing people with obesity can have a hormonal profile that interferes with the development of glandular (milk-making) tissue in the breast and problems with milk production within the available glandular breast tissue," says Jill. Women who have excess weight or obesity may also have larger breasts, which means that positioning their baby for breastfeeding may be challenging. Societal reasons such as weight stigma bias might also play a role, as women with higher BMIs might feel uncomfortable with body exposure through breastfeeding. They may even feel judged by health providers about their weight and, therefore, less inclined to seek breastfeeding help if they need it.

What does Jill's study involve?

Jill is recruiting 280 pregnant people with a pre-pregnancy BMI of at least 25 to take part in a study to see if AME can improve breastfeeding outcomes. "All participants are first-time parents, have no prior breastfeeding experience, and have no major health or pregnancy complications at the time of recruitment," says Jill.

> **"PARTICIPANTS LIKE HAVING THE TIME TO GET USED TO BREASTFEEDING AND ASK QUESTIONS."**

Participants meet with a lactation consultant once a week during their 37th to 40th week of pregnancy. This takes place over a Zoom video session and lets participants practise AME and ask the consultant for advice on AME and breastfeeding in general. "We then encourage participants to practise AME on their own, once or twice a day, for 10 minutes at a time," says Jill.

Each day of the study, Jill's team sends out automated text messages that ask participants questions about their AME practice. "Some people have questions when starting the study, such as whether practising AME will 'use up' their colostrum," says Jill. "The answer to this is no. Milk is made on a continuous basis and colostrum continues until a few days after the birth."

How is Jill controlling this study?

Out of Jill's 280 participants, half are randomly assigned to the AME group and half are assigned to an attention control group – called this because the participants receive the same amount of attention from the staff as the AME group. The control group spend their study sessions watching videos on infant care and topics unrelated to antenatal milk expression or breastfeeding. This should mean that any differences in outcomes between the groups are due to the different content and not because only one group had the opportunity to interact with staff and ask questions.

What results has Jill found so far?

"We aren't far enough in the study to analyse breastfeeding outcomes, so we don't know yet if participants assigned to AME had better rates of exclusive breastfeeding or breastfed longer postpartum," says Jill.

However, Jill has had some feedback from participants already. She often hears that the study has increased people's confidence to breastfeed, and that participants like having the time to get used to breastfeeding and ask questions before birth.

On the other hand, some are disappointed that they did not express as much milk as they expected to during the study. Jill and her team try to stress that everybody is different, and that AME is more about learning the hand expression skill than anything else. "Any milk expressed and banked is a bonus," Jill adds.

What are the team's next steps?

Many of the participants develop complications that lead to them giving birth earlier than the 37th week mark, meaning they do not even have a chance to start AME before they go into labour. "So, we'd like to explore the safety and efficacy of starting AME even earlier in pregnancy," says Jill.

Jill's team also collects breast milk samples from study participants, both before pregnancy and after birth. In the future, Jill would like to analyse these milk samples to look at changes in milk composition (nutrients and immune factors) over time.

Jill is also interested in pursuing more community-driven research in lactation. "This type of research is more likely to create actionable and sustainable solutions, rather than research that is conducted exclusively by academics," says Jill. With more minds working together to improve breastfeeding outcomes, more women will hopefully be able to benefit from this research in the future.

About *nursing science*

Nursing scientists get to make a direct, positive impact on people's lives, and they have the freedom to design their own career. Nursing scientists are trained nurses who have decided to branch into research. They create experiments, publish and write up their results in scientific papers, often teach, and aim to get their work translated into health policies, guidelines and public health campaigns.

What research opportunities will be open to the next generation of nursing scientists?

"Science is always evolving, and there are always new challenges!" says Jill. "There are so many big issues in healthcare to address, and nurse researchers can (and are) leading on so many of them. I think team science is going to be a model moving forward – currently most nurse researchers work individually and bring in outside co-investigators with given expertise on a particular project. In the future, we might see more interdisciplinary and community-based teams that bring complementary skills and work together over time on multiple projects. Another thing is big data (e.g., large national/international and government-based datasets). I think nurses with expertise in this field will be in high demand, as this data can be powerful in guiding policy and action."

Pathway from school to *nursing science*

- To become a nurse scientist, study science subjects such as biology, chemistry and anatomy while at school and at post-16. "Many top nursing schools are looking for well-rounded high school students with some advanced placement courses, particularly in the sciences," says Jill. You will need to complete a bachelor's degree in nursing, before pursuing postgraduate study to become a researcher.
- "The nursing curriculum in universities is usually very prescribed, with core classes and clinical requirements," says Jill. "However, I always think it's a great idea to think about complementary interests and how taking additional courses outside the nursing curriculum might serve your nursing career."
- If you can, try to study subjects outside of nursing to help you figure out where you want your nursing career to take you. At Jill's university, undergraduate nursing students pursue certificates in subjects such as women's studies, global health, philosophy, business and environmental sustainability.
- Jill recommends taking language courses if you are interested in travel and working in global health. "If you are interested in research then study biostatistics and take research-based courses," she advises. "Humanity subjects – such as literature and history – can round out a science-heavy nursing curriculum and enrich your education immensely."

Explore careers in *nursing science*

- Jill recommends looking at university summer programmes for high school students that allow you to work with faculty mentors to explore nursing skills and research. "You can also contact hospitals, community health organisations, or other areas where nurses work to see if shadowing opportunities are available," says Jill.
- Many specialities in nursing have their own organisations and websites. "Reach out via email to an individual faculty member at a school of nursing or a nursing director at an organisation whose work resonates with you, and make that connection," says Jill. "Sometimes, they have opportunities or may be willing to provide mentorship."
- The American Nurses Association's Nurse Focus has lots of useful information about what to think about when considering a career in nursing, as well as a checklist for selecting a nursing school: **nursefocus.org/pre-licensure**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Meet *Jill*

Who or what inspired you to pursue nursing?

Nursing appealed to me because it combined my love of science and my drive to make a positive impact through caring for people at vulnerable times in their lives. In nursing, there are so many opportunities for additional training, too. It is a career with almost endless possibilities, from the setting you work in, populations you work with, and the nature of your day-to-day work. You can chart your own course and change your direction if you choose.

What experiences have shaped your career?

While I was in nursing school, I had opportunities to work as a teaching assistant and an undergraduate researcher. My mentors really encouraged me to consider research and graduate school. They inspired and guided me in pursuing my PhD and a career in research.

I also had an undergraduate lecture on human lactation that fascinated me! Breastfeeding is not only about nutrition but connection, immunity, maternal health and well-being, infant behaviour, and so much more. When I became an obstetric nurse, I just assumed everyone would breastfeed for as long as possible because of all those amazing benefits. Then I saw how difficult breastfeeding could be, particularly without good support. Those experiences shaped my interests.

When I had my own children, I became intimately familiar with lactation challenges and how those challenges come to affect maternal psyche and permeate every aspect of life. I came back to the research field after their births with so many questions, plus an urgency and determination to pursue them. One of my research questions was around antenatal milk expression, which I had tried with great success with my first child.

What do you find rewarding about research in your field?

While clinical nursing, particularly in the hospital setting, can be very rewarding, it is also very demanding physically and emotionally. Sometimes there is limited room for individual creativity or change-making. Research, on the other hand, is a great fit for my personality. I love learning, reading and having the freedom to explore unanswered questions. I love that I design my own days and can work on several projects that are important to me at once. There is a lot of independent work in reading and writing, but it is interspersed with meetings and group work and chats. To me, a career in nursing research is the best of all worlds. Right now, I spend a good portion of my time writing grants, meeting with research staff, collaborating with other researchers, writing research papers, and presenting at health conferences. I also spend time doing clinical lactation consulting, mentoring PhD students, teaching undergraduate and graduate courses, and working on clinical innovations in the lactation field. It is so rewarding, and every day is different!


Some women express milk to feed to their baby later.© Tatiana Foxy/shutterstock.com

What are your proudest career achievements so far?

My proudest moments are hearing from participants in our studies that our interventions made a difference in their breastfeeding relationships and experience as a mother/parent. It has also been rewarding to publish our findings and see our data spur new investigations and be cited in clinical breastfeeding recommendations.

I'd say that even more so than any achievements, it's the process that I'm proud of. I love working with and mentoring undergraduate and graduate students in research. It's so gratifying to realise that they will go on to collectively influence healthcare in a bigger way than I could ever do as a single individual.

Jill's *top tips*

1. Worry less about a perfect GPA/exam score and focus on learning. Take courses and pursue enrichment opportunities outside of what you are typically inclined. You might surprise yourself!
2. You can chart your own course – your career is uniquely yours and it doesn't have to look like anyone else's. Play to your strengths and don't be afraid to dive deeply into what excites you.
3. We spend a good portion of our lives working – make sure it is on something you love.

Can behavioural interventions improve biological health outcomes?

Cardiovascular disease is the leading cause of death in the US, accounting for around one in every five deaths. However, some groups in society are at higher risk than others. At the **University of North Carolina Chapel Hill** in the US, **Dr Yamnia I. Cortés** is investigating whether a community-based behavioural intervention can improve cardiovascular health outcomes for perimenopausal Latinas.

Dr Yamnia I. Cortés

School of Nursing,
University of North Carolina Chapel Hill, USA

PROFILE

Fields of research
Nursing Science, Women's Health, Cardiovascular Epidemiology

Research project
Investigating health outcomes for perimenopausal Latinas

Funders
US National Institutes of Health (NIH) – National Institute of Minority Health and Health Disparities; Betty Irene Moore Fellowship for Nurse Leader and Innovators

TALK LIKE A ...

NURSE SCIENTIST

Cardiovascular — relating to the heart and blood vessels

Clinical trial — a research study performed on people that evaluates a medical, surgical or behavioural intervention

Community-based research — research taking place in community settings and where community members have a say in the research process

Health equity — when everyone has the opportunity to reach their best health outcomes

Latino/a/x — an individual of Latin American descent (i.e., Mexican, Central American, South American or from some Caribbean islands)

Menstruation — the process whereby approximately once a month a woman discharges blood from the lining of her uterus

Oestrogen — the primary female reproductive hormone

Perimenopause — the transition that occurs before a woman stops menstruating at menopause

While everyone experiences changes in their health as they get older, women who menstruate are particularly at risk from certain health problems that may occur during perimenopause. "There are three major reproductive stages in women who menstruate: premenopause, perimenopause and postmenopause," explains Dr Yamnia I. Cortés, a nurse scientist at the University of North Carolina Chapel Hill. Premenopause begins with menarche, the first menstruation, which typically happens when a girl is between 10 and 16 years old and marks the beginning of the reproductive years. Women usually enter perimenopause in their 40s or 50s, when they may notice changes in their menstrual cycle. A woman has reached menopause when she has not menstruated for 12 consecutive months, at which point she enters the postmenopausal stage of life.

Perimenopause is a significant biological transition for women who menstruate. During this time (which, on average, lasts four years), oestrogen levels in the body decrease, leading to several symptoms associated with perimenopause and an increase in certain health risks. "Oestrogen is a female reproductive hormone typically produced in the ovaries," explains Yamnia. "It also plays an important role in other parts of the body, such as the bones, brain and heart. The decline of this hormone during perimenopause can lead to hot flashes, sleep disturbances, depressive symptoms, bone loss, body fat accumulation and rising cholesterol."

Why are Latinas at greater risk of cardiovascular disease during perimenopause?

While the biological process of declining oestrogen leads to health changes during perimenopause, sociocultural and environmental factors can also contribute to the severity of symptoms and health risks, such as cardiovascular disease (CVD). Most perimenopause research in the US has collected data from non-Latina white women, meaning that women of other races or ethnicities (who are more likely to experience negative sociocultural and environmental factors) are underrepresented in current knowledge about perimenopause health outcomes. Yamnia is passionate about health equity and aims to initiate change by focusing her research on perimenopausal Latinas.

Latinas are particularly at risk of CVD during perimenopause as they are more likely to experience adverse sociocultural factors such as discrimination, social

isolation and stress. "Many Latinas live in neighbourhoods with fewer grocery stores and so lack access to healthy food," says Yamnia. "Living in disadvantaged neighbourhoods increases stress, limits physical activity and increases sedentary behaviour, which influence biologic CVD risk factors." As a result, Latinas are at significantly greater risk of developing CVD than non-Latina white women.

Developing a behavioural intervention

Yamnia hopes to reduce the risk of CVD in perimenopausal Latinas by developing a community-based and culturally tailored behavioural intervention. This intervention involves teaching nutrition education, physical activities, stress management techniques and coping skills to perimenopausal Latinas. Yamnia and her team are evaluating whether this leads to improved biological health outcomes.

The nutrition education programme involves teaching participants to understand food labels and sharing healthy recipes. Physical activity sessions include various exercises, such as stretching and Zumba, while stress management techniques taught to participants include mindfulness, aromatherapy and doing arts and crafts. "These behaviours can lead to weight loss, lower blood pressure, lower blood sugar, lower cholesterol and healthier arteries, all of which increase cardiovascular health," explains Yamnia.

Why is it important that the intervention is culturally tailored?

"Culturally tailoring an intervention means taking into consideration the needs and preferences of the target culture or community," says Yamnia. "This makes the intervention more applicable to the values and daily life of individuals."

To ensure it was relevant and accessible, Yamnia specifically tailored the behavioural intervention to Latinas. "We delivered the intervention in a way that addressed Latino cultural values such as *respeto* (respect), *familismo* (loyalty to family) and *confianza* (trust)," she explains. Sessions were led by Latinas who could identify with participants, and all materials were available in Spanish and English. The recipes taught to participants were healthier versions of traditional dishes from multiple Latino backgrounds, including Mexican, Puerto Rican and Argentinian, to reflect the diversity within the Latino community. And the exercises taught to participants were all suitable for the space and materials that were available to the women in their homes.

> **"LIVING IN DISADVANTAGED NEIGHBOURHOODS INCREASES STRESS, LIMITS PHYSICAL ACTIVITY AND INCREASES SEDENTARY BEHAVIOUR, WHICH INFLUENCE BIOLOGIC CVD RISK FACTORS."**

Testing the intervention

To test the effectiveness of the intervention, Yamnia and her team conducted a clinical trial. They enrolled 40 perimenopausal Latinas, who were randomly assigned either to take part in the intervention or to the control group that did not participate (though women in the control group had the opportunity to receive the intervention after the clinical trial was completed). The 20 women receiving the intervention were invited to participate in the programme, which consisted of twelve weekly sessions followed by three monthly sessions. Each session consisted of 45 minutes of nutrition education, 45 minutes of physical activity and 15 minutes of stress management.

Yamnia and her team collected the data from all 40 women at three points during the study – before the intervention began, immediately after the intervention finished and six months after the intervention had ended. "This included a questionnaire about sociodemographic details, medical history, menopause symptoms, stress, sleep, diet and physical activity," Yamnia says. "We also collected blood samples to test for fats (including cholesterol), sugars and proteins, and we collected hair samples to measure cortisol levels (a hormone that indicates stress levels)."

Does the intervention reduce CVD for perimenopausal Latinas?

The results from the team's clinical trial show that women who participated in the intervention had lower stress and lower blood pressure than women in the control group. "This suggests the intervention may be successful in reducing CVD risk factors," says Yamnia. However, while the study shows it is feasible to conduct behavioural interventions to improve health outcomes for perimenopausal Latinas, the team realised that the intervention in its current form is too long. "Of the 20 women in the intervention group, only nine attended more than half of the sessions and only four attended more than 80% of the sessions."

What next?

Yamnia now hopes to implement similar programmes in different locations, allowing more perimenopausal Latinas to take advantage of the health benefits of behavioural interventions. However, a key finding from her initial study was that many of the participants did not have health insurance. This suggests that behavioural interventions alone are not enough to improve the health of Latinas, as sociocultural and structural factors, such as lack of access to healthcare, must be addressed as well.

We need more nurse scientists, healthcare practitioners and policymakers who are passionate about health equity to ensure that everyone, regardless of ethnicity, gender or socioeconomic status, can lead a healthy life.

About *nursing science*

Nurse scientists are nurses who design and conduct health-related research projects, lead research teams, and often teach in academic settings. Like other scientists, they publish their research results in scientific journals and share their findings with the public through presentations, news outlets and social media.

The importance of women's midlife health

There is a difference between chronologic ageing and reproductive ageing. "Some health factors that increase the risk of CVD, such as weight and blood pressure, naturally increase with age," explains Yamnia. "Others, such as body fat and cholesterol, increase more rapidly during perimenopause." When assessing midlife health issues in women who menstruate, it is important to determine which changes are due to general ageing, and which are due to perimenopause.

Women's midlife health is important for everyone in society, regardless of gender or age. "We all have important women in our life – family members, friends, teachers and colleagues," says Yamnia. "To protect their health and quality of life, we need more healthcare providers, researchers, social workers, politicians and community members interested in this topic."

The importance of inclusive health policies

As well as researching women's midlife health, Yamnia's research group, the Cortés MenoLab, also advocates for policies that promote women's midlife health equity. The team does this by working with policymakers and national health organisations to ensure health policies are effective, relevant and inclusive, and by providing advice and guidance for clinical care and research.

A key aspect of this is promoting health research in marginalised populations. "When marginalised populations are not included in health research, we risk not understanding how certain health issues affect these populations," explains Yamnia. "We also risk developing health procedures, medications or behavioural interventions that do not work in marginalised groups. Therefore, we need to include as many people as possible, from all different walks of life, in health research."

Pathway from school to *nursing science*

- Yamnia recommends taking courses in sciences (such as biology, chemistry, anatomy and physiology), statistics and public health. You should also take any other courses that interest you. "My interest in Latina health is no accident," says Yamnia. "In college, I took classes in Latino/a studies and gender studies."
- Completing a Bachelor of Science degree in nursing will qualify you to practise nursing in a clinical setting. To become a nursing science researcher, you will then need to complete a PhD.
- However, there is no set path to becoming a nurse scientist. Yamnia studied biology and Latino/a studies, then public health before turning to nursing. "My path was not typical or linear, and that's okay!" she says. "We can get to the same goal using different paths."

Explore careers in *nursing science*

- "Although I am a nurse scientist, this is not the only career available for individuals interested in women's health," says Yamnia. "I have worked on women's health issues with epidemiologists, biostatisticians, physicians, psychologists, social workers, sociologists, nutritionists and more!"
- Yamnia recommends looking for work experience opportunities to give you a better sense of whether you will enjoy being a nurse scientist. "This is the best way to tell whether a certain career fits with your aspirations," she says. "Look for opportunities in high school and college to participate in research projects, work as a nurse aid or shadow nurse scientists to get a sense of their day-to-day work."
- Explore Health Careers has information about careers in nurse science, as well as other health-related fields: **explorehealthcareers.org/career/nursing/nurse-researcher**
- This article explains the important contribution nurse scientists bring to health research: **www.wolterskluwer.com/en/expert-insights/who-are-nurse-scientists**

Meet *Dr Yamnia I. Cortés*

I am passionate about health equity, especially for Latinas, because I grew up in the Bronx, New York, where many people in my community suffered from asthma, diabetes and heart disease. The Bronx has one of the highest rates of asthma in the US due to the exhaust fumes from nearby highways. In my neighbourhood, there were long waits to see a healthcare provider, few healthy options were available in the grocery store, and we had no safe park spaces.

I received a scholarship to attend a private high school, and the neighbourhoods surrounding it were a stark contrast to my own. These neighbourhoods had green spaces, fresh fruits and vegetables at the market, and well-equipped health centres. This prompted me to ask why these differences existed and how they impacted health.

In middle school, I joined a social justice programme where I participated in community service projects. I learnt how to affect social change when we demanded the clean-up of the Bronx River and the development of a park for the neighbourhood. I also served as a peer educator, presenting health-related workshops in the local community. In high school, I had the opportunity to complete a summer programme where I conducted research in a laboratory at a college and shadowed physicians in a hospital.

I pursued my interest in social justice and health at college. Alongside my studies in biology and Latino/a studies, I worked part-time in a biochemistry laboratory and had the chance to join a medical mission trip to the Dominican Republic. As a child, I had translated for my mother during many interactions with health providers, and, on this trip, I acted as a translator for a group of obstetricians and gynaecologists.

I was the first person in my family to graduate from college. After completing my degree in biology and Latino/a studies, I then did a degree in public health. Some years later, I returned to university to complete a nursing degree. In my work as a nurse, I most enjoyed providing patients with health education.

All my experiences gave me an interest in community work, clinical work and research, so I did a PhD in nursing science. I now love my work as a nurse researcher conducting community engaged research, as it allows me to work with people in the community, listen to their stories and advise them about health.

Yamnia's *top tips*

1. Don't be discouraged by failures. The difference between success and failure is the number of times you keep trying.
2. You don't have to reach your goals by following the same journey as the person next to you.
3. Self-worth and self-compassion are better motiving factors than any titles or awards.

Meet some members *of the Cortés Menolab*

Andrea Cazales
PhD Student

"I enjoy being part of a team that reflects the community it serves. I like that we use strength-based approaches to address menopause health inequities experienced by historically marginalised communities. The Cortés MenoLab does an exceptional job of uplifting not just the communities it serves, but also its members."

Latesha K. Harris
PhD Student

"While in nursing school, I learnt that women have a unique set of healthcare challenges and are at higher risk of developing certain conditions than men, such as heart disease and diabetes. As a nurse, I noticed how women experience health promotion, disease prevention and illness differently, and this inspired me to pursue a career as a nurse scientist. The leading causes of death for women are preventable. My passion for helping everyone achieve their best health set me on a path to investigate women's health disparities."

Alyssa Portes
PhD Student

"As a first-generation Latinx student, I have a deep interest in learning about the racial and ethnic health disparities marginalised women face. I have worked as a research assistant on several projects surrounding minority women's health. In nursing school, I decided to pursue a PhD in nursing science to better understand risk factors for perinatal depression among Latinx mothers living in rural communities."

Protecting the pancreas

Our immune system is highly organised and ruthlessly efficient, but when it goes wrong it can lead to debilitating disease. Our pancreas is critical for metabolism and digestion. At the **Columbia University Irving Medical Center**, USA, **Dr Stuart Weisberg** is studying how immune cells function in both healthy and diseased pancreases, and what this means for treating pancreatic disease.

Dr Stuart Weisberg

Assistant Professor of Pathology and Cell Biology, Columbia University Irving Medical Center, USA

PROFILE

Field of research
Immunology

Research project
Examining the function of tissue-resident memory T cells in the pancreas

Funders
US National Institutes of Health (NIH): National Institute of Diabetes and Digestive and Kidney Diseases; Gerstner Family Foundation

TALK LIKE AN ... IMMUNOLOGIST

Antigen — a foreign substance in the body

Genome — the complete set of genes present in an organism

Immune system — the processes and components of the body that provide resistance to threats, such as pathogens

Inflammation — a strong localised immune response to a particular perceived threat

Pancreas — the organ that secretes digestive enzymes into the small intestine and glucose-regulating hormones into the blood

Pathogen — an organism that causes disease, such as bacteria

T cell — a type of white blood cell trained to detect specific pathogens

Tissue-resident memory T cell (TRM) — a T cell that occupies a specific tissue rather than circulating in the blood

Transcriptome — the full range of genes expressed by a cell (specifically, the mRNA transcripts produced)

When we think of our immune system, we usually think of white blood cells patrolling our blood vessels on the lookout for pathogens. In fact, the vast majority of immune cells are not found in the blood but are hunkered down in our organs. "Taking blood is a convenient way to sample immune cells but only gives us a partial picture of the body's immune system," says Dr Stuart Weisberg, an immunologist at Columbia University Irving Medical Center. "It's like if you were studying all of humanity but only examined the people driving around on roads. This would give you a very biased perspective."

Stuart is building a more detailed picture of how the immune system functions, focusing not on the blood, but instead on one very important organ: the pancreas. "The pancreas is critical for digestion and metabolism," he says. "It secretes digestive enzymes that break down food in the intestine, as well as releasing hormones that coordinate glucose uptake." With this in mind, understanding how the pancreas works – and how to restore its function when something goes wrong – is essential.

What has the pancreas ever done for us?

A functioning pancreas is a complex and highly regulated machine. "The pancreas contains cell clusters that produce and secrete powerful digestive enzymes through a network of ducts until they reach the small intestine, where they break down food so the nutrients can be taken up by the body," explains Stuart. "If the pancreas is damaged or these ducts are blocked, the enzymes can spill out and start digesting the pancreas itself – a painful and sometimes fatal disease known as pancreatitis."

As well as enabling digestion, the pancreas secretes hormones into the blood to control how the body uses sugars. "Small islands of cells (called 'islets') within the pancreas sense blood glucose levels and secrete hormones (insulin and glucagon) into the blood to coordinate glucose uptake by all cells in the body," says Stuart. If these cells are disturbed, we lose our ability to regulate our glucose levels. For instance, Type 1 diabetes occurs if the immune system attacks these cells, while Type 2 diabetes develops if these cells suffer chronic stress due to aging or obesity. "Individuals with diabetes must monitor and carefully control their blood glucose levels at all times, as the pancreas doesn't do it for them," explains Stuart.

What role do T cells play?

Stuart and his team are interested in how the pancreas regulates its own specific section of the immune system. "T cells are highly specialised cells of our immune system that protect the body from infection and cancer," he explains. "Each

T cell has a unique receptor (a 'T cell receptor') that can recognise a very specific molecule (an antigen) as foreign, such as those carried by invading pathogens." Once the T cell receptor recognises its target, the cell replicates vigorously to detect and destroy all cells in the body that contain this antigen. Once the threat is removed, most of these T cells die, but a small number remain as our immune 'memory', ready to quickly detect and replicate if the antigen shows up again. In addition, T cells cannot work alone. Their recognition of antigens requires the antigens to be processed and presented by other cells in the tissue.

Most memory T cells reside in our organs as tissue-resident memory T cells (TRMs). "TRMs are adapted to survive, function and be retained in a specific tissue site," says Stuart. "They help our organs remember past infections and provide a localised defence against pathogens and cancer." Every tissue – from our skin to our lungs to our brain – needs TRMs, but every tissue is also different, each with unique requirements for immunity that are dictated by the anatomy and function of the cells in the tissue. Stuart's research is focused on how TRMs function in the pancreas.

How does Stuart study pancreatic TRMs?

The study of human pancreas cells relies on the generosity of organ donors. When organs from recently deceased donors are not needed or cannot be used for transplanting, they can, with consent, be used for research instead. However, unearthing the systems behind pancreas functioning is no easy task. "Obtaining live cells from the pancreas is difficult because, once the clusters containing digestive enzymes are disrupted, the organ begins digesting itself," explains Stuart. "The separation of the pancreas into its component parts has to be performed rapidly, gently and with careful controls." Stuart's team has refined methods for doing this to place as little stress on cells as possible, so Stuart can observe pancreas cell function in a way that minimises the disruption to the cells.

> ***"OBTAINING LIVE CELLS FROM THE PANCREAS IS DIFFICULT BECAUSE, ONCE THE CLUSTERS CONTAINING DIGESTIVE ENZYMES ARE DISRUPTED, THE ORGAN BEGINS DIGESTING ITSELF."***

Once Stuart has isolated living pancreatic cells, such as TRMs, he studies them using a technique called transcriptome profiling. Our genome describes the entirety of our DNA and all the genes within it and is the same for every cell in our body. Our transcriptome, however, only describes the genes that are actively being used by a specific cell, which depends on its environment and the stimuli it is receiving. Transcriptome profiling involves cataloguing all the activated genes in a cell, including the degree to which they are being activated in any particular scenario.

What has Stuart discovered?

Stuart's work in transcriptome profiling has revealed fascinating insights about pancreatic TRMs. "The most interesting features of these cells are the ones that help them do their job without causing excessive damage to surrounding pancreatic tissue," he says. "Pancreatic TRMs can release powerful toxic molecules capable of directly killing cells and can also make molecules that summon other immune cells and induce inflammation." While these features are great when they are needed – when the pancreas is under attack from a pathogen, for instance – they must be kept carefully in check to avoid damaging the pancreas' own cells.

Pancreatic TRMs have a surface receptor specific to a molecule released by neighbouring cells that, when activated, restrains TRM responses. "Just like well-trained police dogs, these cells have great potential to kill invaders and call in back up, but when not needed, they remain calm and functionally restrained." Stuart's team has found that, in patients with chronic pancreatitis, it is this relationship that is malfunctioning, leading to TRMs being abnormally activated and provoking an unneeded immune response that constantly inflames and damages the pancreas.

From research to healthcare

"As physicians, we often dismiss the biology of healthy organs as they are not causing problems for our patients," says Stuart. "But when we think about it, the maintenance of healthy organs over decades in a danger-filled environment is a remarkable process worthy of intense research." The study of medicine usually focuses on when things go wrong, but Stuart is adamant that understanding healthy organ function is just as, if not more, important. For every discipline, from medicine to automobile mechanics, understanding how something works when it is going right is essential for getting things back on track when something goes wrong.

This is why Stuart's team is examining TRM function in both healthy and unhealthy pancreatic tissue. "It is important that we understand how the healthy pancreas strikes a balance between robust immune defence and avoiding damaging inflammation, because many pancreatic diseases are caused by disruption of that balance," says Stuart. "Excessive TRM activation causes inflammation which can lead to pancreatitis and diabetes, but if TRMs are not activated sufficiently, the pancreas can suffer from destructive infections or develop cancer." Stuart's research has found that a healthy pancreas has abundant resident immune cells, which are maintained in a very specific state and dispersed in certain ways throughout the pancreas. "By defining the specific cells and signalling pathways that maintain this state, we can learn how to better restore health to patients with pancreatic disease," he says.

About *immunology*

Immunology is the study of our body's immune system, including how it responds to threats and what happens when it malfunctions. Immunology is essential for developing effective healthcare for existing and novel diseases and is responsible for directly saving countless lives.

"The human immune system is shaped by the pathogens it encounters, and some of the most important sites for immune defence are the interfaces between the body and environment: our airways, lungs and gastrointestinal tract," says Stuart. "If our environment changes, our immune system has to adapt."

How is globalisation impacting our immune systems?

Societal developments can cause significant changes to the threats that our immune system encounters. For instance, urbanisation exposes us to more air pollution, climate change is altering the number, variety and distributions of pathogens, and habitat destruction is causing humans to come into closer contact with animal diseases.

"Immune responses require a lot of energy to function, so rely on good nutrition," says Stuart. "All forms of malnutrition – over nutrition and under nutrition – impair immune responses." Globalisation has increased nutritional disparities, with some people not having enough to eat and others over-consuming unhealthy processed foods. Our interconnected modern world also means that pathogens can spread rapidly as people travel great distances between countries, potentially carrying diseases with them.

What are the joys of immunology?

While recognising the importance of his work, Stuart also finds it extremely enjoyable and fulfilling. "One of the best aspects of immunology is that, as immune cells interact with all other cell types in the body, it invites exciting collaborations with many different scientists," he says.

Stuart is a physician scientist, so alongside his immunology research, he also works as a medical doctor in a hospital. "As a physician scientist, I'm conscious that my immunology research needs to be directly relevant to potential treatments for my patients in hospital," he says. "Organ transplantation, treating cancer and fighting infectious diseases all rely on immunology."

Pathway from school to *immunology*

- Study biology, chemistry and mathematics at school and college, as these will teach you the fundamental knowledge behind immunology.
- Some universities offer undergraduate or postgraduate degrees in immunology. Studying biology or molecular biology could also lead to a career in the field.
- "You need to understand molecular biology and molecular genetics to understand immunology," says Stuart, so take as many classes as possible in these areas.
- Immunologists commonly analyse large datasets, so take courses that will teach you the skills required to do this. "Learn how to code in various computer languages and learn the statistical methods to create models from these large datasets," Stuart advises.

Explore careers in *immunology*

- Some immunologists are medical doctors who work with patients to diagnose and treat illnesses related to the immune system. Others are academic scientists who conduct research to improve our understanding of the immune system and what happens when it malfunctions.
- Columbia University Irving Medical Center has a rich array of community programmes and initiatives, many aimed at inspiring young people towards medical careers by providing opportunities to participate in research: **www.gca.cuimc.columbia.edu/community-service-programs/community-programs-initiatives**
- This blog describes the steps to become an immunologist and explains what a career in the field involves: **www.inspiraadvantage.com/blog/how-to-become-an-immunologist**

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Meet *Stuart*

I didn't always want to be a doctor. I was originally interested in journalism rather than medicine. However, I soon discovered I enjoyed the investigative aspect of journalism more than the writing, which morphed into a desire to pursue the investigative side of medicine.

As a medical student, I worked in a research laboratory full of friendly, open-minded and rigorous scientists. I enjoyed the experience so much that I transitioned from aiming for a career as a medical doctor to instead becoming a physician scientist. That lab was also where my interest in tissue immunity began, and our interactions with the lab next door primed my interest in pancreas tissue immunity.

I have had a series of outstanding mentors who have inspired me. They have opened many doors to help me develop my career and collaborate with a diverse community of dedicated scientists, without which my studies in pancreas tissue immunity would not be possible.

As a physician scientist, I enjoy it when my research background helps me provide novel insights that inform my clinical work. I can help patients understand their medical problems at a more fundamental level and therefore feel more comfortable with their treatment plan.

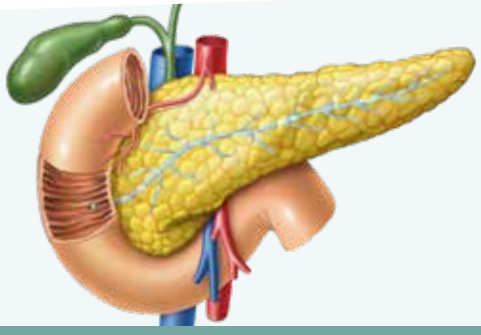
> **I HAVE HAD A SERIES OF OUTSTANDING MENTORS WHO HAVE INSPIRED ME.**

The most challenging aspect of my dual roles as a physician scientist is switching from one to the other. Working with patients in the hospital is nothing like working in a research lab, and sometimes it can feel incompatible. At these times, patient care always comes first, even at the expense of research.

Outside of work, I enjoy spending time with my wife and children and our pet hamster, Bernie. We love doing anything outside, such as camping, swimming, hiking and biking. We enjoy live music, visiting relatives and travelling.

Stuart's *top tips*

1. Don't try to follow in anyone's footsteps. Make your own footsteps, instead.
2. We should always aim to improve on what has come before us, using lessons and insights from others to figure out new and unexpected things.
3. Immunology and medicine are complex fields that can seem overwhelming, so pace yourself and don't think you have to understand everything immediately.



The pancreas (yellow) secretes digestive enzymes into the small intestine (pale brown) and glucose-regulating hormones into the blood (red and blue)
© Andrea Danti/shutterstock.com

How do proteins affect heart health?

Proteins are the building blocks of life as they control the chemical reactions in cells. Despite the importance of proteins, scientists are still trying to determine what many of them do. One such scientist is **Professor Beverly Rothermel**, a molecular biologist at the **University of Texas Southwestern Medical Center** in the US, who has spent over twenty years investigating the many biological processes influenced by one particular protein, Regulator of Calcineurin 1.

Professor Beverly Rothermel

Department of Internal Medicine, University of Texas Southwestern Medical Center, USA

PROFILE

Fields of research
Molecular Biology, Molecular Cardiology

Research project
Investigating the role of RCAN1 in cardiac health

Funders
US National Institutes of Health (NIH; award R01 HD101006), The American Heart Association (AHA; award 19TPA34920001)

TALK LIKE A ...

MOLECULAR BIOLOGIST

Cardiac — relating to the heart

Chromosome — a molecule composed of DNA

Circadian rhythm — a process that naturally recurs on a 24-hour cycle

Degenerative — a progressive and irreversible deterioration

Down syndrome (DS) — a genetic disorder which causes developmental difficulties

Metabolically active — converting food into energy

Mitochondria — the structures in cells that produce energy for the organism

Pathological remodelling — physical changes due to disease

Signalling — the process of a cell receiving, processing and emitting instructions

Calcineurin, also known as CaN, is a protein that is particularly important in the nervous, immune and cardiovascular systems. "CaN is estimated to make up more than 1% of the total protein weight of our brains, and yet we only know a fraction of what it does," says Professor Beverly Rothermel, a molecular biologist at the University of Texas Southwestern Medical Center.

Bev's research has been fundamental to understanding how Regulator of Calcineurin 1 (RCAN1) controls CaN activity and how this impacts human health. Her lab was involved in the initial discovery and characterisation of RCAN1, showing that when RCAN1 levels increase in a cell, the activity of CaN is reduced. This can have a significant effect because CaN is involved in many cellular processes. "The past twenty years of studying this remarkable protein have taken my laboratory in many interesting and often unexpected directions," she says.

What role do CaN and RCAN1 play in the heart?

Heart disease is the number one cause of death worldwide. "The heart is very adaptable," says Bev. "When you exercise, it undergoes beneficial remodelling to increase its power. In contrast, if it progresses to heart failure, it undergoes pathological remodelling. CaN signalling is known to play a prominent role in this process." Bev and her team hypothesised that increasing RCAN1 levels might reduce the chance of heart disease.

Bev used mice to test whether increasing levels of RCAN1 in the heart to inhibit CaN signalling would decrease the risk of heart failure. "We genetically engineered mice to have slightly higher levels of RCAN1 in the muscle cells of the heart," she explains. Amazingly, the engineered mice had improved cardiac function in every model of heart failure that Bev and her team tested.

Where did this realisation lead Bev?

"Initially, we thought that whenever the heart is under stress, it increases levels of RCAN1 as a protective response," Bev says. Although this is indeed true, Bev's team accidentally discovered that hearts which were not subjected to stress also had huge daily fluctuations in RCAN1 levels. "In normal, healthy hearts, RCAN1 levels change as much as 20-fold over the course of a single day," she says.

Since CaN levels are correlated with RCAN1 levels, this discovery suggested that CaN and RCAN1 are activated every day in a healthy heart, leading Bev and her team to the follow-on discovery that CaN and RCAN1 follow a circadian rhythm. "Many cardiovascular parameters are circadian in nature,"

she says. "For instance, you are more likely to have a heart attack shortly after waking up than at any other time of day."

By measuring RCAN1 levels in the hearts of her experimental mice at different times of day, Bev found RCAN1 levels were lowest when the mice were waking up and highest as they transitioned to sleep. Bev then simulated heart attacks in mice at different times of day, to test whether these changes in RCAN1 levels affect how much damage a heart attack will cause. She did this by first blocking the major blood vessel that provides blood to the heart (a process called ischemia) and then reopening the vessel to restore blood flow (a process called reperfusion). "This procedure is called ischemia/reperfusion, or I/R," explains Bev. "It simulates what happens when a person has a heart attack (ischemia) and then makes it to hospital to have the blockage removed and blood flow to the heart restored (reperfusion)."

Bev and her team performed I/R on the mice around the time when they would normally wake up (and RCAN1 levels are low) and around the time they transitioned to rest (and RCAN1 levels are high). The results showed that there was almost twice as much damage to the heart muscle from I/R when it occurred just after the mouse woke up, compared to if the mouse was transitioning to rest, an observation also made in human heart attack patients. Using a drug to inhibit CaN was protective when I/R occurred at waking but provided no additional benefit at the transition to sleep when RCAN1 is present and the heart is inherently more protected.

How could this knowledge improve human heart health?

Bev's findings are important because, while it is not possible to control when a person will have a heart attack, it is possible to carry out surgical procedures on the heart at optimal times. "Scheduling such procedures during times of day when the heart is more resistant to reperfusion damage could be a simple way to improve outcomes," Bev explains.

> **"SCHEDULING SUCH PROCEDURES DURING TIMES OF DAY WHEN THE HEART IS MORE RESISTANT TO REPERFUSION DAMAGE COULD BE A SIMPLE WAY TO IMPROVE OUTCOMES. OUR STUDIES ARE AN EXCELLENT ILLUSTRATION OF HOW THE TIME OF DAY THAT A TREATMENT IS ADMINISTERED CAN IMPACT ITS EFFICACY."**

"Our studies are an excellent illustration of how the time of day that a treatment is administered can impact its efficacy."

Most studies do not consider the impact that circadian rhythms may have on clinical outcomes. Bev speculates this may be a key reason why some treatments that seem very effective when tested on mice fail to work when tested on humans. "Mice are nocturnal, which means they sleep during the day," explains Bev. "Most experiments are conducted during the day when mice should be sleeping, yet we try to apply these findings in humans when they are awake during the day."

How do CaN and RCAN1 affect people with Down syndrome?

Another interest of Bev's lab is the impact RCAN1 has on people with Down syndrome (DS). Humans typically have 23 pairs of chromosomes (46 chromosomes in total) which carry our genetic information. People with DS, however, have three copies of chromosome 21, instead of the usual two, meaning they have a total of 47 chromosomes. "This means people with DS carry three copies of any gene located on chromosome 21, which includes RCAN1," says Bev.

Bev and her team have been studying how this increase in RCAN1 impacts the mitochondria within the cells of people with DS. "Mitochondria are highly dynamic," says Bev. "They are constantly combining with one another (fusion) or breaking apart (fission)." Mitochondria in a fused state are more metabolically active and produce more ATP (a molecule that provides energy), while the process of fission may reduce ATP production but allows damaged mitochondria to be removed and repaired, thereby keeping the mitochondrial population healthy. "Both fission and fusion are essential processes, and mutations disrupting either can cause degenerative disorders," says Bev.

Other laboratories had shown that CaN activity promotes mitochondrial fission, so Bev hypothesised that an increase in RCAN1 in people with DS (due to the triplication of the gene on chromosome 21) may reduce mitochondrial fission, contributing to the degenerative nature of DS, as fused mitochondria are unable to repair themselves. By examining mitochondria in cells isolated from people with DS, Bev found evidence of increased fusion compared to in cells from people without DS. Reducing RCAN1 levels then restored a more normal mitochondrial behaviour.

Bev's team is now genetically engineering mice with DS to explore how this may impact the health of humans with DS. "We already have some very exciting preliminary findings suggesting that increased RCAN1 levels and altered mitochondrial dynamics contribute to obesity in people with DS, particularly in females," says Bev, highlighting how basic molecular biology research can yield new insights into critical health issues.

About *molecular biology*

Molecular biology is an interdisciplinary field combining biochemistry, microbiology, genetics and physiology. "A molecular cardiologist is a scientist who studies the heart at the molecular level, trying to understand how specific genes and proteins impact both normal cardiac function and the progression toward heart disease," says Bev. Since heart disease is the cause of death for nearly 700,000 people in the US every year, working in this field can have a huge impact on improving lives.

"Modern science is a collaborative endeavour," says Bev. Molecular biologists combine their knowledge with the expertise of other researchers to gain a better understanding of their work. "One of the things I enjoy about being a scientist is that you are always learning new things, synthesising new ideas and designing new experiments to test the validity of those ideas," says Bev. "I've always loved figuring out puzzles. How wonderful to be able to make a living at it!"

What challenges will the next generation of molecular biologists address?

Bev believes the future of molecular biology will be shaped by two key challenges: the rapidly expanding wealth of new knowledge and the safe application of these findings to benefit human health. "Keeping up with the explosion of new data and techniques often feels a bit like trying to drink out of a firehose!" says Bev, as our understanding of cells increases with each new scientific contribution. "With the advent of genome-editing techniques, the field of molecular biology is entering a new era of possibility. The future depends on learning how to reap the benefits of these advances while anticipating and avoiding the pitfalls."

Pathway from school to *molecular biology*

- "The best molecular biologists are integrative biologists, able to think and make hypotheses outside the confines of their own specific specialty," says Bev. "Therefore, gaining a broad scientific foundation in physics, chemistry and mathematics is as important as learning about biochemistry and physiology."
- At school, therefore, it would be good to study all science subjects in depth. Scientists need to explain their research to others, so language and writing classes are also useful.
- At university, study a bachelor's degree such as biology, molecular biology, biophysics or biochemistry. If you want to work in research, you will then need to complete a master's degree or PhD.
- To be successful as a molecular biologist, you will need strong critical thinking, analytical, communication and problem-solving skills.

Explore careers in *molecular biology*

- Molecular biologists may find themselves designing experiments to study biological tissues, using cloning or DNA sequencing techniques, analysing biological samples or studying genes.
- "The most useful thing you can do is seek out research opportunities in a lab as soon as possible, even if it is just washing dishes as a volunteer," advises Bev. "Basic research is not for everyone, and the only way to know if it's for you is to take part in it. Be careful though, it can be easy to get addicted!"
- Bev recommends taking your time to figure out what area you want to pursue. "The standard advice for being successful in science is to identify your field of interest as soon as possible and stay focused. I have violated this at multiple points, and although it may have slowed the pace of my career, I think I have become a more insightful scientist as a result."
- The American Society for Biochemistry and Molecular Biology has a wealth of educational and career resources: **www.asbmb.org/education/science-outreach**

Meet *Bev*

I was very involved in music when I was younger. I played the cello and piano, sang, and studied music theory. Most people assumed I would pursue a career in music, but I had always planned on becoming a scientist. Both my parents were research chemists, and I always wanted to know what things were and how they worked.

When I started my undergraduate studies, my plan was to major in physics or biology, but definitely not chemistry. Then, I took my first biochemistry class, and I was hooked. This was only a few years after the first animal gene had been cloned into bacteria, and the tools to manipulate DNA were only just being developed. Who wouldn't want to become a 'Gene-Jockey'?

I completed a PhD at Yale and then two postdocs, but, though I was passionate about molecular biology, I was still trying to figure out where I fit in, as my work had covered plant genetics, mitochondria in yeast and cardiology. In the summer of 1989, shortly after CaN had been identified as a key player in heart disease, I heard a talk about a protein in yeast which inhibited CaN. This talk set my brain on fire, and I began to plan a series of experiments to test whether this protein also inhibited CaN in humans. I remember trying to explain to a non-scientist friend just how important I thought this gene was and that I might well be working on it for the rest of my career. Two months later, I had cloned RCAN1 from both human and mouse cells and shown that it inhibited CaN signalling in muscles.

In basic research, if 10% of your experiments are successful, then that's a winning average on which you can build a career. In the first couple of years working on RCAN1, everything worked. While it was very gratifying, most of these initial experiments were the logical extension of things we already knew about CaN and muscle biology. I'm most proud of the unanticipated directions my lab has taken as we have pursued RCAN1, such as investigating circadian rhythms and mitochondrial dynamics.

Most summers, my lab hosts students who participate in research by testing one of 'Bev's crazy ideas' to see if they might lead to productive research projects. Students get a feel for how basic research works by crafting a hypothesis, designing a controlled experiment and learning to discuss their findings in the context of a bigger picture. In return, the lab and I get to see things from a new perspective and find out whether we really understand what we're doing.

Bev's *top tips*

1. Ask questions and be sceptical. Don't settle for a surface understanding of the things you learn.
2. Explore outside your comfort zone.
3. Don't get discouraged when things aren't working. Science, like most things of value, requires persistence.

Meet *Rebecca*

Rebecca Allen worked in Bev's lab as a high school and undergraduate student. She is now about to qualify as a medical doctor and hopes to work as an emergency medicine physician.

When I was younger, I spent a lot of time waiting at the hospital for my aunt to finish her shifts as an intensive care nurse. Seeing patients in critical conditions, I was always mesmerised by the beeping and whooshing of the complicated machines that kept them alive. I knew I had to be part of that world. It was a place of wonder, curiosity and humanity.

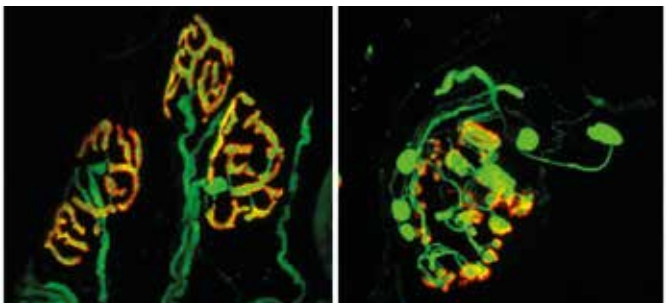
Bev first invited me to her lab as a high school student when I was deciding if I wanted to pursue a career in medicine or research. I spent a summer cataloguing reagents and enzymes and conducting Western blot assays (preparing gels, mixing solutions, developing results, etc.). I then returned for two summers while in college, working with cells, flies and mice to contribute to Bev's research on circadian rhythms.

There were countless benefits from working in Bev's lab. I was exposed to brilliant women scientists, and it was inspiring to watch Bev lead her own lab team. It was incredible to witness the seemingly endless run of important experiments. I also had the opportunity to hear from, talk with and even shadow prominent scientists and medical professionals.

I come from a powerful and inspiring set of women healthcare professionals – many of my Filipino relatives are doctors and nurses in the US, and they have overcome great challenges. As one of very few women anaesthesiologists when she arrived in Texas, my aunt worked long hours and experienced micro- and macro-aggressions of every kind. While working as a nurse, my Godmother was once threatened by a doctor who said he would have her fired and deported. She is now pursuing her PhD in nursing, and it is her stethoscope I wear around my neck. It is an honour to wear the stethoscope she used to save so many lives and declare the end of many others. I am very proud that we will both graduate together, me with my medical degree and her with her PhD.

Rebecca's *top tips*

1. Pick a mantra, write it on your mirror and read it aloud every time you wake up.
2. Seek research opportunities, whatever your age. Researchers are always eager to recruit young and upcoming scientists into their field.



The neuromuscular junction in a normal mouse (left) and in a mouse lacking the RCAN1 gene (right)

Could a nettle a day keep the doctor away?

Nettles are known for their sting, but research by **Dr Diana Obanda** at the **University of Maryland** in the US suggests that eating them could strengthen our gut and protect us from obesity.

Dr Diana Obanda

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Assistant Professor
College of Agriculture and Natural Resources,
University of Maryland, USA

PROFILE

Field of research
Nutrition and Food Science

Research project
Investigating the health benefits of eating nettles

Funders
US Department of Agriculture-National Institute of Food and Agriculture (USDA-NIFA), Maryland Agricultural Experiment Station (MAES)

agnr.umd.edu/about/directory/diana-n-obanda

TALK LIKE A ...

NUTRITION AND FOOD SCIENTIST

Calorie — a unit used to describe the amount of energy available in food

Foraging — collecting food that has grown naturally instead of being farmed

Genus — a group of animals, plants or organisms that share common attributes in a larger biological group

Gut microbiome — the community of bacteria, fungi and viruses living in your digestive system

Immune system — the cells and organs that defend our body from infection

Pathogen — a microorganism that can cause disease

Symbiosis — two or more distinct organisms living together for the benefit of each

Urtica dioica — scientific name for the common stinging nettle

When out for a walk in summer, nettles are little more than a nuisance, their sharply serrated leaves warning you to steer clear of their venomous hairs and hardly inviting the thought of putting them in your mouth. Yet they are edible, and indeed are eaten in many cultures around the world. So what is it about nettles that makes it worth getting past the stings?

Dr Diana Obanda, Assistant Professor in Nutrition and Food Science, is on the case. Her team at the University of Maryland is using mice and cultured cells to try to understand how *Urtica dioica* contributes to a healthy diet. The evidence is pointing at nettles' ability to protect us from obesity and diseases associated with it, which they do by impacting the bacteria in our gut microbiome.

Are bacteria all that bad?

In a world full of antibacterial cleaning products, it is easy to forget that bacteria are not our enemies. Although some do cause disease, there are trillions of bacteria from around a thousand species in your gut right now, doing no harm at all. In fact, you are living in symbiosis with these bacteria: while they thrive in the conditions of your gut, they perform important tasks for you in return.

Gut bacteria help us get the nutrients we need from our food. They do this by breaking down complex chemicals and even creating new ones, such as vitamin K2, which is needed by the body for blood clotting. As a result, these 'good bacteria' contribute to a healthy immune system and help keep us safe from disease.

How can we look after our gut?

In the same way an ecosystem is strongest when it has high biodiversity, the gut biome works best when it contains a wide range of bacteria species. "A diverse microbiome functions better than one with only a few types of bacteria," says Diana, "because if one microbe is unable to fulfil its function, another is available to cover that function."

Exercising and eating a varied diet are the best ways of keeping our gut bacteria happy. On the flip side, eating too much fat or sugar can lead to an unbalanced microbiome. "A high-fat and high-sugar diet reduces diversity, changes the activity of

bacteria in a negative way, increases inflammation in the intestine and impairs the protective gut barrier," warns Diana. Some scientists suspect that this can lead to obesity, heart disease, diabetes and even some types of cancer. This is why Diana is keen to investigate whether eating nettles could help keep gut bacteria in good shape.

Do people really eat nettles?

It is unlikely you have ever seen a nettle farm or nettles on the shelves of a supermarket. This is not because nobody eats them, but because they are mostly foraged from the wild. Nettles are traditionally eaten in soups or as cooked greens in countries spanning the globe including Mexico, Spain, Turkey, China and Nepal. In North America, they are increasingly being eaten by hobby foragers, who often view it as a medicinal food.

"The stinging nettle is a poster child for healthy food," says Diana. This has led to the development of dietary supplements containing some of the chemicals from the plant, which are marketed as treatments for allergies, joint pain and several diseases. However, Diana thinks that there could be more benefits from eating the whole plant as a food. This way, you would ensure you get all of the protein, fibre, vitamins and minerals that the nettle contains. To test this in the lab, Diana and her team have been researching how the inclusion of nettles affects the gut microbiome and overall health of mice.

What happens when mice eat nettles?

Diana's first experiments involved 36 mice, which were split into four groups of nine and given different diets over a 12-week period. The first group was fed a low-fat diet, the second group was given a high-fat diet, while a third received the high-fat diet plus *Urtica dioica*. The final nine mice were fed the high-fat diet for six weeks, and had *Urtica dioica* introduced for the second six weeks. All the diets were controlled to make sure they had exactly the same number of calories, overall.

> **"THE STINGING NETTLE IS THE POSTER CHILD FOR HEALTHY FOOD."**

As expected, the mice on high-fat diets put on more weight than those on the low-fat diet. However, the mice who were fed nettles did not gain as much weight – even those who were only given nettles for six weeks. To find out why this might be, Diana and her students investigated the gut biomes of the 36 mice by looking at the DNA of bacteria in their intestines.

It turned out that mice who were eating nettles had a more diverse gut microbiome. In particular, they noticed an increase in a group of bacteria called *Clostridium*. "Not much is known about the benefits of this genus," says Diana, "because it contains some well-known life-threatening pathogens, but in reality *Clostridium* also includes a lot of beneficial species, and eating nettles increases these species."

Should we start eating nettles?

Although her study is still ongoing, Diana is sure that eating nettles is good for human health through its effects on the gut microbiome. Furthermore, research using cultured cells shows that nettles have positive effects that are independent of the gut microbiome. In particular, Diana hopes that eating nettles could reduce the risk of obesity, as it did in her experiments with mice. "Given the heavy burden of obesity on the healthcare system, this would have huge public health implications," she says. This impact could be global, given that nettles grow well in many climates.

Diana's results could lead to clinical studies in humans, which would confirm exactly what nettles can do for us. But in the meantime, there is certainly no harm in giving them a try – just remember a good pair of gloves for picking nettles to make sure you do not get stung. Once boiled or cooked, the sting is eliminated!

Diana at work with one of her students

About *nutrition and food science*

"A career in nutrition science provides the opportunity to influence the health and well-being of individuals and entire communities," says Diana. "Having knowledge about food and nutrition can land you in a variety of work settings, including laboratories, hospitals, schools and food companies."

Nutrition and food science researchers try to understand how what we eat affects our health. This typically involves studying certain foods, often called functional foods or nutraceuticals, that are known to have health benefits.

Many fruits, vegetables, nuts, legumes and grains are considered functional foods due to their high nutrient density. "Being full of nutrients and linked to a wide range of health benefits, the stinging nettle is definitely an example of a functional food," says Diana.

The scientific study of functional foods is a relatively new field, with Japan being the first country where the promotion of functional foods was actively pursued to improve population health in the 1980s. These days, as populations consume more calories from excess sugar and fat, obesity is on the rise, making knowledge of and careers in nutrition and food science important worldwide and a rapidly growing field.

Pathway from school to *nutrition and food science*

- Nutrition science programmes at university focus on the chemical and biological components of our food and the ways in which these ingredients affect our health.
- To prepare for these programmes, take chemistry and biology at school. Mathematics is also important for calculating statistics.
- Food science also includes the social impacts of food, including how it affects our economy, psychology and culture, so taking social science subjects at school can be useful.

Explore careers in *nutrition and food science*

- According to the US Bureau of Labor Statistics, the job opportunities for nutritionists rose by 21% between 2012 and 2022, much higher than the average for all occupations.
- Find out more about different nutrition jobs, requirements and wages in the USA at **www.nutritioned.org/careers**
- Learn how dieticians in the UK apply nutrition science to help patients on a daily basis: **www.healthcareers.nhs.uk/explore-roles/allied-health-professionals/roles-allied-health-professions/dietitian**

Q&A **Meet** *Diana*

You have a master's in environmental science from Louisiana State University. Why did you change your focus to nutrition and food science?

While in high school, I wanted to be a medical doctor. However, I did not get into medical school and pursued a career as an environmental scientist instead. As an environmental scientist, I studied the chemistry of natural plant compounds and how they can be applied in preserving timber used in buildings against insects like termites.

In the back on my mind, I always wanted to know how these compounds could be applied in a health setting. Even though I did not get into medical school, I still desired to be involved in research to improve human health. With my experience working with plant extracts, I applied for a National Institute of Health- (NIH-) funded postdoctoral training position at Pennington Biomedical Research Center.

> ***"A CAREER IN NUTRITION SCIENCE PROVIDES THE OPPORTUNITY TO INFLUENCE THE HEALTH AND WELL-BEING OF INDIVIDUALS AND ENTIRE COMMUNITIES."***

I worked on a project focusing on improving insulin sensitivity in skeletal muscle cells. This experience enabled me to apply for further research funding in the broad area of plant phytochemicals and their applications in human health.

How did where you grew up influence your career choice?

Growing up in a small rural town taught me several lessons for which I am still grateful. As an adult, I moved to a big city for college and work. Although sometimes it may feel like you're running to catch up with the hustle and bustle of big city life, kids from rural areas and small towns understand that patience is a virtue.

Going too fast can lead you to miss out on many simple pleasures in life. Research requires patience and attention to detail, and taking time to get to know and interact with those around you a well as those you work with.

Growing up eating produce (vegetables and fruits) that we grew at home rather than purchasing them also helped me appreciate nature. We ate food from the land and prepared food from scratch, rather than eating processed foods, which contain too much sugar and are calorie dense.

What is the worst piece of advice you have been given?

'If you do what you love, you will never work a day in your life; it will never feel like work.' I think the right job may not be as hard as going to a job that you hate on a daily basis, but work is still work. You will not love some aspects of it even though you generally love your job, and that is life!

What is your philosophy that has helped drive you forward?

Every day I wake up and go to work, and I have a new job to do. So, my philosophy is to be better than yesterday.

Do you like cooking?

Yes, I cook a lot and only eat out once in a while. I am a 'foodie'! I like to taste new foods from different cultures especially plant-based and fermented foods. My diet is very varied and I try to eat healthily by including a lot of plant-based protein sources in my diet, as I know those are what are most healthy for the gut microbiome.

How are advances in technology improving dietary research?

To uncover how diet influences health, dietitians and nutritionists need easy but accurate ways to assess what people eat. However, current methods of dietary assessment are either time-consuming to record or rely on participant memory for recalling what they eat. To overcome these challenges, dietitians **Professor Deborah Kerr** and **Associate Professor Carol Boushey** have teamed up with computer engineer **Associate Professor Fengqing (Maggie) Zhu.** By combining their skills and expertise, they are developing new technologies to improve dietary assessment.

Professor Deborah Kerr

Curtin School of Population Health,
Curtin University, Australia

Fields of research
Dietetics, Nutrition Science

Associate Professor Carol Boushey

Director of the Nutrition Support Shared Resource,
University of Hawai'i Cancer Center,
University of Hawai'i at Mānoa, USA

Fields of research
Dietetics, Nutritional Epidemiology

Associate Professor Fengqing (Maggie) Zhu

School of Electrical and Computer Engineering,
Purdue University, USA

Field of research
Electrical and Computer Engineering

PROFILES

GLOSSARY

Dietary intake — all the food and drink a person consumes

Dietary patterns — the quantities, proportions, variety or combination of different foods, drinks and nutrients in diets, and the frequency with which they are consumed

Fiducial marker — an object used as a point of reference for image processing

Machine learning — a type of artificial intelligence in which computers learn to complete tasks

Nutritional value — the amount of nutrients (e.g., carbohydrates, proteins, vitamins) in food or drink

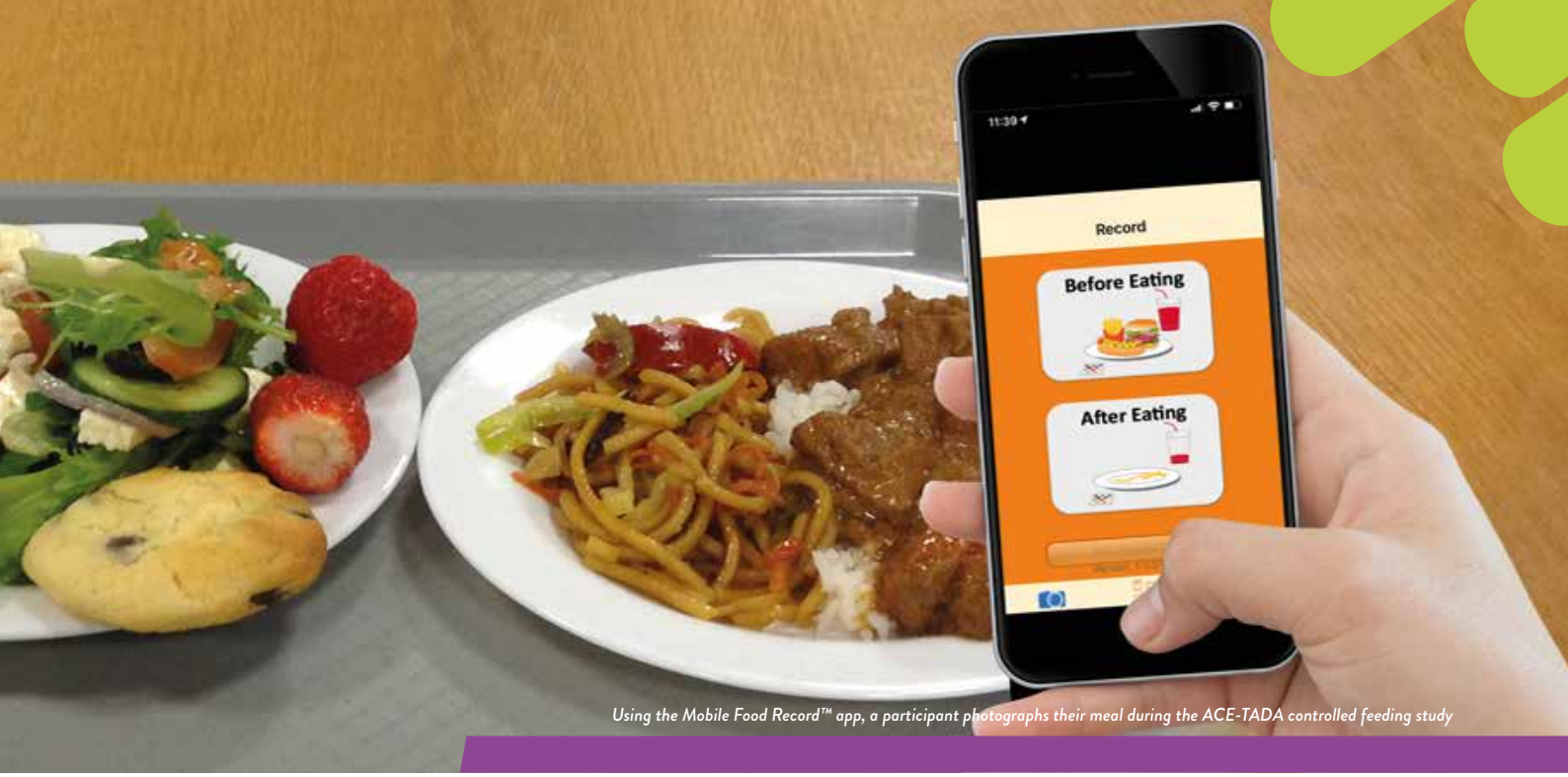
How would you describe what you eat and drink, and how much? Without being a trained dietitian, evaluating dietary intake is not easy! However, analysing what people eat and drink can be important, as accurate assessment of dietary intake is essential to understanding how people's diet may be associated with health and well-being. As people eat food, not nutrients, dietitians describe what people eat in terms of dietary patterns. Dietitians and nutritionists study what people eat and drink, both to help individuals monitor their health and to investigate the dietary patterns of populations and how these compare with patterns recommended in dietary guidelines.

How is dietary intake assessed?

Common methods to assess food and drink intake include 24-hour dietary recalls (24HR) and keeping dietary records. The 24HR method typically involves an interviewer prompting participants to recall the food and

Research project
Accuracy and cost-effectiveness of technology-assisted dietary assessment (ACE-TADA)

Funders
This work is supported in part by the Australian Research Council (ARC) under the discovery grant (DP190101723). The Image-Assisted Mobile Food Record 24-Hour Recall app is funded by National Institutes of Health – National Cancer Institute (1U01CA130784-01) and National Institutes of Health – National Institute of Diabetes and Digestive and Kidney Diseases (1R01-DK073711-01A1 and 2R56DK073711-04). The term Mobile Food Record™ is a registered trademark.



Using the Mobile Food Record™ app, a participant photographs their meal during the ACE-TADA controlled feeding study

drink they consumed the previous day. A significant limitation of this method is that people often forget what they ate and drank and struggle to explain exactly how much they consumed. Dietary records require the participant to keep detailed notes about everything they consume, each time they eat or drink. A dietitian or nutritionist then enters the food and beverages into a special food composition program so that dietary intake can be assessed for food groups and nutritional value. However, this is very time-consuming for both participants and researchers.

How can technology improve dietary assessment?

Addressing the challenges of accurately assessing dietary intake while minimising the burden on participants requires an innovative, interdisciplinary approach. As researchers who specialise in dietary assessment, Professor Deborah Kerr and Associate Professor Carol Boushey realised they needed to combine their knowledge of diet and food composition with the skills and expertise of computer engineers Associate Professor Fengqing (Maggie) Zhu and Professor Edward Delp, if they were to overcome the challenges of assessing diet.

Deborah, Carol, Maggie and their team are harnessing the power of technology to improve dietary assessment methods. By combining expertise from different disciplines, the team has created a Technology Assisted Dietary Assessment (TADA) system. Participants simply take a photo of their meal on their phone using the app designed by the TADA team, and the software behind the system recognises what food or drink is in the image. Determining the volume of food is still a challenge and requires a trained analyst to estimate the portion size and calculate the nutritional content, but the aim is for this process to also be automated. TADA dramatically reduces the burden on the participant and eliminates the need for them to remember what they have eaten and drunk. However, while this makes dietary assessment easy for the participant, developing TADA was far from simple.

How does TADA identify food?

The TADA system consists of two main components: an image-based dietary recording app called Mobile Food Record™ (mFR), and a server that processes and stores the food images. While the use of facial recognition technology is well-developed, Maggie was one of the first people to apply the principles of image recognition to food. "As no one had done this before, it was quite challenging to get started," she says. "It was hard to know what tools we needed to build."

Maggie used machine learning to train the TADA system to recognise different types of food. For example, by showing it hundreds of pictures of an apple, it learnt to recognise the features of an apple. However, teaching TADA to differentiate between foods with similar appearances, such as a bowl of mashed potato and a bowl of porridge, and to recognise foods that come in many forms (e.g., a potato may be mashed, boiled, roasted, baked, etc.) is challenging. "Factors such as food preparation and personal preferences can also affect the appearance of food ingredients," explains Maggie.

The advantage of machine learning is that TADA keeps learning as it is exposed to new images, so its capabilities are still improving. When participants use the mFR, the app labels what food and drink it thinks are present in the image and the user can confirm or correct this information. Over time, the system learns the dietary patterns of each individual, enabling it to become more accurate in its food identification.

How will TADA calculate the nutritional value of a meal?

Once the system has correctly identified the food in the image, the next challenge to overcome is how to convert a 2D picture into a numerical value of a food's nutritional content. Maggie is using image processing and machine learning techniques to estimate the 3D volume of the portion sizes in the 2D image. When using the mFR, participants include a fiducial marker (an object used as a point of reference for image processing) in the photo of their food. The TADA fiducial marker is a small piece of white card covered in coloured squares. TADA knows the exact size of each square and will use this information, along with image processing techniques, to calculate the 3D volume of the food. Automatically estimating the volume of foods from images is still a challenge, so the portion size estimation is currently still done by trained analysts.

With the portion size estimated, the nutritional value of the food can be calculated by linking to a food composition database that contains details of the food and nutrient content of different foods. TADA uses these data to calculate the amount of food groups consumed or the nutritional value of all the food and drink in the photos.

Testing TADA

The team has been developing TADA for several years and the system has undergone many tests to evaluate its effectiveness. In the recent ACE-TADA study, the team conducted a controlled feeding study. "Participants visited our food laboratory, where they selected their food choices from a menu, just like at a restaurant, and took photos of their food with the mFR," says Deborah. As the researchers knew exactly what types and amounts of food and drink the participants consumed during the study, they could compare the real nutritional values with the values calculated by TADA.

"We also asked participants what they thought about the system, as usability and consumer acceptance of the mFR has been a critical part of the development process," says Carol. "We have found that most people like using the mFR for dietary assessment. When we first started this research, it wasn't common to take photos of your food, but now everyone seems to have their phone handy when they're eating!"

"Dietary assessment provides rich data on what people are eating and can inform key decisions related to nutrition policy," says Deborah. By developing new techniques for dietary assessment, Deborah, Carol and Maggie are contributing to improved health and nutrition outcomes for individuals and whole populations.

Meet *Deborah*

Food and cooking were a big part of my childhood. My family are all excellent cooks, and I began experimenting in the kitchen from a young age. My other interests revolved around sports and being outdoors.

In high school, my friends and I entered a state science competition. I grew up in Kalgoorlie, a country town in Western Australia, and my parents had to drive us 350 km to reach the competition. We didn't win, but it was a great experience which sparked my interest in designing science experiments.

It was my combined love of food and science that led me to qualify as a dietitian. After graduating, I worked as a clinical dietitian for several years before specialising as a sports dietitian due to my love of sport. At the time, to assess what people were eating involved them keeping detailed records of everything they ate and drank for up to four days. I soon realised how burdensome it was for elite athletes, who were very busy training for long hours, to weigh and record everything they ate – especially as they ate a lot!

> ***MOST RESEARCH PROJECTS FACE UNPLANNED CHALLENGES, SO IT IS IMPORTANT TO BE CREATIVE AND GOOD AT PROBLEM SOLVING.***

These experiences shaped my interest in improving dietary assessment. I wanted to make it easier to record what people were eating. In 2005, Carol and I asked teenagers to test different dietary assessment methods, and discovered they weren't keen on many of our suggestions. However, when we gave them cameras to take pictures of their food, they loved recording what they were eating.

I enjoy designing studies to test research questions. I especially love working with the volunteers who participate in our studies. Without them, we wouldn't be able to conduct research, so I believe it is important for them to enjoy the experience. For example, our current project involves testing different dietary assessment methods using a feeding study. It was fun to develop a menu for the feeding study that the participants would enjoy eating.

The ACE-TADA project has been both exciting and challenging. Most research projects face unplanned challenges, so it is important to be creative and good at problem solving. Completing the feeding study successfully and safely, while overcoming the problems posed by COVID-19, has been a highlight, as has knowing that the participants enjoyed taking part in the study and helping us discover and test new ways to advance the field of dietary assessment.

Deborah's *top tips*

1. Follow your passions. The combination of what you love to do plus what you are good at may lead to a career you had never considered.
2. Be open to opportunities that lead you in different directions. When I began my career as a clinical dietitian, I never expected to end up as a research dietitian.
3. If you have a curious nature and enjoy puzzling over things, consider a career in science. Although 'scientists' are commonly portrayed wearing lab coats and examining test tubes, there are so many different areas of research to explore. You will never be bored as there is still so much to discover.

Meet *Maggie*

When I was younger, I was always curious about the world outside of where I grew up, in a large city in China. I enjoyed reading – for a time I was interested in Greek mythology, then I became interested in the real-life stories of people and started reading lots of autobiographies. I was fascinated by how people think and what inspires them to do the things they do and make the decisions they make. This curiosity into how different people choose their paths in life motivates me to do the work I do.

> ***I ENJOY THE FACT THAT I CAN DO FUNDAMENTAL SCIENCE THAT HAS IMPACTS FOR REAL-WORLD PROBLEMS.***

At school, I was good at math and physics, but I wanted to study something that had a practical aspect at university. Engineering was a natural choice – I didn't know much about engineering at the time, but I thought I might enjoy it, so I signed up.

I studied electrical and computer engineering, which is a very rapidly growing field. It is also a very interesting field as it involves both the hardware and software side of computing. Electrical and computer engineers design and build the physical components of computers, such as semiconductor devices, and develop the software and algorithms that support computer functioning.

My research focuses on signal and image processing, which require both abstract mathematical thinking and analytical skills to apply theories to engineering challenges. I enjoy the fact that I can do fundamental science that has impacts for real-world problems. For example, one project involved developing image processing software that could analyse videos of poultry farms to assess animal welfare. In another project, I worked with infant speech development researchers to create software to analyse the interactions between caregivers and babies in research study videos.

As a professor, I enjoy teaching and mentoring students. I like motivating them, but, even more importantly, I love that they motivate me. Interacting with my students exposes me to their brilliant minds and their curiosity.

Maggie's *top tips*

1. Whatever discipline you chose to study, it is important to have both depth and breadth of knowledge in your subject.
2. Try new things and don't be afraid to explore outside your comfort zone.
3. Cherish and enjoy the good things you are blessed with.

Meet *Carol*

My mother was a registered dietitian. She and her colleagues were passionate about their work and very effective at communicating the opportunities it presented. They sold me on the idea of being a dietitian, too!

I went to university to study dietetics and nutrition, and never looked back. After graduating, I was fortunate to start my career with the Washington State Health Department, as part of the team initiating the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC). This important national scheme still operates today, providing low-income pregnant and breastfeeding women and their children with nutritious foods and nutrition education.

I became interested in developing better methods to estimate dietary intake, so I moved to Hawai'i to work with Dr Jean Hankin, a pioneer in the field of recording dietary intake and the founder of the Nutrition Support Shared Resource (NSSR). The NSSR assists researchers as they establish what people, from birth to old age, eat and drink, and I became the director of the NSSR in 2011.

The idea for TADA was born when Deborah and I asked teenagers to take photos of their daily meals. There were no mobile devices at the time, so we gave them cameras, and the teenagers really liked the idea. I realised that image capture methods were evolving, so I looked for computer engineers working in this field who could assist us. I discovered Edward and Maggie, and the rest is history! Since then, we have worked together to successfully advance the methods and technology for dietary assessment, and I look forward to our anticipated future developments.

Getting official patents for the technology we have developed has been an exciting highlight of this project. It has also been inspiring to establish connections between different disciplines and institutions.

Carol's *top tips*

1. Stay positive about your ideas.
2. Welcome feedback and embrace it, both the good and not so good.

About *dietetics and technology*

Advances in technology are improving many aspects of our everyday lives, and diet and health are no exception. If you are interested in how diet influences health or would like to contribute to new inventions that improve our understanding of this topic, then there are many different options for becoming involved in the interdisciplinary field of dietetics and technology, as shown by Deborah, Carol and Maggie's team.

What disciplines contribute to advances in technology assisted dietary assessment methods?

The TADA project is a unique collaboration between research dietitians, nutrition scientists and computer engineers. "As dietitians, we have skills in dietary assessment and food composition," says Deborah. "Through our shared experiences and expertise, we try to balance our pursuit of accurate dietary assessment with finding a method that people will want to use. We have the ideas but it's the brilliant engineers that make it happen!" It is the engineers' job to translate the dietary problem into an engineering problem. "As engineers, we learn from the subject experts about the challenges in the field," says Maggie. "We have to take this information and develop engineering-based solutions."

Creating technology to solve dietary challenges also relies on several other disciplines. "Biostatisticians help us undertake statistical analyses to test the accuracy of our methods," says Carol. Using statistical modelling, the team can assess whether people with different characteristics (e.g., age, gender or other lifestyle factors) report different outcomes when using TADA.

Health psychology plays a significant role in dietary assessment. "It is important to have a deep understanding of human behaviour, as individual factors might influence how people report their dietary intake," says Deborah. For example, 24-hour dietary recall methods rely on participants' memory and participants might not be able to recall as accurately if they are under time pressure or distracted with the stresses of everyday life.

The team has developed TADA to help research dietitians and nutrition scientists study dietary patterns and associated health outcomes. This means that as well as being accurate and easy to use, the system must also be cost effective. "Health economists helps us determine both the financial costs and time costs of different dietary assessment methods, to both researchers and participants," says Carol. "By comparing the costs and outcomes of different methods, health economists can determine which methods are the best use of resources." This is particularly important information for organisations such as the Australia Bureau of Statistics (ABS), responsible for collecting Australian population health statistics, including dietary intake data. Paul Atyeo, who works at ABS, is in the TADA team to ensure the project is policy-relevant for planning future population surveillance to assess dietary intake.

Why is consumer input also essential?

Engaging with participants is a key part of research. "As researchers, we need to put ourselves in our participants shoes and understand what we are asking them to do," explains Deborah. "Would we be prepared to do what we are asking our participants to do?" From the start, the TADA team has actively engaged with the end-users of the technology. "Over the years, the many people who have taken part in our research studies have helped shape the TADA system to what it is today."

Explore careers in *dietetics or technology*

- A career as a clinical dietitian or nutritionist will involve working with individuals to help them manage their diet for their health, while a career as a research dietitian or nutrition scientist will involve conducting diet-based research to understand how diet impacts health.
- Dietitians Australia (**www.dietitiansaustralia.org.au/working-nutrition-and-dietetics-australia**), the Association of UK Dietitians (**www.bda.uk.com/about-dietetics/how-become-a-dietitian/career-faqs.html**) and the Academy of Nutrition and Dietetics (**www.eatright.org/become-an-rdn-or-ndtr**) all provide information and advice about careers in dietetics and nutrition.
- A huge range of careers are available for computer engineers, as computing skills can be applied to many topics.
- Computer engineers working in signal processing can join the Signal Processing Society (**www.signalprocessingsociety.org**), a branch of the Institute of Electrical and Electronics Engineers (**www.ieee.org**).

Pathway from school to *dietetics or technology*

- Undergraduate degrees in dietetics, nutrition science or food science could all lead to a career as a research-based or clinical dietitian
- Undergraduate degrees in electrical and computer engineering or computer science could lead to a career developing the technology to address dietary challenges.
- To get excited by research, science and technology, investigate outreach programmes run by universities near you. For example, Curtin University, where Deborah works, offers outreach programmes so high school students can engage with research activities (**www.curtin.edu.au/engage/schools-teachers-advisors/education-outreach**) and Purdue University, where Maggie works, hosts a 'Girls Excelling in Math and Science' (GEMS) club (**www.gems.education.purdue.edu**)

Meet *the rest of the research team*

Professor Clare Collins

University of Newcastle, Australia

Field of research: Dietary assessment

Professor Barbara Mullan

Curtin University, Australia

Field of research: Health psychology

Dr Megan Rollo

Curtin University, Australia

Field of research: Dietary assessment

Professor Satvinder Dhaliwal

Curtin University, Australia

Field of research: Biostatistics

Associate Professor Richard Norman

Curtin University, Australia

Field of research: Health economics

Professor Edward Delp

Purdue University, USA

Field of research: Electrical and computer engineering

Dr Tracy McCaffrey

Monash University, Australia

Field of research: Dietary assessment

Paul Atyeo

Australian Bureau of Statistics

Field of research: Health statistics

Associate Professor Sharon Kirkpatrick

University of Waterloo, Canada

Field of research: Dietary assessment

Associate Professor Christina Pollard

Curtin University, Australia

Field of research: Public health policy

Clare Whitton

Curtin University, Australia

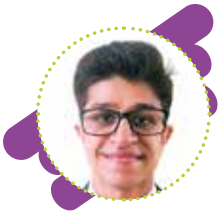
PhD student examining reporting error in dietary assessment

Janelle Healy

Curtin University, Australia

PhD student examining user feedback on dietary assessment methods

Vinod Gautham



Purdue University, USA

PhD student in electrical and computer engineering

Zeman Shao

Purdue University, USA

PhD student in electrical and computer engineering

Jiangpeng He

Purdue University, USA

Postdoctoral researcher in electrical and computer engineering

The mathematics behind medicine

Medicine is advancing daily, as increasingly specialised treatments and techniques are continuously developed. Biostatisticians, such as **Professor Sumithra Mandrekar** and **Professor Jay Mandrekar** at **Mayo Clinic** in the US, are behind every medical advance, as they use their statistical skills and knowledge to bring real-world benefits to every field of healthcare.

Professor Sumithra J. Mandrekar, PhD

Professor of Biostatistics and Oncology, Department of Quantitative Health Sciences, Division of Clinical Trials and Biostatistics, Mayo Clinic, USA

Professor Jay N. Mandrekar, PhD

Professor of Biostatistics and Neurology, Department of Quantitative Health Sciences, Division of Clinical Trials and Biostatistics, Mayo Clinic, USA

PROFILE

Field of research
Biostatistics

Research project
Using biostatistics to design and analyse clinical trials, leading to improvements in healthcare and medical treatments

Funder
US National Institutes of Health (NIH), US National Cancer Institute (NCI)

TALK LIKE A ...

BIOSTATISTICIAN

Biomarker — a biological molecule in the body, the presence of which indicates a specific condition

Biostatistics — the branch of statistics that studies data related to living organisms

Clinical trial — a research study that investigates the effects of new medical interventions on humans

Demographic data — statistical information that describes the characteristics of certain groups, such as age, race and sex

Intervention — any medical treatment

Mutation — a change in the DNA sequence of an organism

Neurology — the branch of medicine that involves the study and treatment of disorders of the nervous system

Oncology — the branch of medicine that involves the study and treatment of tumours, typically cancerous tumours

When was the last time you took medication? Perhaps you swallowed a painkiller, had a vaccine or used an inhaler. How could you trust that the drug you took was safe and effective? Or, if you have ever been to hospital for a medical procedure, how did the doctor know the best method for treating your condition? The answer to both these questions relies on data and biostatistics.

Before any new drug or medical treatment can be used, it must undergo a rigorous testing process to ensure it is not only effective, but also safe. Biostatisticians, such as Professor Sumithra Mandrekar and Professor Jay Mandrekar at Mayo Clinic, play a key role in this procedure, as they analyse the data collected at each stage of the process to statistically evaluate the effectiveness and safety of the intervention.

"Biostatistics combines data and biology," explains Jay. "Biostatistics helps in all stages of medicine, starting with the development of new drugs in the lab, through the initial testing of experimental drugs or treatments on animals, to finally testing them on humans in clinical trials."

What are clinical trials?

This last step – testing treatments on human patients – forms the focus of Sumithra and Jay's work. "Clinical trials are research studies performed on humans, to help understand and evaluate medical interventions," says Sumithra. "They are the primary way that researchers discover if a new treatment is safe and effective." Every new medical intervention – including drugs, diets, surgical procedures, psychiatric techniques and medical devices (e.g., pacemakers and blood sugar monitors) – must be assessed in a clinical trial before it is used on patients.

Clinical trials rely on patients with the medical condition of interest, who volunteer to take part. Some participants in the trial will receive the usual intervention given to patients with that condition, while others will receive the new intervention being investigated. By examining the data

collected on the health outcomes of each group of participants, biostatisticians can statistically determine which intervention is best.

Clinical trials are all about the data. Researchers collect a wealth of information about each participant, including demographic data, medical history, lifestyle factors that may affect their medical outcome (e.g., smoking, diet, exercise), how they respond to the intervention (e.g., Did their condition get better or not? Was their quality of life improved by the intervention?) and any side effects they experience. With so many variables to consider, and as most clinical trials contain hundreds of participants and continue for several years, they produce very large, incredibly detailed and highly complex datasets.

Why do clinical trials need biostatisticians?

"As biostatisticians, we help design the trial so it can answer the questions posed by the researchers," says Jay. "For example, researchers may want to know if the intervention can prolong participants' lives and, if so, for how long?" This information determines how many participants need to be enrolled in the trial, and for how long researchers will need to collect data from them.

"When the trial is completed, all the collected data are reviewed to ensure there are no questionable data points or missing information," says Sumithra. The data are then analysed using a variety of statistical techniques to draw conclusions about whether the new intervention benefitted participants and should, therefore, be made available to other patients.

In this way, biostatisticians contribute to medical advances, by providing the evidence to prove which treatments should be given to which patients, and paving the way for new drugs, surgical procedures and medical devices that enhance patients' quality of life.

Real-world applications of biostatistics

Organ donations can save lives by supplying patients with a healthy organ to replace a deficient one of their own. While living people can donate some organs, such as a kidney, most donor organs come from people who have died. However, to be usable, the organs must be taken very soon after death. "In many instances, patients with catastrophic neurological diseases, who have no possibility of survival, are the best candidates for organ donation," says Jay. "Once life support is withdrawn, death is inevitable, but predicting the time of death is challenging." By statistically analysing data collected from such patients, Jay's team identified simple neurological and respiratory measurements that can predict the time of death to within an hour's accuracy, allowing doctors to maximise the chances of successful organ donation. "By providing up to eight organs and a variety of tissues, a single patient can save or enhance the lives of over 50 people," says Jay.

> **"BIOSTATISTICS HELPS IN ALL STAGES OF MEDICINE, STARTING WITH THE DEVELOPMENT OF NEW DRUGS IN THE LAB... TO FINALLY TESTING THEM ON HUMANS IN CLINICAL TRIALS."**

In his work as a biostatistician, Jay has not only evaluated healthcare data and clinical trial results, but he has also helped improve the clinical trial process. Most clinical trials collect data using surveys answered by patients or their caregiver. For example, to determine the severity of neurological symptoms, patients had to answer 169 questions about their condition. "Long questionnaires can be time-consuming, burdensome for sicker patients and overly complex," says Jay. "This increases the risk of missing important information and reaching biased conclusions." Jay's team statistically evaluated which data were most important for assessing neurological symptoms and designed a much simpler questionnaire, containing only 31 questions, that still provides statistically robust data. "This survey is being used in clinical trials and has improved the quality of data being collected, leading to more reliable conclusions," he says.

While Jay applies biostatistics to neurology, Sumithra applies it to oncology. Chemotherapy is a common treatment for cancer, but it attacks the rest of the body as well as the cancerous cells, leading to unpleasant side effects such as nausea, hair loss and an increased risk of infections. "However, cancer is becoming increasingly understood on a cellular and molecular level," Sumithra explains. "These days, many cancers can be described using biomarkers or tumour genetic mutations." New therapies are being developed to target the tumour mutations specifically, many of which have successfully completed clinical trials and been approved for use. "More recently, therapies that unleash the patient's own immune response to fight cancer cells are being tested in clinical trials," says Sumithra, who has been designing and analysing clinical trials in oncology.

Medicine is becoming increasingly personalised, so instead of being tailored to a certain disease, it is tailored to a specific individual. "Certain molecular or genetic traits can capture information on the nature of a disease along with relevant patient-specific information," says Sumithra. "This allows doctors to define the optimal course of treatment for each patient." For instance, there is a clinical trial in progress to screen patients with a particular form of lung cancer, to see if their tumours contain specific biomarkers that can be targeted by specialised treatment. Such personalised treatments, supported by statistics, have the potential to revolutionise the whole field of medicine, bringing benefits to everyone receiving healthcare.

About *biostatistics*

Biostatistics involves the application of statistical mathematics to any area of biology, be it medicine, genetics or epidemiology. Within medicine, where Sumithra and Jay work, it provides the analytical tools necessary to ensure that research into medical interventions is robust and accurate.

What skills do biostatisticians need?

A mathematical mind can bring big benefits to the world of medicine. "The ideal biostatistician is excited by data," says Sumithra. "They are adept at analytical and logical reasoning, have good communication and teamwork skills, can think outside the box, and can learn and understand the biology behind experiments and clinical trials."

Why is biostatistics exciting?

Sumithra and Jay were both drawn to biostatistics as it takes mathematics, which can seem like a theory-based subject, and applies it to find exciting and impactful solutions for real-world problems. "Biostatistics is a fundamental discipline at the core of modern health data science," says Sumithra. "It underpins most key public health research efforts, whose solutions have far-reaching positive impacts for society."

Collaboration is a necessary and highly rewarding part of a biostatistics career. "Biostatistics is an exciting field, where individuals often work with other health scientists and professionals in an interdisciplinary environment," says Jay. "Such people collaborate to identify, measure and solve problems that pose threats to public health. As a result, biostatistics touches the lives of people in a meaningful and measurable way."

Pathway from school to *biostatistics*

- Mathematics and biology are key subjects to study at school and post-16.
- Some universities offer degrees in biostatistics. A degree in mathematics, statistics, data science or public health could also lead to a career in biostatistics.
- Sumithra and Jay recommend taking classes in data analyses, public health policy, health services research, clinical trials and experimental design.

Explore careers in *biostatistics*

- Biostatistical skills are valuable in a wide range of careers, providing a variety of career opportunities. "Biostatisticians can work across many different sectors, using their skills in analysis, problem solving, communication and critical thinking," says Jay. "This can involve working in the healthcare industry, government, public health policy organisations or biomedical firms."
- Mayo Clinic where Sumithra and Jay work, offers summer internships and training opportunities for high school and college students: jobs.mayoclinic.org/trainingprogramsandinternships
- Sumithra and Jay recommend This is Statistics (www.thisisstatistics.org) as an excellent resource to explore the many avenues for pursuing a career in statistics, going beyond medicine and public health.

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Biostatistics helps in all aspects of medicine
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Meet *Sumithra*

Growing up, I always had an interest in the field of medicine. Originally, I wanted to be a cardiologist, focusing on the heart. I wanted to find a career that combined my interest in biology and medicine with teamwork, leadership and human connections.

Working as a team is highly rewarding. I love the ability to interact and work closely with world-class doctors and scientists to find new treatments for cancer.

I fill my free time with creative pursuits. I enjoy reading, music, travelling and spending time with my family.

It is important to have a passion for what you do. And don't feel shy to reach out and ask for information, advice or training opportunities from experts in the field you are interested in.

Meet *Jay*

I have always been interested in numbers and analytics. When I was younger, I was interested in becoming an applied mathematician, but not necessarily in the medical field. It was my personal health issues that made me curious to learn about biology and medicine. This then prompted me to explore opportunities to apply mathematical and statistical skills to the medical field.

I love working with a wide range of individuals from a variety of disciplines. In my work, I collaborate with nurses, doctors, statisticians and engineers, among others. Additionally, it's incredibly rewarding to see my work go on to transform patients' lives.

> ***STATISTICS CAN SEEM DAUNTING, BUT DON'T BE PUT OFF BY STATISTICAL COURSEWORK!***

I have a variety of hobbies outside of work. I enjoy travelling, listening to music, watching movies, powerlifting and spending time with my family.

Statistics can seem daunting, but don't be put off by statistical coursework! These days, most real-world statistical work is conducted by sophisticated software, and solving real-life clinical problems using these statistical tools is fun.

How can we detect and prevent brain injuries?

Inside your skull sits your brain, an incredible computer that controls everything you do. The skull does its best to protect our brains from injury, but, sometimes, it is not enough. **Professor Christian Franck**, from the **University of Wisconsin-Madison** in the US, leads the **PANTHER** programme, researching new ways of detecting and preventing traumatic brain injuries.

Professor Christian Franck

Department of Mechanical Engineering,
University of Wisconsin-Madison, USA

PROFILE

Fields of research
Mechanical Engineering, Biomedical Engineering

Research project
Investigating the cellular processes that underly brain injuries to find new ways of detecting and preventing them

Funders
US Office of Naval Research (ONR),
Bjorn Borgen Professorship

TALK LIKE A ...

BIOMECHANICAL ENGINEER

Asymptomatic — when there are no detectable indications (symptoms) that a person is suffering from a condition

Induced hypothermia — the deliberate reduction in temperature of a patient

Neurodegenerative — when cells in the brain or nervous system stop working or die

Strain rate — the speed at which something is deformed

Traumatic brain injury (TBI) — when the brain becomes damaged as the result of an impact or shock to the head

We experience the world through our brains. Everything that you see, hear, taste, touch, smell, think and imagine has passed through the inside of your head. In there, underneath your thick, bony skull, lives a squidgy, pink mass that is home to an incredibly complex network of roughly 86 billion neurons. This network of neurons is in control of everything that we think, feel and do.

As well as being wildly intricate and vital to our continued existence, our brains are also exceedingly delicate. Although our skulls do a stellar job at protecting them, it is all too easy for our brains to become damaged. Even something as simple as being hit on the head by a ball can have serious consequences.

If you have ever had a concussion, you will know how unpleasant it can be. Whether you fell off your bike, hit your head in the playground or collided with someone playing football, the chances are that your concussion came from a relatively minor incident. Even so, concussion should not be taken lightly. You only have one brain, so it is important to take care of it!

Understanding how best to protect our brains can be a tricky business, not least because brain injuries can be hard to detect. Many mild brain injuries can be asymptomatic, meaning that there may be no outward or obvious signs that any damage has been done. Even so, these injuries can lead to significant problems later on, so it is important to identify them.

It might surprise you that it is the field of mechanical engineering that could offer the answers to the questions related to traumatic brain injuries (TBIs). Professor Christian Franck, from the Department of Mechanical Engineering at the University of Wisconsin-Madison, is working on a programme that he hopes will improve the prevention and detection of TBIs. Called PANTHER, this programme relies on a large interdisciplinary team and uses the latest advances in experimental mechanics and molecular cell biology to study TBIs and to develop new ways of preventing them.

Why is it so important to detect asymptomatic brain injuries?

If asymptomatic brain injuries are left untreated, they can lead to serious neurodegenerative diseases such as

Professor Christian Franck and scientist Dr Jing Zhang examine an image of brain cells in the Franck Lab (© University of Wisconsin-Madison College of Engineering)

Alzheimer's, Parkinson's and dementia. Detecting brain injuries early can help to lower the risk of a patient developing any of these diseases.

Asymptomatic brain injuries can also lead to mood disorders such as depression and suicidal tendencies. As mental health disorders are common, it can be hard to spot when a disorder is related to a brain injury. As a result, patients are at risk of being given the wrong diagnosis and treatment, which can lead to further complications.

Young people who have sustained an asymptomatic head injury may find school difficult. They may struggle to concentrate in class or focus on an exam. This can destroy a student's self-confidence and create challenges that may stay with them throughout their educational journey. Identifying whether an asymptomatic head injury has caused these issues can help students get the support they need.

How does PANTHER study brain injuries?

Christian and his team of researchers use the latest technology in their experiments. Participants wear cutting-edge, flexible sensors which track how their heads move in different situations. Data from these sensors is fed into a computer model which then simulates how the brain moves in response to particular types of head movement. Using knowledge of how physics and biology influence the brain, Christian's team can analyse the output from this computer model to understand which head movements are likely to result in injury.

By using innovative advances in 3D imaging and microscopy, Christian and his team can take a closer look at what is really happening. "We are now able to recreate the kind of physical deformations and impacts that the head and brain might experience during a TBI at the cellular scale," explains Christian. By using advanced experimental techniques, the team can track molecular changes in brain cells that are responding to injury and get a much clearer picture of what happens to the brain after a TBI.

You will read more about the different elements that go into the PANTHER programme – biomechanics, the mechanics of materials, and sensing and motion – over the next few pages.

How can PANTHER help to prevent brain injuries?

The lab-based, experimental approach that Christian uses to study TBIs lends itself well to testing potential therapies and treatments. For example, his team has conducted experiments which show that cooling the brain down, sometimes known as induced hypothermia, is an effective way of preventing further injury to the brain in the aftermath of a TBI.

Christian's research can also support the development of new protective materials. These materials can be designed based on his detailed understanding of the physical stresses that can damage brain tissue, such as the amount and speed of tissue stretching. The new materials that are produced can be tailored specifically to reduce the impact of these particular stresses. "These materials can then be integrated into new helmets and helmet designs and be provided to consumers for the military, sports and recreation," says Christian.

In addition to creating new safety equipment, Christian's team also hopes to prevent brain injuries through the development of better safety guidelines. PANTHER's research into the root causes of brain injuries will allow the team to inform and update safety protocols to keep people out of harm's way.

What makes studying brain injuries so challenging?

"The most formidable challenge remains the brain itself," says Christian. "Understanding the physical and biological response of over a billion cells requires a lot of careful analysis, dedication and a diverse, focused team!"

There are 25 researchers working in the PANTHER programme, with expertise ranging from mechanical engineering to cell biology and neuroscience. Whilst having such a large, diverse team is exciting, it can present its own challenges. Maintaining clear communication between all of the researchers can be difficult, especially as the programme continues to grow.

What successes has the PANTHER programme had so far?

The PANTHER programme has enabled important research into brain injuries that are caused by explosions or blasts. Christian's team conducted experiments in which brain tissue was subjected to the kind of intense deformations that would be experienced during an explosion. The team was then able to quantify the damage caused to the brain in such situations for the first time.

The PANTHER programme has also helped to develop a unique system for categorising advanced helmet liner materials based on their properties and how they respond in different situations. This system can hopefully be used to inform and improve the design of new helmets.

What is next for the PANTHER programme?

"There are many next steps as they are still so many unanswered questions," says Christian. For example, one of their next research projects involves looking at whether male and female brains respond to injury in different ways. But they are not just looking at more research projects. Within the next two years, Christian hopes that PANTHER will get their first 'brain-protective' helmets on to the market. In doing so, he hopes that they can provide protection both to military personnel and civilians alike.

About *biomechanics*

Much of the research conducted in the PANTHER programme involves biomechanics. This is an area of science that studies the physics of living things, from single cells to whole organisms. Christian and his team have been using biomechanics to study what happens to brain cells when they are subject to the forces of a traumatic brain injury (TBI).

How do brain cells respond to traumatic brain injuries?

Through PANTHER, Christian and his team have discovered that brain cells respond differently to different types of TBI. One of the key factors is the speed at which the injury occurs, and thus the speed at which the brain tissue is deformed, also known as the strain rate.

If the strain rate is very slow, on the scale of minutes to hours, the brain tissue can withstand significant amounts of stresses and force. An example of this kind of injury would be a brain oedema, when fluid builds up in, and exerts pressure on, the brain. If the oedema is treated quickly enough, the brain tissue may survive unscathed. Our brain cells are often able to adapt to this kind of gradual change in force, stress or pressure.

When injuries involve a faster strain rate, such as from a fall or a head-to-head collision in football, the brain cells are likely to undergo a process known as secondary injury. For injuries resulting from blasts or explosions, the strain rate is extremely fast and brain cells will undergo primary injury, which is potentially the worst outcome.

What are primary and secondary injuries?

The terms primary and secondary injury describe what happens to brain cells during a TBI. During an extremely fast injury, like an explosion, brain cells will be physically ripped apart, as they are unable to withstand the immense stresses involved. When primary injury occurs, the cells are destroyed immediately, so there is no way to restore them. Recovery from this kind of injury takes a long time and has less favourable outcomes.

Secondary injury mostly occurs when the TBI is slightly slower, as with being hit in the head by a ball. In these cases, cell death is driven more by biochemical responses that play out over the course of a few hours. "The interesting thing is that right before and immediately after a traumatic impact, the tissue and its cells generally look intact and healthy," says Christian. However, a few hours later, many brain cells may begin to die.

In some cases, the amount of cell death may not be particularly extensive, and the brain may continue to function as normal. The brain has a network of billions of cells which can continue to function properly even if some cells are lost. A person suffering from this type of injury may show no outward symptoms.

However, if these types of injury keep accumulating, the network may become so degraded that it begins to break down. It is vital to detect asymptomatic TBIs because they can build up and, eventually, cause a catastrophic loss of brain function. "This is something we want to prevent at all costs," says Christian. "Essentially, our goal is to safeguard every brain cell."

In contrast to primary injuries, secondary injuries have the potential to be treated. There is a short window of about four to six hours in which therapeutic treatments, such as induced hypothermia, could prevent irreversible cell loss.

What tools are used to study these cellular processes?

Christian and his team use ultra-precision devices that subject brain cells to the kinds of forces that they would experience during a TBI. These devices are integrated into state-of-the-art 3D microscopes through which they can track the impact of these forces at a molecular and cellular scale. "This allows us to directly measure and quantify how brain cells respond to physical insult in real time, which is a unique aspect of our work," explains Christian.

Meet the *team*

Annalise Daul
Role: MS Student

Fields of study: Mechanical Engineering, Experimental Neuromechanics

Funder: Office of Naval Research (ONR)

I studied mechanical engineering and aerospace engineering at Oregon State University and graduated during the COVID-19 pandemic. One of my professors recommended that I talk to a colleague of his, Christian Franck, who was looking for a graduate student. He told me my curiosity and desire to learn made me a great candidate. After speaking with Christian, I was convinced that graduate school was the next stepping stone on my path.

Currently, I am focusing on the effect of mechanical strain and strain rate on neural cells to quantify and develop a TBI threshold curve at the cellular level.

I had a TBI, so I bring a unique perspective to the PANTHER programme, and my background of mechanical engineering allows me to apply the fundamentals of mechanics to neuronal cells.

A typical day consists of classes, coursework and spending time between the office and lab spaces. In the lab, I perform hands-on, experimental tasks, whilst at the office, I focus on analysing data.

Our work is very engaging but can be relentless: research, critical thinking and creativity never stop, so a big challenge has been learning to find a good balance of working hard while also resting. Another challenge is the work itself: biology-based work is sensitive and variable – learning how to pivot from my mechanical engineering experiences to biological applications has been challenging, but rewarding!

Some of the key successes I've had so far are

establishing key relationships between the mechanics and resulting injury of neural cells. There have not been any eureka moments yet in my research, but I have confidence there will be soon!

I want to make an impact on the lives around me, so I hope to continue to live a life that makes the world a better place.

Annalise's *top tips*

1. Question everything and never stop learning.
2. Chase what excites you and don't doubt yourself.
3. Life rarely follows the path you envisioned for yourself; allow it to happen as it comes, and take advantage of opportunities that pique your interest.

Undergraduate student Grace Kreissler examines a surrogate human brain made in the Franck Lab (© University of Wisconsin-Madison College of Engineering)

Jamie Sergay
Role: PhD Student

Fields of study: Biomedical engineering, Biomechanics

Funder: Office of Naval Research (ONR)

When choosing to go to graduate school for engineering, I knew I wanted a field that would have a direct, positive impact on people in difficult circumstances. This led me to pursue biomedical research. While studying my undergraduate degree, I decided to take a neuroscience class for my own curiosity and ended up loving it. The Franck Lab's TBI research was a perfect opportunity to merge my neuroscience interest with my engineering mechanics background.

I am contributing to a newer side of PANTHER by looking at electrical activity in the brain. My biomedical background brings a more biological perspective to a predominantly mechanical group.

In a typical day, you can either find me at my office desk or in the wet lab space. At my desk, I am often reading research articles, planning future experiments or creating presentations. When in the lab space, I am usually taking care of my neural cell cultures or running experiments.

> ***"THE FRANCK LAB'S TBI RESEARCH WAS A PERFECT OPPORTUNITY TO MERGE MY NEUROSCIENCE INTEREST WITH MY ENGINEERING MECHANICS BACKGROUND."***

Researching biological materials can sometimes be unpredictable and more difficult to control. The PhD process takes persistence and perseverance; it can sometimes be hard to stay self-motivated during the long programme. However, the successes feel even more rewarding for this.

I have presented my research at numerous mechanics and neuroscience conferences, which helped me make important connections and discover further interests.

I hope to become a university professor and run my own research lab that blends the field of neuroscience and engineering.

Jamie's *top tips*

1. Don't be afraid to make unconventional choices.
2. Reach out to people online who have jobs or research that interest you.
3. Keep trying and exploring; you may get some amazing opportunities.

PhD student Jamie Sergay preparing brain cells for microscopic examination (© University of Wisconsin-Madison College of Engineering)

Simulation

Meet *Rika*

Dr Rika Carlsen
The Injury Biomechanics Lab, Department of Engineering, Robert Morris University, Pennsylvania

Fields of research: Mechanical Engineering, Computational Biomechanics

Funder: Office of Naval Research (ONR)

What motivated you to be part of the PANTHER programme?

I really enjoy working on multidisciplinary teams with people who share the same passion as me. Given the complex nature of traumatic brain injury (TBI), we cannot make significant progress by working alone on this research. It takes a team of people working together, bringing expertise from various fields, to make real breakthroughs. The PANTHER programme does just this, bringing together researchers with expertise in many areas such as biology, engineering and medicine. Everyone in PANTHER is passionate about improving our understanding of TBI, and it's exciting to work with such a dynamic and collaborative team on this important research.

Which three words best describe a 'typical day' for you on this research?

Impactful, engaging and collaborative.

What simulations do you produce, and how?

We build detailed computational head models directly from a person's medical imaging data, such as magnetic resonance images (MRI) or computed tomography (CT) scans. We use several different software programs and codes to generate these models. We often refer to these models as 'human digital twins', i.e., a digital representation of a person. These digital twins are used with measured sensor data from real-world head impacts to run a computational simulation of the impact event and predict the risk of brain injury.

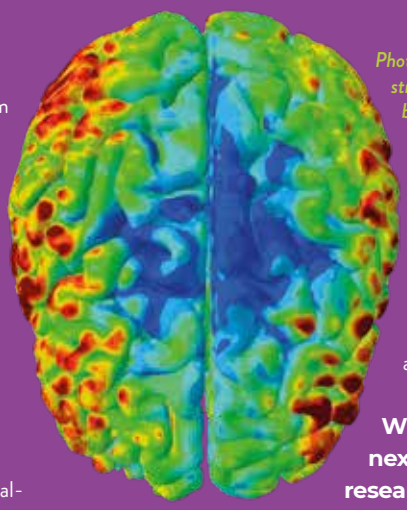

Photo caption: The predicted strain distribution in the brain from a computational simulation of a concussive head impact is shown. Regions of the brain with the largest strains are shown in red.

What do these simulations reveal about what happens at the cellular level?

Since we cannot see in real-time what happens to a person's brain when they sustain a TBI, we turn to computational models to get a picture of what happens inside the head during an impact event. Brain tissue is very compliant, much like gelatine, and can undergo large deformations when the head is impacted. Computational models can reveal the extent to which the tissues deform and how neurons in our brain might become damaged. We have learnt that when neuronal cells are stretched too much and too fast, they can become permanently damaged, which can lead to brain injury.

What do these computational models allow you to predict?

The ultimate goal is to use these computational models to predict the risk of brain injury. These computational models can also be used to identify those head loading conditions that cause the most injury. This information can, in turn, be applied to guide the design of next-generation protective equipment or to develop new safety standards.

What key successes have you had so far?

Some of our major successes include the integration of anatomical details from high resolution medical imaging into our computational models and the use of wearable sensor data as inputs into our models. As medical imaging and sensing technology has improved, it has allowed us to increase the accuracy of our models.

What are the next steps for your research?

We are moving toward real-time estimates of injury. We can imagine a future where all protective equipment, such as helmets, will have embedded sensors in them. The sensor data can then be used as inputs into models that will be able to predict the risk of brain injury any time the head is impacted. This information could potentially be used in the future to diagnose injury, inform treatment or guide 'return-to-play' decision-making in sport to prevent permanent, long-term damage to the brain.

What are your proudest career achievements?

Being the first in my family to get a four-year bachelor's degree was an achievement in itself. When I was younger, I never imagined that I would go on to get a graduate degree, let alone a PhD. I'm so grateful each and every day to be able to do the exciting and impactful work that I do.

Rika's *top tip*

Continue to seek out opportunities to challenge yourself and gain new knowledge and skills. When you challenge yourself, you are going to fail from time to time. I certainly have, but each one of those failures was a learning opportunity. Don't let fear of failure prevent you from trying new things and getting to where you want to go in the future.

Measuring inputs

Meet *Joseph*

Dr Joseph Andrews
Head Sensing Lead,
University of Wisconsin-Madison

Fields of research: Mechanical Engineering, Electrical and Computer Engineering

Funders: US Department of Defense (DOD), US National Science Foundation (NSF), US Department of Agriculture (USDA), Wisconsin Alumni Research Foundation, Discovery To Product

What motivated you to be part of the PANTHER programme?

One of the key motivations for my work is developing light-weight sensing technologies for wearable applications. Through PANTHER, I can work with experts across many disciplines, build and validate wearable sensing technologies to help us understand brain injury at a deeper level.

What types of sensors do you use in this research, and how do you make them?

We use a methodology called Flexible Hybrid Electronics (FHE). We combine traditional microelectromechanical accelerometers with flexible electronic components and sensors to enable system level integration within a wearable form. We can either make prototypes in the lab through printing, which allows for a high degree of customisation and immediate turn-around, or we can use flexible, printed circuit board technology to enable more robust flexible systems.

What data do your sensors provide?

Currently, we are working on two sensing technologies. One enables kinematic (motion) measurements through multiple acceleration sensors. This allows us to understand impact events and, ultimately, recreate the scenario in simulation. We are also working on developing pressure/force sensors. These large-area pressure sensors can allow us to understand what led to the accelerative event, providing information to help us better understand the injury scenario.

> ***THROUGH PANTHER, I CAN WORK WITH EXPERTS ACROSS MANY DISCIPLINES TO DESIGN, BUILD AND VALIDATE WEARABLE SENSING TECHNOLOGIES TO HELP US UNDERSTAND BRAIN INJURY AT A DEEPER LEVEL.***

What are these data revealing about what happens in the brain in a brain injury?

The sensor data will allow us to have a high-fidelity recreation of the event that led to injury. This will reveal to us many of the nuances related to injury in terms of the variables associated such as impact magnitude, impact direction, rotational components and others.

What key successes have you had so far?

We have successfully developed a fully flexible sensing system that offers eight 3-axis accelerometers and weighs only five grams. We have demonstrated the ability for the system to recreate kinematics within head model drop tests and are excited to continue development.

What are the next steps for your research?

Currently, we are working on making our technology field deployable. This includes tackling challenges related to comfort and battery consumption.

What are your proudest career achievements?

There are two things that make me proud in my career. Seeing technology from the lab translate to real-world impact and observing my students' success. The former I experienced during my PhD, when a tire sensing technology I helped invent enabled a start-up company. The latter I see in small ways every day, but most significantly when students graduate.

Photo caption: Joseph's research focuses on wearable sensing technologies to further understanding of brain injury at a deeper level.

Joseph's *top tips*

1. Try to find a mentor in your field and work with them.
2. Be curious and outgoing in your discussion, and learn from those around you.

Mechanics of Advanced Materials

Meet *Theva*

Professor Ramathasan Thevamaran
Departments of Mechanical Engineering, Engineering Physics, and Materials Science and Engineering, University of Wisconsin-Madison

Field of research: Mechanical Engineering

Funders: US Army Research Office (ARO), Office of Naval Research (ONR), US Department of Energy (DOE), US National Science Foundation (NSF), Wisconsin Alumni Research Foundation, US National Aeronautics and Space Administration (NASA)

What motivated you to be part of the PANTHER programme?

The PANTHER programme brings together researchers from biomechanics to mechanics of materials and material design to tackle a longstanding multidisciplinary challenge of tackling traumatic brain injury (TBI). My lab focuses on developing a fundamental understanding of process-structure-property-function relations in materials. We exploit that understanding to create innovative new materials with superior properties and functionalities for extreme environments, making us a perfect fit for PANTHER.

Why is developing a fundamental understanding of process-structure-property-function so vital?

We humans build knowledge by interrogating ourselves and the environment around us with curiosity to learn how nature functions. We also have an urge to get more efficient at performing certain functions important for our day to day lives, as well as to advance as an intelligent species – which led us to engineering! An advancement merely by trial by error can get us only so far. It's important to understand the fundamentals, in detail from the bottom up, so we can engineer new materials in unprecedented ways.

What innovations are enabling you to develop next-generation protective materials?

We often work with design and experimental methods to learn about a complex material we fabricate – for which there aren't readily available computational models. We occasionally learn unusual process-structure-property relations that may emerge when we fabricate and test these materials. Then we exploit such relations in ways that can offer better protective functionalities. Depending on the nature of the application, we engineer new protective materials starting with components that have exceptional intrinsic properties – for example, carbon nanotubes and certain polymers – and build them up across different length scales, from a few nanometres to several centimetres, with efficient structural design rules that yield superior properties. We also focus on making these materials lightweight yet robust.

How do you model material response?

Some of the material systems we study exhibit properties that are not previously known or not well understood, so a computational or theoretical model may not already exist. We often develop our own models, taking into account the fundamental physical mechanisms we identify through our experiments on these materials. We also work with our collaborators in theoretical physics and mechanics to develop models.

Have there been any eureka moments during this research?

Absolutely! These moments are the ones that keep us motivated to reach new frontiers. The most recent eureka moment in the PANTHER programme was when we discovered an unusual process-structure relation that emerged when we synthesised vertically aligned carbon nanotube (VACNT) foams. This improved the stiffness and energy absorption capabilities of the foams, and we are exploiting this to design better protective, ultra-lightweight materials.

What are your next steps?

We will study how materials behave in different conditions so that we can tackle the most common impact scenarios on helmet systems. We are also learning about the material's thermal properties to make them robust for extreme environments, from Arctic cold to desert heat. Finally, we are working with our industry partner, Team Wendy, to test and learn about performance in more realistic conditions.

What are your proudest career achievements?

Numerous along the way like anyone else with a growth mindset – from topping the class during my undergraduate studies in Sri Lanka and getting a doctorate degree at Caltech, to joining UW-Madison and now receiving an Early Career Award from NASA, Innovation Award from Wisconsin Alumni Research Foundation (WARF), and Outstanding New Mechanics Educator Award from the American Society for Engineering Education (ASEE). Closest to my heart is mentoring my students and seeing them reach for the stars in their own universe. It is pure joy to be part of their journey.

Theva at the Argonne National Lab

Theva's *top tips*

1. In whatever pursuits you commit yourself to, don't be afraid to fail and learn from those failures. Stay committed, focused and persevere—that is the way we will walk our way into the unknown.
2. Learn different things from sciences to arts. Hold on to the knowledge that one day they will come together to enable you to do mighty things!

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Research to industry application

Meet *Ron*

Ron Szalkowski
Director, Product Development and Research Collaboration, Team Wendy

Field of research: Material Development (helmet design for protection against TBI)

Funder: Office of Naval Research (subaward on an ONR grant to UW-Madison)

Research to industry application: www.teamwendy.com/about/science-and-technology/innovate

How has your career path led you to the PANTHER programme?

I started at the company, Team Wendy, out of college. The company's origins are in ski and snowboarding helmets, but it transitioned into making the inner padded liners for military helmets. I went from working in quality control to product development and, eventually, directing the engineering group. I was put in contact with Christian, who was trying to understand how brain cells become injured. We wanted to combine that type of cellular research with figuring out how to build better helmets, and even outfit them with sensors that could predict injury. Those ideas became part of the PANTHER programme.

Which three words best describe a 'typical day' for you on this research?

Collaborative. Challenging. Rewarding.

Why are helmets so important?

When your head is accelerated (sped up or slowed down) too quickly, the brain can become injured. A helmet allows those movements to occur more gradually, spreading out the forces over time, and even if it's just for a fraction of a second, that can prevent a severe injury.

What types of tests do you conduct at Team Wendy?

We mostly conduct 'drop tests' in which the helmet is put on a metal head that is dropped onto a hard surface. Now, under PANTHER, we're using a car crash test dummy to better replicate how a real person responds.

What key successes have you had so far?

A major moment was building a cap with sensors in it (the type inside every smartphone that can tell when you turn it), and using a new mathematical algorithm developed by partners at Brown University to crunch the data. It was able to perfectly match the measurements of a test dummy wearing it (the dummy was actually inside the compartment of an airplane that was dropped from 14 feet above the ground to simulate a crash landing). This showed us it would be possible to use wearable sensors and get very accurate data.

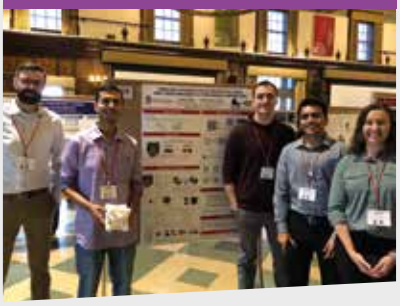
How close are you to introducing a new helmet to the market?

We could be releasing improved pad systems, performing better at high speeds, within the next year!

What are the next steps for your research?

We're building a new test rig that will replicate a person's full body falling onto the ground. We're also developing computer simulations so we can run tests on different helmet designs without having to build them all in real life.

Ron presenting work done in collaboration with UW-Madison to implement 3D printed structures in helmets



What are your proudest career achievements?

The first major ballistic ('bullet resistant') helmet I worked on was selected by the Australian Defence Force (ADF) to be issued to all soldiers. Winning that contract was a big achievement.

Ron's *top tips*

1. Don't be afraid to expand into different areas and learn new things, even if they seem outside your main area of focus. While the engineering field does require developing concentrated knowledge in certain areas, it can also allow you to learn 'how to learn' – and it's helpful when you can combine technical knowledge with other strengths. Never stop learning!
2. I would encourage all types of prototyping, like building things in a makerspace, learning to fabricate with metals, building electronics, or woodworking, anything that interests you and allows you to learn skills along with gaining a deeper understanding of how and why things work. You can find tons of resources online for different areas of interest like this, as well as clubs to join to share and expand your knowledge with others.

“The heroes of this story are the women. They’re the ones that make the difference.”

BAREFOOT COLLEGE INTERNATIONAL

As the saying goes, teach a person to fish and you will feed them for a lifetime. Putting this adage into action, **Barefoot College International** is teaching thousands of women in the world’s poorest communities to become solar engineers. **Sue Stevenson**, Director of Strategic Partnerships and International Development, talks about the immeasurable impact this is having on these women, their livelihoods and the communities in which they live.

What does Barefoot College International do?

We work with some of the most remote and poorest communities on the planet. These rural communities have no formal access to power, water or education. By providing them with an energy platform for social and economic uplift, in other words, more than solar electrification, rural communities can overcome multifaceted and numerous barriers that are linked to poverty. People in these communities become architects of their own social and economic uplift.

Why is Barefoot College International women-centred?

Initially, we tried to train everybody, but we found that, once trained, men tended to move to the city to earn money and young women, though not moving to the city, were also not as community focused. The older women are keen to support their communities and will go back to their families after they have been trained. When I say ‘older women’, they’re not that old. In the places we work, many girls are married off at the age of 12, so the women I’m talking about are in their early thirties; they’re grandmothers and respected in their communities.

Women in these communities are expected to stay at home and care for the children; they’re not taught to aspire. So, not only do we train women to become solar engineers, but we also work on their aspirations so that they have the confidence to do things they would never have imagined they could do. They can dream of a better life, and with this positivity, they become agents of change.

Barefoot College International is empowering thousands of women in the world’s poorest communities to become solar engineers.
© Barefoot College International

Can you give an example?

Like in many remote and poor communities, women in Mali, in western Africa, aren’t accepted in certain social and economic roles. We trained two Malian women to build, install and maintain solar electrification in their community. The head of this community was a man, who held regular town council meetings that were only attended by men. One of our woman solar engineers went to a meeting and the head town councillor said, “Hello, nice to see you but what are you doing here? You’re a woman.” She responded by saying, “I’m not here as a woman, I’m here as an engineer.” To which he replied, “Okay, you can stay, then.” I think that’s a very powerful illustration of how we reach hearts and minds and change people’s attitudes about what women can do.

How do you train women who haven’t had a formal education?

The women we train are illiterate or semi-literate, but they’re not unintelligent. Our aim is to upskill them as quickly as possible, without waiting years for them to become literate. So, we use pictures, colour coding, repetition and learning by doing.

Why is solar electrification key to social mobility?

There are so many benefits that come from solar electrification. Communities have access to light at night and in the early mornings, which means children can do their homework and people in cottage industries, such as basket or rug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weavers, can work later in the evenings. It's safer for people, particularly women, to walk around at night. Families, primarily women and children, are no longer subjected to hazardous fumes from kerosene lamps and there's less risk of a fire. With solar power, it's possible to have a water pump, which means women no longer have to spend hours fetching water and firewood. Instead, they can focus on their livelihoods, which is a key part of this.

How are solar engineers recruited?

In order to have a global reach, we work in partnership with non-governmental organisations (NGOs), such as the World Wide Fund for Nature (WWF) in Madagascar, for example, and community-based organisations (CBOs) – essentially, organisations that are well-known and trusted by the local community.

These organisations contact us, and we go with them to the area where they work to help select suitable women trainees in an egalitarian way. What I mean by this is that the community is integral in helping us choose who attends the training. But, let me make this point very clear: it won't be the wife or relative of the head of that community. That's very important.


© Barefoot College International

What is the criteria for being chosen?

We want women who have the drive to fulfil their aspirations for both themselves and those around them. Women who exist at the nexus of family, economic and social life and have the light of progress in their eyes.

What happens when the solar engineers return home after their training?

The idea is for them to build, install and maintain solar lighting systems in their local communities. We also have a conversation with the leaders of that community about portioning money that is traditionally spent on kerosene, candles and batteries to a community solar electrification fund. This fund has to be run by at least three women and two men – more women than men – and it is used to pay a solar engineer's salary and replacing parts, if necessary.

> **"WE WANT WOMEN WHO HAVE THE DRIVE TO FULFIL THEIR ASPIRATIONS FOR BOTH THEMSELVES AND THOSE AROUND THEM."**


© Barefoot College International

Meet Sue

Tell us about your background.
My degree was in economics, and when I graduated, I worked for IBM (a technology company) as a systems engineer. I then went into marketing and worked in the US, Belgium and France.

When I was based in the UK in the 1990s, I was seconded as Director of Business in the Environment. HRH King Charles III was its president, and the objective was to prove to for-profit companies (PLCs) that it's possible to be environmentally sustainable and make a positive difference to the economy. It centred on the idea of the double bottom line, i.e., measuring a for-profit's business performance in terms of financial profit or loss – the bottom line – and adding a second bottom line to measure its positive social impact. We were so successful that two of my board members, who included CEOs from major UK businesses, were given knighthoods. They didn't receive these titles solely off the back of Business in the Environment, but it was a contributing factor.

Led by women, rural communities are supported to transition to regenerating agriculture and land management. © Barefoot College International

> ***"WORKING FOR BAREFOOT COLLEGE INTERNATIONAL IS SERENDIPITOUS BECAUSE I WENT FROM MY DOUBLE BOTTOM LINE TO THE TRIPLE BOTTOM LINE – FINANCIAL, SOCIAL AND ENVIRONMENTAL IMPACT."***

I stopped working when my husband got a job abroad, and I brought up our family, but I sat on various boards in the fields of education and the arts, including one at Stanford University in the US. When my youngest went to university, I decided to go back to work. I met the founder of the Social Work and Research Centre, started volunteering two days a week and then became employed full time. For me, this was serendipitous because I went from my double bottom line to the triple bottom line – financial, social and environmental impact.

What is the most rewarding aspect of Barefoot College International for you?
It's the difference we make to the women. Let me share another story with you. Ten communities in the north of Senegal are very close to the Mauritanian border. These communities are a six-hour drive from what you would call a normal road. When the Barefoot College International team first went there to select women for the solar engineer training, they couldn't see any women anywhere – only men.

Ten women were trained from December 2021 to March 2022 and the 10 communities became solar electrified in May.

Now, if you go there, the women will greet you and the men stand respectfully behind them because they're very proud of what these women can do. I think this is another brilliant example of how we genuinely change the social fabric of communities and the way women are regarded.

So, for me, it's the improved social standing of those women that makes this work rewarding, or it's the smile on the face of an 11-year-old girl who once told me, "Until I came to this school, I didn't think I was as good as a boy."

That is a relatively short time for that level of impact.
The change we can make in 12-18 months is amazing. And just think what that means after 2, 3 or 4 years! There's a saying: how do you travel a thousand miles? One step at a time. You have to start somewhere and then a ripple effect takes place.

The heroes of this story are the women. They are the ones that make the difference.

About Barefoot College International

Barefoot College International was set up in 2015 to be a fit-for-purpose global entity, with all of the staff moving to it from the Social Work and Research Centre. Its mission is to forge a unique women-centred network, dedicated to sustainable development for marginalised rural communities around the world. Its programmes cover 14 of the 17 UN Sustainable Development Goals.

Barefoot College International's flagship programmes are Solar Enterprise and ENRICHE, designed to create solar engineers, educators and entrepreneurs. Over 3,000 women have been trained in 93 countries and 125,000 households have been solar electrified. These women go on to train other women and there are more than 2.2 million direct beneficiaries.

Solar – Solar engineers are trained to build, install and maintain solar electrification systems in their local communities.

ENRICHE – Women embark on an empowerment journey to give them the confidence, skills and knowledge to reach their full potential as agents of sustainable change.

Ecological livelihoods – This programme is key to economic uplift. Led by women, rural communities are supported to transition to regenerating agriculture and land management and includes livelihoods such as beekeeping and turmeric, cacao and coffee farming. Aspects of Solar Engineering also fall under this programme.
www.barefootcollege.org

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From poverty to empowerment

Rural and Indigenous women in Guatemala face extreme inequality, so how do they become skilled and knowledgeable wage-earners? **Barefoot College International** trains women to become solar engineers, giving them the social and economic uplift they need to light up their communities.

BAREFOOT COLLEGE INTERNATIONAL

How would it feel to be the last one to be allowed to eat at the dinner table, to be bound to household chores, and to be continually discriminated against because of your sex and ethnicity? Imagine having little or no access to education, healthcare, water and sanitation. This is the reality for many rural and Indigenous women in Guatemala.

Offcially known as the Republic of Guatemala, the country's Indigenous Maya make up about half of its population and yet, according to the BBC, rights campaigners say they face extreme inequality. What if rural and Indigenous women were given opportunities to become skilled and knowledgeable wage-earners? What impact would this have on their families and the communities in which they live?

"An amazing landmark"

The aim of Barefoot College International is to empower women to become the architects of their own social and economic uplift in some of the most remote and poorest regions of the planet. It does this by offering practical and locally-relevant training programmes, one of which is known as Solar Enterprises. This programme empowers women to become solar engineers, or 'Solar Mamas', who have the skills and knowledge to build, install and maintain solar electrification in their local communities. Some of the women go on to become Master Trainers, who are responsible for training other Solar Mamas.

Barefoot College International has been working with partners in Guatemala for the past 10 years and, in January 2014, 165 families from the Xeputul, Cotzal and Quiché departments

Juana (left) and Rosenda (middle) are presented with the Presidential Environmental Medal by the President of the Republic of Guatemala, Dr Alejandro Giammattei. © Presidential Press Office, Guatemala.

of Guatemala experienced the untold and positive impacts of solar electrification. Previously, Solar Mamas travelled to Barefoot College International's central training centre in India, but in recent years, it expanded its network of training centres to include Guatemala, Senegal, Burkina Faso, Zanzibar and Madagascar. It was in April 2022, that Barefoot College International launched the Guatemalan Vocational Training Centre.

"A lot of effort, energy and love has been poured into this project," says Rodrigo Paris, Barefoot College International's CEO and Regional Co-ordinator for Latin America. "We have dealt with many challenges and setbacks, such as political turmoil, lack of engagement and the COVID-19 pandemic. In the end, through pure willpower and perseverance, we have achieved an amazing landmark and we are very happy and grateful that all the work has paid off."

Today, there are 27 Solar Mamas and three Master Trainers in Guatemala. Thanks to their ingenuity, 12 rural villages in the Quiche, Alta Verapaz, Huehuetenango and Izabal departments are solar electrified.

One woman's journey

Juana Emelia de León Marcos is a 27-year-old Ixil Mayan woman from the remote village of Xecotz in Nebaj, Quiché. Her involvement with Barefoot College International began as a translator and facilitator for its Coffee Livelihoods programme, back in 2018, but it soon became evident that Juana had great potential. Juana became Purchase Manager as well as a member of the Coffee Cooperative, an initiative set up by Barefoot College International to support women coffee farmers in the Ixil region.

In 2020, Juana was given the opportunity to attend Barefoot College International's Solar Enterprises training programme in India. "The idea was for her to become a Solar Master Trainer when the dream of opening the Vocational Training Centre in Guatemala came true," Rodrigo explains. "Juana still lives in her village with her parents, and her main activities before becoming involved with Barefoot College International were household chores, weaving and coffee farming."

How incredible, then, that in just two years, Juana is now responsible for leading the training at Barefoot

Barefoot College International's Coffee Livelihoods programme supports women coffee farmers. © Barefoot College International

College International's Guatemalan Vocational Training Centre. "Juana explains every concept, tool, technique and skill with such patience," says Rodrigo. "She makes sure everybody understands the curriculum so that they can keep up with the different rhythms of the class. Nobody is left behind and, by the end of the training, every woman is capable of assembling, installing and troubleshooting home lighting systems."

Recognition from the highest order

In December 2022, the President of the Republic of Guatemala, Dr Alejandro Giammattei, presented Barefoot College International with the Presidential Environmental Medal, the highest recognition given by the Guatemalan state to organisations or individuals for environmental work.

"During the medal presentation, President Giammattei praised us for our work with rural women and for the generation of energy to transform lives," says Rodrigo. "He also expressed a desire to expand this model to more locations in Guatemala, which we look forward to exploring further with him."

Juana and her fellow Solar Mama, Señora Rosenda Francisca García, attended the ceremony, which was held in the Mirror Hall of the Presidential Palace. Rosenda is a semi-illiterate woman, who lost her husband earlier in 2022. Her dream is to provide light to more than 34 homes in her community, Cumbre La Botija, a remote, rural village in a mountainous region of Guatamala, which previously had no access to electricity and has been completely reliant on candles and wood.

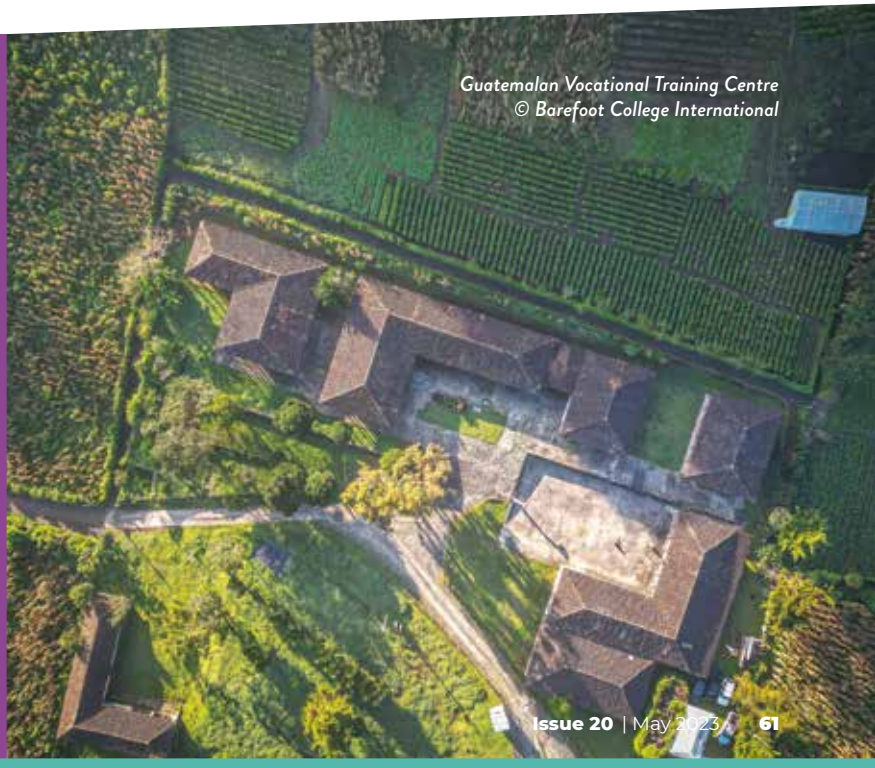
Flying to the moon

The Organisation for Economic Co-operation and Development (OECD) describes social mobility as, "The extent to which people have the same chances to do well in life regardless of the socio-economic background of their parents, their gender, age, sexual orientation, race, ethnicity, birthplace or other circumstances beyond their control." The Solar Enterprises programme in Guatemala is an illustration of the social mobility Barefoot College International is providing for thousands worldwide.

"To be given an opportunity to pursue a career is life-changing for these women," says Sue Stevenson, Barefoot College International's Director of Strategic Partnerships and International Development. "As the saying goes, we're giving rural and Indigenous women a fishing rod, not just the fish. Whether it's Juana in Guatemala, Sophie in Senegal or Mama Fatma in Zanzibar, we're providing them the skills and education that they can take and fly to the moon with."

To read more, visit:
www.barefootcollege.org/first-solar-cohort-at-our-guatemalan-training-centre-begins

> **"AS THE SAYING GOES, WE'RE GIVING RURAL AND INDIGENOUS WOMEN A FISHING ROD, NOT JUST THE FISH."**



Guatemalan Vocational Training Centre © Barefoot College International

The importance of community for reducing social isolation

Social isolation is caused by a lack of social contact. It can lead to loneliness and depression and is often experienced by women immigrants. In their home country, these women were likely to stay at home and create in-depth relationships with other women in their neighbourhood. In the US, they commonly need to work to make ends meet, but the responsibilities of work and family result in a lack of social connection. This leads to high levels of depression and stress. At the **University of New Mexico**, USA, **Dr Janet Page-Reeves** and her team hope to reduce the social isolation of Mexican immigrant women by providing peer support groups so women can build new communities.

Dr Janet Page-Reeves

Department of Family and Community Medicine, University of New Mexico, USA

PROFILE

Field of research
Cultural Anthropology

Research project
Investigating whether peer support groups can reduce social isolation and depression among Mexican immigrant women

Funders
This research was funded by the National Institute of Minority Health and Health Disparities (grant number #1R01MD014153-01) and supported by an award from the National Center for Advancing Translational Sciences, National Institutes of Health (grant number UL1TR001449). Dr Bearer is partially funded by The Harvey Family Endowment.

TALK LIKE A ...

MEMBER OF THE TERTULIAS TEAM

Immigrant — a person who has moved to a different country from the one in which they were born

Peer support — support from people with similar life experiences

Randomised controlled trial — a scientific method to evaluate an intervention, by comparing the outcomes of participants who received the intervention with participants who did not

Ripple effects mapping — a scientific technique to map the impact of something that happens

Social isolation — a lack of social contact

Social network analysis — a scientific technique to map social connections

Undocumented immigrant — an immigrant who does not have the official paperwork to legally live in a country

Have you ever moved to a new neighbourhood or school? What about a new country? If so, what was it like trying to settle into a new environment, a different culture or a different language? If not, how do you think you would feel if you had to find your place in a new community that was unknown and unfamiliar to you? Moving can be hard for many reasons, so it is important that new members of a community are supported as they build their new life.

This is why, at the University of New Mexico, Dr Janet Page-Reeves and her team have created peer support groups for Mexican women who have moved to the US. "Social isolation is common among Mexican immigrant women, which can lead to depression and illness," explains Janet. "We want to prevent this by helping women to find new connections and a supportive community."

Why do Mexican immigrant women experience social isolation?

"In the Mexican culture, people have strong ties with their extended family and community," explains Lidia Regino. "When they leave their home, these connections are broken." Many Mexican immigrants experience a sense of loss at not only having left their friends and family, but also their culture. "Language is also a barrier to social inclusion in the US," explains Lidia. "If immigrants don't speak enough English to get by, they will struggle to access resources and fully integrate into a new community in a new country." And, if immigrants are undocumented, they may live in fear of discovery and so avoid social contact.

Back in their home country, Mexican men tend to work to support their family while women stay at home as caregivers. After immigrating, men enter the workforce first. "This means Mexican immigrant men are interacting in society sooner," says Maria Tellez. "Mexican women often follow their partners into the workforce to support the family income, but they also tend to have primary responsibility for children, family and the home, meaning that the time they have left to socialise

and develop meaningful relationships with other women is scarce. This leads to feelings of social isolation and depression."

What are Tertulias?

To reduce social isolation, the team has established Tertulias (Spanish for 'conversational gatherings'). The Tertulias are peer support groups, facilitated by team members, where Mexican immigrant women living in New Mexico come together in weekly virtual meetings. "Each Tertulias group is different," says Jackie Perez. While the overall model is the same (a virtual peer support group where women share their experiences), every group has its own personality and its own format.

In some meetings, the facilitators lead discussions around themes the women bring to the group. In others, guest speakers give presentations about topics the women are interested in, such as navigating the US education system for their children or the importance of vaccinations. Some groups read books and listen to songs, to both stay connected with their Mexican heritage and learn about American culture. The women use creative projects to reflect on and express their own experiences, and the facilitators introduce useful resources that will help women in their life in the US. "Sometimes, the women don't let us talk!" says Jackie. "But we love it when they take the lead in the discussions. This is their group, and the aim is for them to support each other."

How do Tertulias reduce social isolation?

By participating in a Tertulias group, Mexican immigrant women gain a community. They meet other women in similar situations, who have been through similar experiences and are facing similar problems. This newfound community supports them, provides social interaction and gives them the opportunity to support one another, both within the group and externally.

"For example, two women in my group were experiencing grief and loss," says Jackie. "It was beautiful to see how they motivated and helped each other through their difficulties."

Comments from the participants themselves highlight just how valuable peer support groups are for improving well-being. "My time at my Tertulias group is the only time I have for me," said one woman. "It's the only time I'm not running around doing things for my family." Having experienced trauma in her own life, another participant commented that, "By joining a Tertulias group, I became the person I was before the chaos happened in my life." As a result of her involvement in a Tertulias group, this woman trained as a community health worker and now volunteers with women who have also experienced abuse.

Originally, the Tertulias meetings were going to be in-person, but COVID-19 forced them to change to a virtual format. This meant that women in the Tertulias groups gained practical technology skills in addition to opportunities for social interaction. "Many women told us they were initially intimidated by technology," says Daniel Perez Rodriguez, "but now they are confident in using technology to stay connected, which again helps reduce social isolation."

Evaluating the impacts of Tertulias

The team has witnessed how the Tertulias groups have improved the lives of the individual women involved and seen how much these women enjoy being part of a Tertulias community. However, to scientifically evaluate whether peer support groups can reduce social isolation among Mexican immigrant women, the team is conducting a randomised controlled trial to compare the outcomes of women who do and do not attend support groups.

Over four years, the team is recruiting 60 Mexican immigrant women a year, 30 of whom are randomly assigned to attend a weekly Tertulias group and 30 of whom are randomly assigned to the 'control arm' of the research project in which they do not receive peer support. To analyse the impacts of participating in a Tertulias group or not, the team collects quantitative and qualitative data from both groups of women.

Each year, all participants complete a survey before the study begins, which asks questions about social interactions and well-being, then they complete the same survey again at the end of the study, after they have either spent a year in a Tertulias group or a year with no formal peer support network. The facilitators make observational notes during each Tertulias meeting and, at the end of each year, the Tertulias participants give feedback about their experience of being part of the group. The team conducts social network analysis, to map the social relationships that develop between participants, and ripple effects mapping, to understand how seemingly inconsequential events led to or were caused by other events. Additionally, hair samples are collected from participants to quantitatively analyse and measure cortisol levels, a hormone produced when the body is stressed.

What do the data show?

The randomised controlled trial is still in progress, so the team does not yet have final results. "However, the qualitative data gathered so far shows powerful benefits of peer support groups," says Janet. "These data also indicate that the Tertulias format is a replicable model, as different women in different Tertulias groups in different years all gave similar feedback about the positive impacts they experienced."

The Tertulias groups provide women with the opportunity to gain community and support, and these social connections are far deeper than the study project. "Many Tertulias groups continue to meet even after their study period is over," says Lidia, highlighting how much the women enjoy their new friendships. "It's like a party when they meet up!"

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About *cultural anthropology*

"Anthropology is the study of humans being human," says Janet. There are many branches to the field, and cultural anthropology is the branch that studies human societies. "Anthropologists use a holistic perspective to consider people both as individuals and as embedded in their context." It is important that anthropologists do not just examine issues in the present, but also consider historical perspectives and understand how people, ideas and issues have changed through time. "Anthropology gives you a different way of thinking about the world," says Janet.

What methods do anthropologists use?

"The classic anthropological approach is doing fieldwork using ethnographic methods and participant observation," explains Janet. Ethnography is an anthropological approach that involves understanding the context and relationships of communities or culture. This is commonly achieved by participant observation, in which anthropologists spend time with the community they are studying and take part in everyday activities. "Participant observation gives anthropologists unique insights into the lives of people in the communities they are working with and the issues they are studying," says Janet.

Why is anthropology rewarding?

"I LOVE being an anthropologist!" says Janet. "You have to think incredibly deeply about the data to make sense of the complexity, so I enjoy the thoughtfulness and intellectual quality of anthropology." Being involved in community-driven research means that Janet does not base her projects on the issues she thinks need to be addressed or use the methods she thinks are best to solve them. Instead, she works with people in the community to discover what issues are important to them, then they work together to find solutions. For example, in a previous project, people were concerned about incidences of diabetes in their community, so Janet worked with them and together they co-created a project to investigate the issue. "It is good to know that my work is directly connected to making the world a better place in practical ways," says Janet.

Why should you study anthropology?

The skills you learn by studying anthropology will make you attractive to employers in a wide range of different careers. There are many different branches to anthropology, so you can tailor your studies to address the topics and questions that most interest you. "I didn't start out as a health researcher," says Janet. "I'm not even a medical anthropologist. I'm a political economic cultural anthropologist, but this still allows me to contribute to health research, as anthropology is at the crux of important health issues, especially those related to social injustice and inequity."

Pathway from school to *anthropology*

- Any subjects you study at school will prepare you to study anthropology. "I believe in being a generalist," says Janet. "Study a broad range of subjects to discover your interests. I would never have discovered anthropology if I hadn't done that."
- Many universities offer degrees in anthropology, but other social science degrees could lead to a career in the field. The Society of Applied Anthropology contains a list of universities with applied anthropology degree programmes: **www.appliedanthro.org/about/resources**
- "A broad, liberal education will give you the tools to think," explains Janet. "This is more important than having expertise in a specific anthropology topic."

Explore careers in *anthropology*

- "An anthropology degree will teach you to think deeply, which will make you employable for many different jobs," says Janet. "Anthropologists can morph their range of skills to fit many career options."
- Their ability to uncover connections and relationships means many anthropologists work in politics or government or follow careers that require negotiation and socialisation skills. Anthropologists also work as social workers and community development workers.
- The American Anthropological Association has a wealth of resources related to careers in the field: **careercenter.americananthro.org/careers**
- Prospects provides information about careers available for people with an anthropology degree: **www.prospects.ac.uk/careers-advice/what-can-i-do-with-my-degree/anthropology**

Tertulias groups provide women with friendship and community

Meet *the team*

Dr Janet *Page-Reeves*

Role: Tertulias Project Leader

I have always been fascinated by different cultures, and I have a special love for everything related to the Andes. At college, I studied history and international development as I dreamt of working for an organisation that promoted health and welfare in regions where people lack access to resources or political power. When I took an introduction to anthropology class, I fell in love with the subject, but struggled to see how I could apply it to my interests in politics and inequality, specifically in Central and South America.

After college, I did an internship at a 'think tank' in Washington DC while working as a waitress to earn money, until I had saved enough to travel to Central and South America. I spent a month in rural Costa Rica followed by two months in Bogota, Colombia. In both places, I lived with local families while attending immersive Spanish language courses. I then travelled through Colombia, Ecuador, Peru and Bolivia to Chile, where I spent six months volunteering with a human rights organisation and a women's handcraft cooperative in Santiago. This was during the violent and oppressive regime of the then Chilean president, General Pinochet.

> ***I HAVE ALWAYS REJECTED THE IDEA THAT IT IS OK THAT SOME PEOPLE HAVE THINGS THEY NEED TO LIVE A GOOD, HEALTHY LIFE AND THAT OTHERS DO NOT.***

One day, I was chatting with someone in a café in Santiago and was excited to discover he was an anthropologist. When I asked what he was studying, his response was, "Poverty". This was an epiphany for me. I had never considered that I could use anthropology to focus on issues related to poverty, and I realised this was what I wanted to pursue. I returned to the US to do a PhD in cultural anthropology, conducting research with Indigenous women in Bolivia who were knitting sweaters in a cooperative.

I have always rejected the idea that it is OK that some people have the things they need to live a good, healthy life and that others do not. Anthropology has helped me understand that this is not just some 'natural' occurrence, but that these inequities and injustices are reproduced every day. I have devoted my career to developing strategies to do something about it.

Tertulias team members and participants

Jackie *Perez*

Role: Tertulias Group Facilitator

I am a clinical social worker, and for the past 20 years I have been privileged to serve the Spanish-speaking immigrant population. Before becoming a social worker, I worked with survivors of domestic violence and those who had limited resources.

I have always been inspired by people willing to give their own lives to improve the lives of those most in need. Archbishop Oscar Romero and missionary Jean Donovan are two of my heroes. They were martyred in El Salvador in the 1980s due to their commitment to and love for marginalised communities.

I am excited by the Tertulias project because I can provide support for women who suffer from social isolation due to their immigration status. I enjoy interacting with the women in the groups and learning from their experiences and resiliency. I also enjoy the different research activities we do to evaluate the impacts of the Tertulias project.

I have seen the blessing these groups have been for the many immigrant women who have participated in them, as they have decreased social isolation, anxiety and depression. Seeing the women interact and support each other is a highlight of the project.

Tertulias team members recruit participants for the randomised controlled trial

Daniel *Perez Rodriguez*

Role: Tertulias Data Manager

The Tertulias project is important to me because, although I am not a woman, I am a Mexican immigrant. Our work is shedding light on the issues that Mexican immigrant women deal with daily. I am excited by the project because it is giving a voice to people that don't often get to speak their minds or share their wisdom. We can use what we learn to help others in similar situations, and it is fulfilling to know that the Tertulias groups have positively affected people's lives.

As the data manager, I work closely with all the project data as they journey from the study participants to the data analysis team. I oversee the data collection to ensure it is as 'clean' as possible, without any errors or missing data, as a clean dataset will make for a more accurate and smoother analysis.

I enjoy mysteries, puzzles and curious tinkering with software and hardware, and I use all these interests in my work. I treat data inconsistencies and errors like a puzzle as I figure out why information is missing or incorrect. If you think working with computers is interesting but coding is overwhelming or not engaging, then a career in data management could be for you.

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Maria *Tellez*

Role: Tertulias Project Coordinator and Group Facilitator

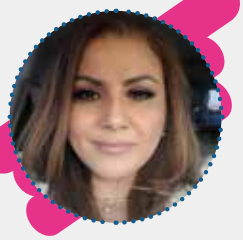
My father was a great source of inspiration in my life. He didn't have the means to attain a high school diploma (he only finished 4th grade), but he was very smart, and he always encouraged me to work hard and finish my college education. With his inspiration, I obtained a law degree.

Growing up, I saw that my community had many different needs. I became interested in social work because I saw how better community organisation could lead to more positive outcomes. When people are motivated to work towards a common purpose, great change can happen in communities.

I am a community healthcare worker and I love supporting my community. I enjoy seeing people educate themselves about issues facing their community, such as health, education and the environment.

I became involved in research projects because I was curious to learn what research entails. This curiosity also led me to join the Tertulias project, because I was interested in being part of a project focused on Mexican immigrant women (a group that historically has been hard to reach for research). For me, a key finding from this project is that when women socialise, we learn the importance of supporting each other. We discover our inner strength and find the value we have as women.

Tertulias team members and participants



Lidia *Regino*

Role: Tertulias Project Director and Group Facilitator

I was powerless as a child. I was an undocumented immigrant who didn't speak English, living in a family that was struggling to make ends meet. I constantly read fairy tales because those stories always had a happy ending. I realised I needed to study to better the lives of those in my family, and I decided becoming a lawyer would give me power to make positive changes in broken systems.

In middle school, I started advocating for equality and equity, and I would always defend students who were bullied. When I was about to graduate from high school, I found an angel in my life. This was at a time when undocumented immigrants couldn't attend college on in-state tuition. He helped me and other Mexican immigrant students to walk a path we didn't think we could follow, and I obtained a degree in university studies. My studies were focused on political science, but I was also drawn to public health, community advocacy, public policy and community work.

> **"WORKING CLOSELY WITH THE TERTULIAS PARTICIPANTS AND SEEING THEIR GROWTH HAS BEEN A HIGHLIGHT OF THIS PROJECT."**

As a community health worker, I have spent 30 years advocating for the immigrant community to remove structural barriers that immigrants face. For example, I have advocated for healthcare access for everyone, including undocumented immigrants, and campaigned for every New Mexican resident to receive in-state college tuition, regardless of immigration status. I am also passionate about working directly with people in need and helping them navigate systems, by linking them to resources and supporting the creation of non-existent ones. For example, I have worked with non-profits and community advocates to develop translation and interpretation services in public institutions, such as the UNMH hospital.

Working closely with the Tertulias participants and seeing their growth has been a highlight of this project. As a Mexican immigrant woman, it is rewarding to see the positive change other Mexican immigrant women experience through their participation. I am proud that this project has made a difference in the lives of women and their families and disrupted the pattern of isolation for many women.

Dr Cristina *Murray-Krezan*

Role: Tertulias Biostatistician

As a biostatistician, my role in the Tertulias project is to help design and analyse the randomised controlled trial. Before beginning, we had to figure out how we would determine whether participants in the Tertulias groups had reduced social isolation compared to participants who weren't in a Tertulias group. This meant figuring out what variables we could measure to show a difference in social isolation, how big these differences would need to be to be statistically significant, and therefore how many participants we needed to include in the study.

My journey to become a biostatistician was rather untraditional. As I child, I wanted to be a doctor, but then I went to college to study flute performance. I ended up graduating with a degree in astrophysics, then worked in a medical research lab. When I realised I could apply math to my interest in medicine, I returned to college to study statistics. The best thing about being a biostatistician is that I can work in any medical or social science field.

I love being part of this project because I get the opportunity to help people who are often ignored in American society. Immigrants face so many obstacles in a new country, so it is rewarding to know our work is helping people live happier and healthier lives by improving social connections. It is exciting to analyse the data and see how participants' social networks have grown though their involvement with Tertulias.

Dulce *Medina Bustillos*

Role: Tertulias Group Facilitator

I arrived in the US as a teenager and had difficulties adjusting as I didn't have the required support. As a Mexican native and first-generation immigrant, I understand the importance of social and family support in my culture.

My father instilled in me the importance of a college education, but, at that time, undocumented students had no access to scholarships. I was determined to go to college, so I worked multiple jobs to afford my tuition, and my mother found an organisation that helped me apply. In the end, I graduated with two degrees in business. I have since returned to university to pursue master's degrees in social work and business administration.

Twelve years ago, my destiny took me to work at a mental health agency, where I discovered the need for Spanish speaking providers. Since then, I have been working as an interpreter, translator and community health worker for Latino community members.

I developed an interest in research during my master's studies and have participated in other research projects. However, Tertulias is special to me because it hits close to home. Many Mexican women leave family in Mexico and lack support when they arrive in the US. I facilitate a Tertulias group and have seen how it helps Mexican women feel closer to their culture, build support for each other and become friends.

Tertulias *art*

"I painted this butterfly because I am her. Like a butterfly, I had to go through a process of change to be the woman that I am now. And, like her, I was once a cocoon that had to walk slowly before I transformed into a beautiful butterfly. I was made to feel ugly, inside and out. But, little by little, I started to change. In my process of change, I was also being hurt. Six months ago, my transformation, as a woman and as a person, began.

"The colours have a meaning of their own. The black represents the pain I went through to get here. The blue represents my children, life and motivation to be the best mother, a better person and a great woman. The white dots represent my dreams. There are a lot of dots because I am a dreamer.

"I thank Tertulias for the support that was given to me. When I would break down, they would give me a breath of fresh air to keep on going. They are a great team of great women who construct other women.

"Now, I am a butterfly. I have my wings wide open because I know I am beautiful inside and out. There are people fighting a war in their heads that keeps them from seeing their own beauty. Like the butterflies, they don't see their own beautiful wings. If you see something beautiful in a person, make them aware of it.

Laura Venegas
Tertulias participant, 2023

Camille *Vasquez*

Role: Tertulias Coordinator

I became involved in the Tertulias project because I love working with people. I truly believe *'nuestra cultura se cura'* ('our culture heals'). I believe in cultural empowerment, people empowerment and community empowerment.

I am a first-generation Chicana (American of Mexican descent) and am passionate about helping communities. I have aspired to improve health outcomes throughout New Mexico because impacts to health do not just affect us personally – the unhealed and untreated traumas follow for generations.

My dad came to the US from Mexico in his 20s, with dreams of becoming a doctor that he has been unable to fulfil. My mom is from a long lineage of rural New Mexicans. As a result, I have felt the generational impact of systemic racism, trauma, inequality and inequity. This is part of my 'why'.

At university, I studied nursing, Spanish and Chicano/a studies. In 2018, I started my own company, Camille's Consulting, which provides support for organisations focused on improving health outcomes through social and economic development. When I work with projects, I always ask myself, "Could this have made a difference for my sisters, my brother, my mom or my dad, or for my life?" I believe everyone should have equitable access to pursue their dreams and reach their greatest potential.

Virginia *Sandoval*

Role: Tertulias Project Manager and Group Facilitator

Working with women from different walks of life inspires me. I have heard very powerful stories from women who have suffered traumatic experiences, but, after all their hardships, they have still survived. They are a clear definition of what resilience means.

I am a Mexican immigrant, and my involvement with the Tertulias project gives me the opportunity to help other women like me. I support them in accessing resources, continuing their education and finding ways to engage in community programmes.

> **WORKING WITH WOMEN FROM DIFFERENT WALKS OF LIFE INSPIRES ME.**

As a community health worker, I work with my community to address health-related needs. I know how important this role is for communities, so I encourage Tertulias participants to obtain their community health worker certification.

I love working on community research projects because they teach me many different ways of seeing things. I have a degree in psychology, but community research has opened new ways of thinking. Through this work, I have also had the opportunity to train as a phlebotomist (someone who takes blood samples).

Dr Elaine *Bearer*

Elaine is a neuroscientist and pathologist. She is leading the cortisol measurement aspect of the Tertulias project.

Dr Reuben (Jack) *Thomas*

Jack is a sociologist studying the social structure of relationships. He conducts the social network analysis for the Tertulias project.

The team's *top tips*

1. Remember that even the smallest actions can make change and build a better world.
2. Always work unselfishly for the community and be the voice of those whose voices have been oppressed.
3. Participate in community research because you will gain important skills and learn about human lives.
4. Don't give up when you face hard times or obstacles. Stick with it; you will succeed!
5. Remember that your interests may evolve and your goals may move as you grow up. Life experiences may cause your path to change, and that's okay.
6. Surround yourself with people who believe in you and support you. Most importantly, believe in yourself.
7. Whatever you do, do it with passion, and work to be the best you can be.

How are streaming services affecting the way we consume media?

Subscription video on demand (SVOD) platforms, such as Netflix, have grown to become a core way that we watch films and television. The amount of choice we have over what to watch and when to watch it is unparalleled in the history of media, but also raises questions about what this means for screen industries and local production. **Professor Amanda Lotz**, at **Queensland University of Technology**, Australia, is scrutinising what these changes mean for markets and for us as consumers.

Professor Amanda Lotz

Digital Media Research Centre, Queensland University of Technology (QUT), Australia

PROFILE

Field of research
Media and Communication Studies

Research project
Investigating the impacts of global SVOD platforms on national television markets and national policy

Funder
Australian Research Council (ARC)

TALK LIKE A ...

MEDIA AND COMMUNICATIONS SPECIALIST

Broadcast — a means of sending a signal over the airwaves using the electromagnetic spectrum (not cable, satellite or the internet)

Competition — when two or more organisations or people are aiming to establish superiority over the other

Complementary — when two or more products or services complement other products/services. For example, while Netflix and Amazon Prime offer similar streaming services, they have different attributes that complement rather than compete against each other. See this article in *Forbes*: **www.forbes.com/sites/greatspeculations/2017/06/01/netflix-and-amazon-competitors-or-complementary/**

Market — the 'place' for transactions of goods and services

Policy — a proposed course of action, typically by a government

Regulation — a rule made and enforced by an authority, typically a government

Streaming — the technology of transmitting audio and video files in a continuous flow over a wired or wireless internet connection

Subscription on demand (SVOD) — services where the consumer pays a regular (usually monthly) fee to access as much content as they wish within a particular platform. Well-known SVOD services include Netflix, Amazon Prime Video and Disney+

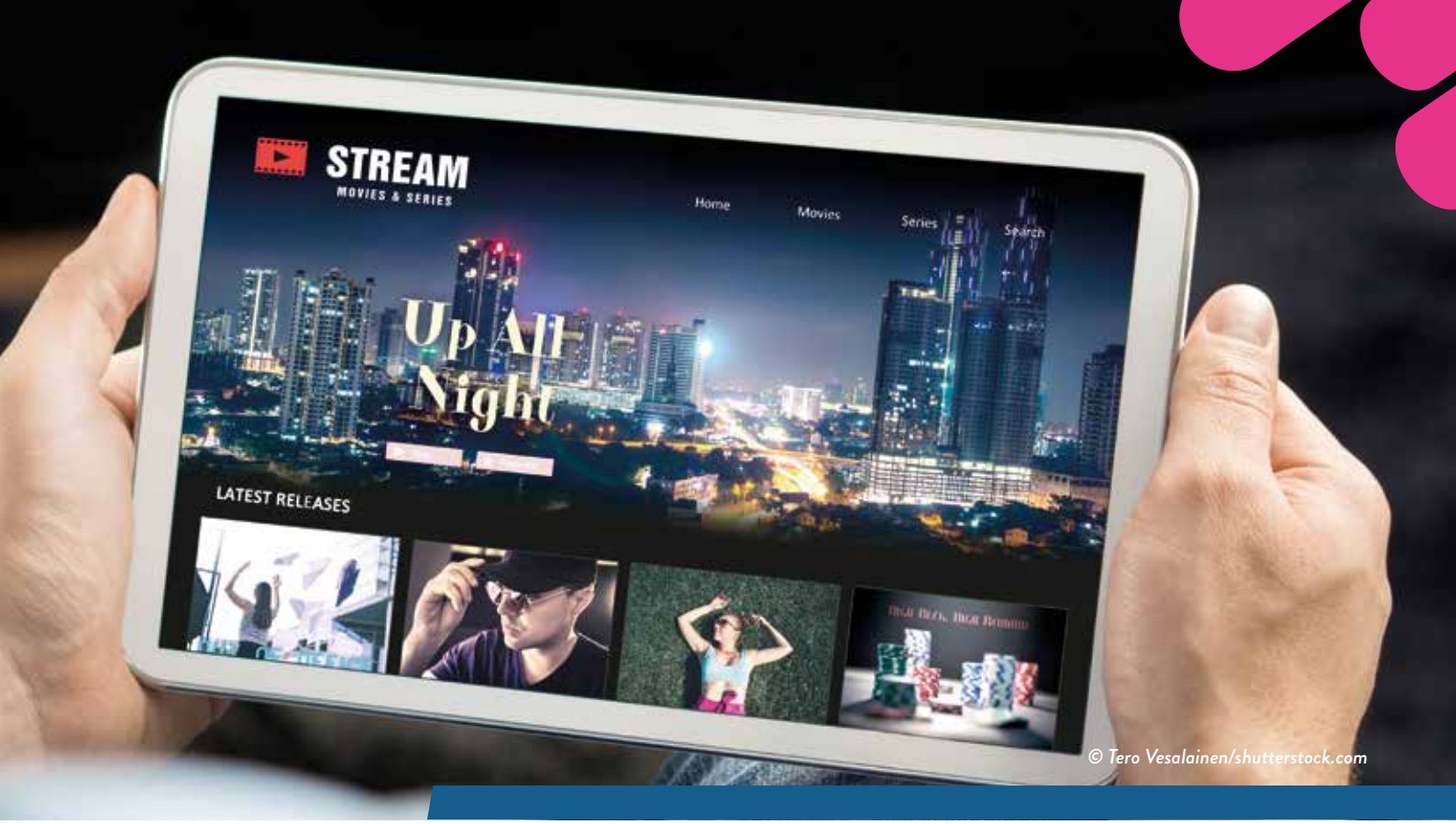
Television has changed dramatically within its relatively short history. For many years, only a small number of channels within your country were available to watch. This was then succeeded by satellite and cable television, which opened up a much wider array of channels, including from other parts of the world. Then, in recent years, we have seen the rise of streaming services, which have enabled gigantic libraries of media from across the world to be instantly accessible.

These days, if we choose to pay a monthly fee, we can have unprecedented access to content from across the globe. "Our access to TV used to be tied to domestic or regional production," says Professor Amanda Lotz, who works at Queensland University of Technology's Digital Media Research Centre. "Nowadays, streaming services make titles from many countries available." For many decades, TV channels principally broadcasted series or movies made within the viewer's country, or material from other nations that had been chosen and licensed by the local broadcasters. This is no longer the case – things have changed on a variety of levels.

"Streaming services have changed the way we watch stories on the screen, and which stories we have access to," says Amanda. "Even when we are watching TV 'for fun', the media we consume contributes to how we understand ourselves and the world around us." For this reason, it is important to understand how the world of media is changing and what this means for society.

Studying streaming

Amanda's discipline involves studying how media affect, and are affected by, global markets and the consumers within them.



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Streaming services make this a complicated challenge. "It is very difficult to compare the range of titles in a streaming library with a television schedule," she says. "Also, because recommendations are personalised, it is difficult to know what titles are promoted to other viewers – making it challenging to gauge the 'circulation power' exerted by these services to drive viewers to watch certain things."

Additionally, metrics such as number of subscribers or viewers of any one show or film are less useful, given people subscribe to a streaming service's library of titles rather than any particular title. Many members of a neighbourhood may access the same service but watch entirely different shows and films. "While streaming services may seem like broadcast services, there are some things that make them very different," says Amanda. Understanding these differences and how to study them is important. As we all know, media can play a considerable role in how we understand the world, especially the parts outside our own experience, so investigating the ideas and stories that media make available is vital to understanding societal trends at large.

The Hollywood monopoly?

While streaming services may seem like an amazing way to ensure diverse content on the surface, it is important to note that virtually all the big global streaming organisations – Netflix, Disney+, Amazon Prime Video, HBO Max, to name a few – are based in the US. Hollywood has long played an outsized role in producing screen entertainment around the world, which creates concerns about its influence on the global market for a variety of reasons. For instance, Hollywood's size and scale may stifle the production of local content, which cannot compete in terms of budget, and movies and series produced outside Hollywood often have more difficulty reaching viewers outside their country of production.

Scholars in Amanda's field have long been concerned that this may lead to more 'culturally similar' media, where people are exposed to a narrower diversity of content. There are also some who worry that US dominance provides a route for the US to push particular political views in other parts of the world.

While Amanda recognises these points are valid, she notes the situation is more complex. "The majority of global streaming services are US-based, and this is something that needs to be watched closely," she says. "However, the greater access to global distribution may also diminish Hollywood's centrality. The key is understanding that these services are part of a mixed ecosystem of content – some on SVOD, some on social media, and some on broadcast – that people are exposed to."

The role of regulation

There is an argument that stricter regulation could help mitigate such US-focused media domination around the world. Regulation refers to how a nation's laws and policies act to exert control over many parts of our lives. For instance, building regulations aim to ensure that new houses are safe and efficient; business regulations aim to ensure that businesses act in ethical and fair ways. For television, regulations may ensure that explicit content is only shown at certain times, or that a certain proportion of content must be locally produced.

Streaming services disrupt this landscape of regulation, as they don't follow the normal 'rules' of broadcast media. "For instance, streaming services use the internet rather than the airwaves used by broadcasters," says Amanda. "These airwaves are typically considered a public good, which has until now formed the basis of broadcast regulation." Given that streaming services do not use airwaves and also typically span across many countries, they are proving harder to regulate, both nationally and internationally. For some people, this raises cause for concern, most notably with regards to the lack of any obligation for global streaming platforms to host content local to viewers.

Amanda thinks this complex picture makes it difficult to say whether stricter regulations to ensure access to local content for streaming services is the answer. "It's possible that market demands may be sufficient to ensure the continued production of local content," she says. "For example, a key reason that Netflix has been globally successful is that, unlike many other streaming services, it has a large amount of non-US content on its platform." Lots of nations also have streaming services specifically for locally produced content, arguably a complementary – rather than competitive – service to global streamers.

The power of stories

As part of the ARC Discovery Project, Amanda's team is now investigating in more detail how SVOD platforms affect national television markets. This will include comparing the responses of different governments around the world and the types of new regulations they are introducing. It will also look at how the production of local content and diversity are affected, and provide insights to inform policy decisions.

Despite the variety of concerns about streaming platforms, Amanda believes they are improving quality of life overall. "The extensive libraries and alternative business models used by these streaming services means that they support the development of a much greater range of rich and engaging stories," she says. "As individuals, we should think about what kinds of story we engage with and whether we might be missing out on others, but I think preferences and reasons why we engage with stories are personal decisions."

About *media and communication studies*

Media and communication studies is an interdisciplinary field that uses social sciences and humanities to study communication and human interactions with society.

Media is closely tied to technological development. The rise of streaming services, video-based social media platforms and interactive forms of digital communication have all only been made possible by new technologies. "Many things have changed considerably since the emergence of media studies, when our understandings, built then from norms of mass media, first developed," says Amanda. "There is a lot of work to be done by researchers to update our theories and ideas as media constantly changes."

Inventors and companies may not fully consider possible societal impacts of new technologies before they are rolled out. For instance, while social media has a wealth of positive effects on our ability to communicate, there is also evidence of its negative effects. It places new demands on young people. Academic study of these effects is essential for society to take appropriate action and be properly informed.

Policy and regulation often take time to catch up with technological development, which is why streaming services and social media platforms are relatively lightly regulated at present. Effective policy depends on robust evidence, which is where researchers such as Amanda come in. The research that academics like her produce is often integral to ensuring that new regulations are well considered.

Amanda also notes that beginning a career in media and communication studies opens many doors. "Media and communication degrees develop critical thinking, reading, writing, and communication skills that are useful in virtually every career," she says.

Pathway from school to *media and communication studies*

- Many subjects are useful and relevant for a degree in media and communication studies. In particular, universities may like to see English, psychology or sociology.
- There are many undergraduate degrees focused on media and communication, but this is not the only route into the field. For careers within academia, an understanding of the social sciences is typically very useful. Degrees in psychology, economics or other social sciences may prove helpful in this regard.

Explore careers in *media and communications*

- The majority of jobs in media and communications are outside academia, and include roles within the film industry, journalism, publicity, website development, and the written world. Within academia, the study of media and communications tends to draw from social science traditions such as sociology, psychology and political science.
- Media and communication studies typically involves a lot of interaction with media industries. Work experience or internships in public relations (PR), journalism or advertising are likely to come in useful.
- Careers within media and communications can vary enormously. In Australia, according to Glassdoor, average salaries within the field are around $65k per year.

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Meet *Amanda*

Professor Amanda Lotz is a media scholar, professor and industry consultant. She leads the Transforming Media Industries research programme in QUT's Digital Media Research Centre, and has authored several books exploring television and media industries. She has worked with a number of media organisations and with national governments to advise on the changing media landscape, and has also helped cultivate a global network of media scholars with expertise on streaming. She explains how her career arose.

When I went to college, I thought I wanted to be a news presenter. I enrolled in introductory communication classes, but outside the classroom – in the campus TV station and on internships – I quickly learned that it wasn't work I enjoyed. I did, however, find the material in my classes interesting.

Until my last semester at university, I thought I would work in the TV industry or go to law school. A professor suggested I continue studying communication and media in graduate school, and I really loved it. I trained with the expectation that I would primarily teach. I never expected to have such a robust research career.

Digital technologies are changing all the time. This has dramatically changed how the media industry operates. Keeping up with these changes can be frustrating but are also what makes it so interesting.

Persistence is my philosophy, plus a bit of 'fake it till you make it'. It took decades for me to truly find my voice as a writer and feel in command of my ability to identify important questions and know how to answer them.

Amanda's *top tip*

Be curious. Watch a lot and read widely (not just stuff on the web). Figure out the questions you are curious about answering.

"Streaming services have changed the way we watch stories on the screen, and which stories we have access to." © Diego Cervo/shutterstock.com

Bias, assumptions and emotions: why we think what we think

While highly efficient, the way we process information to make decisions is far from perfect. Finding out how this process works – and how we can use this awareness to make better decisions – is at the heart of cognitive science. At **The University of Melbourne** in Australia, **Professor Andrew (Andy) Perfors** is studying the nature of bias and other features of cognition, and even applying these findings to machine learning.

Professor Andrew (Andy) Perfors

Director, Complex Human Data Hub,
Melbourne School of Psychological Sciences,
The University of Melbourne, Australia

PROFILE

Fields of research
Psychology, Cognitive Science

Research project
Using experimental and modelling techniques to investigate where biases come from, and using these findings to inform the development of machine systems that reason like people

Funders
Australian Research Council (ARC), Australian Defence Science & Technology Group (DSTG)

TALK LIKE A ...

COGNITIVE SCIENTIST

Artificial intelligence (AI) — computer systems able to perform tasks normally requiring human intelligence

Bias — a tendency to believe or support a particular perspective

Cognitive science — the study of thought, learning and mental organisation

Machine learning — a type of artificial intelligence in which computers learn from past data in order to predict outcomes

Misinformation — false or inaccurate information created and spread without an intention to harm others

Reason — to think logically, based on facts and evidence

Every day we are bombarded with information, ranging from things we read online, to conversations with family and friends, to events we see and hear in the world around us. Our brains have the unenviable job of taking all this information in, deciding which bits are important, and using these bits to inform our opinions and behaviour. However, as Professor Andrew Perfors at The University of Melbourne knows all too well, this process is subject to bias – when certain pieces of information are favoured over others – which can lead to us making decisions based on dubious assumptions or poor reasoning.

The nature of bias

"Biases aren't intrinsically bad," says Andy. "In fact, they're often very useful. They are what allow us to make lots of decisions quickly, without having all the data, which humans are actually very good at." For instance, we all have a bias to pay attention to (and like) things we see frequently. This is useful for learning language, understanding social norms and recognising neighbours. However, this bias is also exploited by advertisers, who know that people who see a brand more frequently are more likely to buy it.

Biases also contribute to us choosing to accept some types of information and ignore or reject others, which can lead to people believing misinformation. "It's very hard to know what's true when you don't have direct evidence," says Andy. "While we all know the sky is blue because we can see it, we don't have much direct evidence on things like how vaccines work or how the economy is doing."

Truth and sense

Because we often do not have direct evidence, we have to rely on two other things: our trust in the source of information, and whether it makes sense to us. "However, the issue with trust in the modern world is that people are very good at lying, and we also usually don't know the person stating the information personally," says Andy. Even if we are told something by a trusted friend or relative, they might have heard the information from a politician or journalist whose trustworthiness is difficult to gauge.

"Because trust is difficult, we often also rely on whether the information makes sense to us," says Andy. "Unfortunately, in our minds, whether something makes sense usually equates to whether it's easy to process or whether it fits with our prior experience." This is dangerous, because it means we are more likely to believe 'simpler'

explanations over nuanced ones, and we fall back on our preconceptions rather than open up to new ideas. "We usually don't have the time or expertise to scrutinise information properly, so it's more 'efficient' to believe the simpler thing," says Andy.

Assumptions

While we all like to think our decisions are rational, this is actually an impossible pursuit, as we can never have all the data needed for total objectivity. "There's no such thing as 'perfect' rationality," says Andy. "Even the most advanced machine needs to make assumptions about what information is most relevant when making a decision. The real question is to ask ourselves why we are making the assumptions we do and whether they're beneficial, correct or neither."

The problem with assumptions is that we often do not notice we are making them until we take a moment to step back and reflect. "While it's really hard, it's important to recognise that we might sometimes make incorrect assumptions and need to change our mind," explains Andy. "Building trust in your own reasoning – for instance, by seeking out alternative viewpoints when given a certain perspective and making a decision based on more evidence – is the best way to ensure your decisions are as good as they can be."

Emotions vs logic

Decisions based on emotions and those based on logic are often viewed as two ends of a spectrum, but Andy says they are actually part of the same system. "Facts are useless to us on their own. Emotions tell us what to do with the information we get," he says. "For instance, if something makes me feel scared, I know it's time to run or fight; if I feel ashamed, I know I've probably done something wrong that I should try to make right." However, while these reactions are useful in the majority of cases, they can be abused. "Emotions are blunt tools and can be manipulated," says Andy. "Someone might tell me something they know will make me scared because they want me to stop being sceptical and have an emotional response that benefits them, rather than me."

Taking time to reflect on the information you are being given and your emotional response to it can help you avoid manipulation. "If something is making you feel angry or fearful, especially if it is about a group or person you don't know, stop and ask yourself why you are being told this information," says Andy. "What is the goal of whoever is spreading this information? Does it actually make sense? Is it possible the information has been distorted or key parts have been left out?" Misinformation often works in exactly this way, seeking to sow hatred and make people fear and hate each other, relying on half-truths to stimulate an emotional response in people.

Thinking machines

The rise of artificial intelligence (AI) has been heralded by some as the start of the age of 'machines that think like us', but Andy thinks we still have a way to go. "You've probably heard of AI like ChatGPT and DALL-E that produce impressive results, but the thing to remember is they are trained on huge amounts of data – trillions of words or billions of images – far more than any human could ever see in their life," he says. "These models need that much data to make good decisions, but humans don't. This indicates we learn in a very different way to machines."

These machines are basically learning by association, analysing which sort of things typically 'go together' within the datasets they use and replicating these associations. "There isn't any actual knowledge beneath this ability," explains Andy. "Machines don't have basic ideas like causation or sensation or emotion, whereas these are instinctive concepts for people." This is why machines make mistakes that humans never would: made-up facts, logically inconsistent strings of sentences, 'lumpy' faces or extra fingers in AI art, and so on. "AI will continue to get better, but my guess is that it will think differently to people for a long time," says Andy. Though there is a long path ahead, his research into why we make the decisions we do is helping to pave the way for such machines in the future, by applying these cognitive processes in artificial systems.

Experiments and models

Testing the concepts behind cognitive psychology involves carefully planned experiments and the support of models. "We use models as a tool to transform what might be quite a vague concept, like 'people's beliefs are influenced by social media', into something precise and testable," says Andy. "A good theory needs to specify as much as possible: what sorts of information sources we're examining, what we mean by influence, how we consider social groups, how we measure beliefs, and so on."

As an example, Andy's team – led by research fellow Keith Ransom – recently used a mixture of experimentation and modelling to examine the more specific question of whether people are more likely to change their minds if presented with many different people on social media arguing for a viewpoint, as opposed to just one person arguing many times. "While considering this question and deeper theories about how we process information, we made a model that makes very precise predictions about how these beliefs should change in a range of scenarios," says Andy. "Then, we designed an experiment that tests this model using real scenarios." For this experiment, participants were presented with fake social media posts created by the researchers, either from multiple 'accounts' or from one 'account'. By being asked about their beliefs before and after, the researchers found a strong match with what the model predicted: that participants exposed to the same viewpoint from multiple people were more likely to shift their beliefs. Once the model has been tested using various experimental conditions, it can then be used to extrapolate predictions about how people might behave in similar scenarios, without the need to experimentally test that specific scenario.

About *cognitive science*

Cognitive science involves the study of the human mind, how we learn, how we process information, and how we make decisions. Andy explains more about what drew him to the field and how he thinks it will develop in the future.

"There are so many open questions in cognitive science. I began my undergraduate studies thinking I wanted to do physics, which I really enjoyed, but I realised all the basic questions had been solved, and the remaining questions seemed too complicated to make realistic progress. Cognitive science is the 'sweet spot' for me, as we have the tools and knowledge to study it scientifically, but there's still so much we don't know.

"I've found the kind of people who end up in this field are awesome. They're smart, interested in important questions, value people as well as reason, and are a lot of fun. Ultimately, good science has a lot to do with playing and exploring, and I'm able to do that with my research and the people around me.

"There's a lot still to learn in cognitive science. Looking ahead, I hope we'll be more able to get data from the real world rather than just behaviour in the lab, but it's challenging to measure people's real-life environments and behaviour accurately while also respecting their privacy and autonomy. Historically, participants in cognitive science experiments have tended to be fairly well-off and well-educated, usually white and English speaking, and often male and heterosexual, which is obviously a tiny proportion of humanity! I hope the next generation blows this open and we learn a lot more about everyone and how our backgrounds shape how we think.

"There are plenty of ways to learn more about the discipline. Universities will often have public talks from real scientists on the cutting edge of psychology. You can find cognitive science reading lists and recommendations online. Follow your nose on what you find most interesting. For experience in computer programming or data science, there are plenty of free YouTube introductions, and open-source programming software like R can be used for everything from data analysis to making webpages or art. Play and try things, and explore what captures your interest."

Pathway from school to *cognitive science*

While Andy says that psychology is useful, he especially advises taking subjects such as computer science, data science, statistics and linear algebra. Being able to program experiments and analyse results are important skills for modern-day cognitive scientists. He also suggests investigating philosophy, anthropology and linguistics, which all have important lessons about what it means to be human.

Explore careers in *cognitive science*

- PsychTalks is the Melbourne School of Psychological Sciences forum for ideas and discussion. It provides public talks, podcasts and a newsletter. Find out more: **psychologicalsciences.unimelb.edu.au/engage/psychtalks**
- The University of Melbourne runs a number of school outreach programmes, including a computer science summer school, science events for girls and Indigenous students, and work experience opportunities. **study.unimelb.edu.au/connect-with-us/information-for-schools/Australia-and-New-Zealand/school-outreach-programs**
- According to Payscale, graduates of cognitive science degrees in Australia earn an average of AUS$129,000 per year.

Meet *Andy*

I thought I wanted to be a physicist when I started university. Before that, I wanted to be an astronaut, and my career has also involved random things like the Peace Corps. Like many, my path to my current role has been anything but direct!

Rather than specific eureka moments, science is more like slowly building an awesome temple. The best scientists are not lone geniuses but smart, thoughtful people surrounded by other smart, thoughtful people. Just like laying bricks, the scientific process can, at times, feel tedious or repetitive, but when you step back and look at your section of the temple, and how it fits with the sections built by others, you appreciate the importance of collaborative work.

Any advice I received that told me to 'be someone I wasn't' was terrible. I was told that I should be more feminine and conciliatory to get a job, to not come out as transgender as academia was hostile to trans people, to study things I wasn't interested in, and that I shouldn't move to Australia. I realised that if I had to follow any of this advice to succeed, I didn't want that 'success'. And, as it turns out, people appreciate authenticity and bravery.

No obstacle is as insurmountable as it first appears. That's one of the best things about age: now I can look back and see all the times something went wrong but I survived, and I know this time I will survive as well. I also keep an eye on my values. I love my career, but I love my family a lot more. Perspective is important!

It's nice to get awards and papers, but the things I'm most proud of are more intangible. I'm proud that I'm a good teacher and have made a difference to a lot of students. I am very proud that I have made my choices in line with my values and interests rather than external pressures.

I hope to keep doing what I'm doing and take more of a leadership role in the field. I want to help ensure that our academic system embodies important values and nurtures the next generation through that system.

Andy's *top tip*

Almost nobody knows what they're doing when they start their career. Don't worry about following a direct path, pay attention to who you are and what makes you happy, rather than what you 'should' do. Nobody knows you better than you. The very best scientists approach their work as play and enjoy what they do.

SHAPE in Schools: Changing mindsets in support of social sciences, humanities and the arts

Social sciences, humanities and the arts are vital for addressing complex challenges, but do young people truly understand their value? **SHAPE in Schools** aims to increase the visibility of these subjects and demonstrate how SHAPE thinking is not only enriching for students, but also necessary for society.

What is SHAPE?

SHAPE stands for Social sciences, Humanities, and the Arts for People and the Economy/environment. It aims to help us understand the collective power and importance of these subjects, which are integral to solving global issues. Rather than being in conflict with STEM (science, technology, engineering and mathematics), SHAPE complements it. SHAPE and STEM depend on each other, and a prosperous society prioritises both.

The SHAPE in Schools pilot

A pilot programme for SHAPE in Schools was introduced to 11 secondary schools across Wales, Scotland, Northern Ireland and England from November 2020 to June 2022, with almost 1,000 learners aged 12-14 taking part. Evaluations from each year detail both the baseline learner attitudes to SHAPE subjects and the positive impact of engaging learners in workshops, which were designed to increase the visibility of SHAPE and highlight the connectivity between SHAPE subjects and their daily lives.

Organisations involved in SHAPE in Schools

British Academy, London School of Economics (LSE), Cardiff University, UK

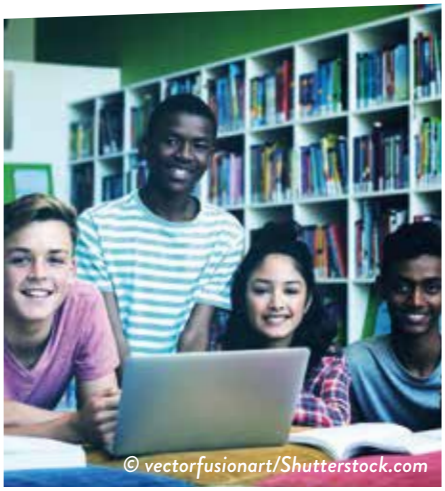
Recent years have seen a strong drive in encouraging school students to take up further education and careers in STEM subjects. This is with good reason: science and research careers are vital to the UK and a global society, helping to develop technologies and our understanding of the world around us. However, an unfortunate side effect of this push has been the growing perception of SHAPE as the 'poor cousin' of STEM, with SHAPE careers sometimes considered as less preferable or even inferior. Such attitudes filter down to school students, who may be led to dismiss prospective careers in SHAPE, even if that is where their skills and interests are best aligned.

SHAPE subjects are, in fact, just as vital to society as STEM. Lessons from SHAPE form the cornerstone of governance, culture and community. While developments in SHAPE might be less tangible than, say, a new medicine or technology, they teach us important lessons in how to make modern life fulfilling, just and resilient. Society depends on creatives just as much as scientists.

SHAPE in Schools is a recent initiative to boost the visibility and interest in SHAPE subjects within schools. A recent pilot study funded by the LSE trialled ways of achieving this, engaging with teachers and learners in 11 schools across the UK through a range of activities. This has involved creating innovative resources, training teachers as SHAPE practitioners, demonstrating the links between the different subjects within SHAPE, and challenging teachers and learners to understand their personal connection with SHAPE. The outcomes of these efforts were then recorded and studied.

Baseline attitudes and understanding

The SHAPE in Schools team surveyed students' perspectives on STEM and SHAPE subjects and gained some interesting insights. First, they found that students' understanding of which subjects fall under STEM and SHAPE was often quite patchy. For instance, almost a third of students thought that English was a STEM subject, suggesting that STEM is mistakenly perceived by students to relate to 'core' subjects in the curriculum. The definition of social sciences was also poorly understood, with a third of learners including biology, chemistry and physics within it. This indicates that an initial challenge is to help learners understand the definitions of these umbrella terms, why they are useful, and how they interlink with one another.



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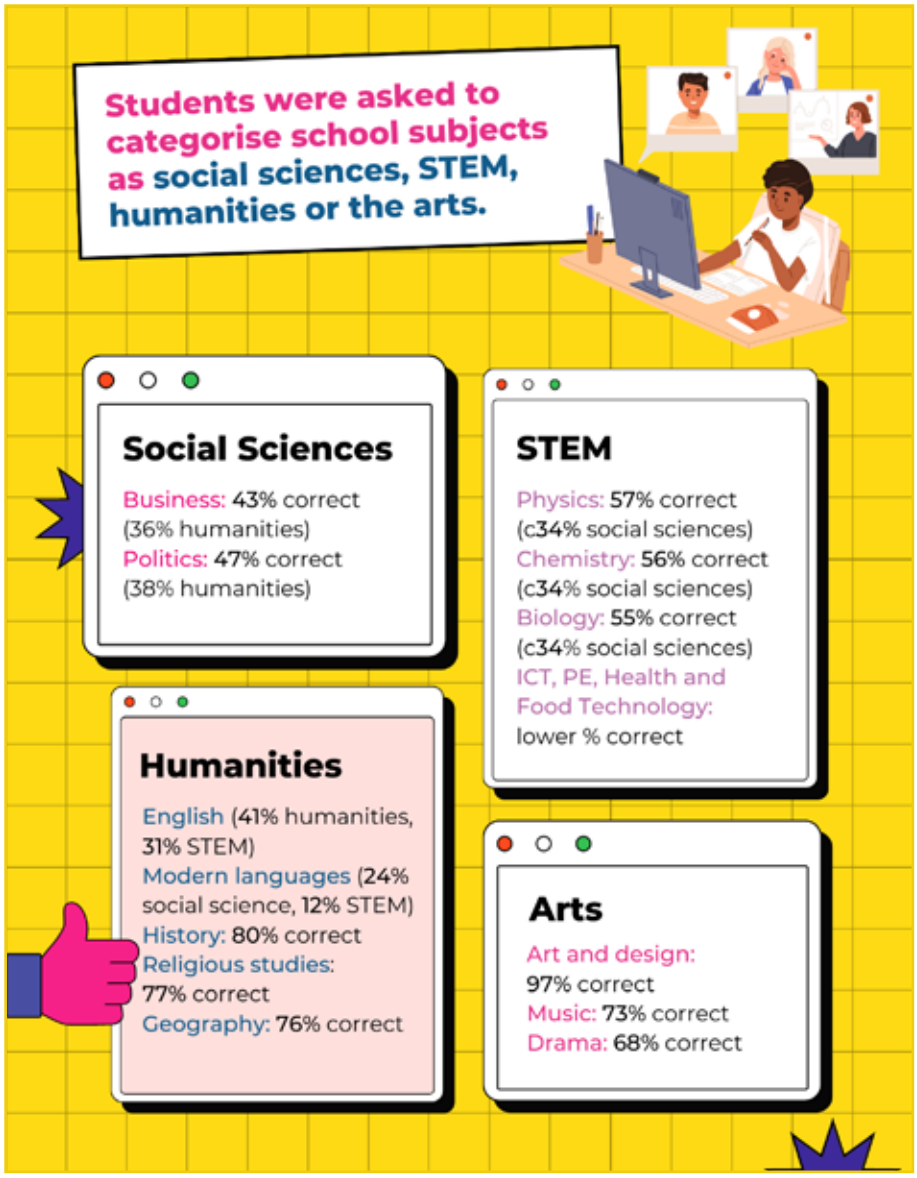


Students' enjoyment of different subjects was also surveyed. On average, learners displayed a preference for STEM subject groupings over SHAPE subjects, but, when it was examined in more detail, it was found that male learners showed a strong preference for STEM subjects, while female learners showed a slight preference for arts subjects. Surprisingly, when learners were asked to rank the 12 individual subjects, the overall favourites (for male and female learners) were art and design, physical education and English. However, students ranked STEM subjects as more important than SHAPE subjects for their future careers – a starker difference than when ranking enjoyment.

Modes, methods and mindsets

The underlying framework for SHAPE in Schools follows the concept of 'modes, methods and mindsets'. This concept captures one way in which SHAPE subjects can be thought about, and inspires the SHAPE in Schools materials for teaching and learning.

Modes are the 'building blocks' of learner resources. These are typically real-world examples that can be used as a starting point for deeper thinking about SHAPE ideas. This might be a direct source of information, such as a film, book or quiz, or it might be an object to provoke deeper thinking. In the pilot project, four objects – masks, trains, sugar and shoes – were the modes for the workshops.

Methods describe the ways of teaching or exploring SHAPE concepts. They come under three levels: methods used to create resources; methods used to encourage learning; and methods that learners practise. It was important for the pilot to emphasise the interdisciplinarity of SHAPE through these methods, by capturing how the objects related to different aspects of society and, more immediately, different parts of the curriculum.

Mindsets describe the influences on patterns of thinking: considering one's own perspectives and lived experiences, as well as the perspectives of others in society. These ways of thinking are important skills in themselves, and their development is encouraged within SHAPE in Schools.

Object-based learning

The pilot project invited teachers to training sessions, where they were introduced to the SHAPE approach and ways to put it into practice within their lessons. A key method for doing this was object-based learning (OBL). More commonly practised in museums and galleries than schools, OBL uses objects to challenge people to think about these objects' role in society, how this role has changed over time, and how this links to wider societal trends and meaning.

Teachers then used the OBL method with students through workshops, which focused on masks, trains, sugar and shoes. The purpose was to explore these everyday objects through the lens of different SHAPE subjects. Learners were also given a 'disorientating experience', the idea of which is to challenge preconceived ideas of these common items. For instance, for shoes, questions included:

- What are the roles of shoes in our culture and identity?
- What might be the environmental impacts of shoes?
- How are people's lives affected if they cannot access shoes and are experiencing shoe poverty?

The aim of these exercises was to create a personal connection between the learner and the SHAPE experience, by stimulating curiosity in the everyday and demonstrating how SHAPE is embedded in the world around us. Because there are no wrong answers to these exercises, students can be more confident in engaging with their learning and presenting their opinions and thoughts in their own terms.

Key findings

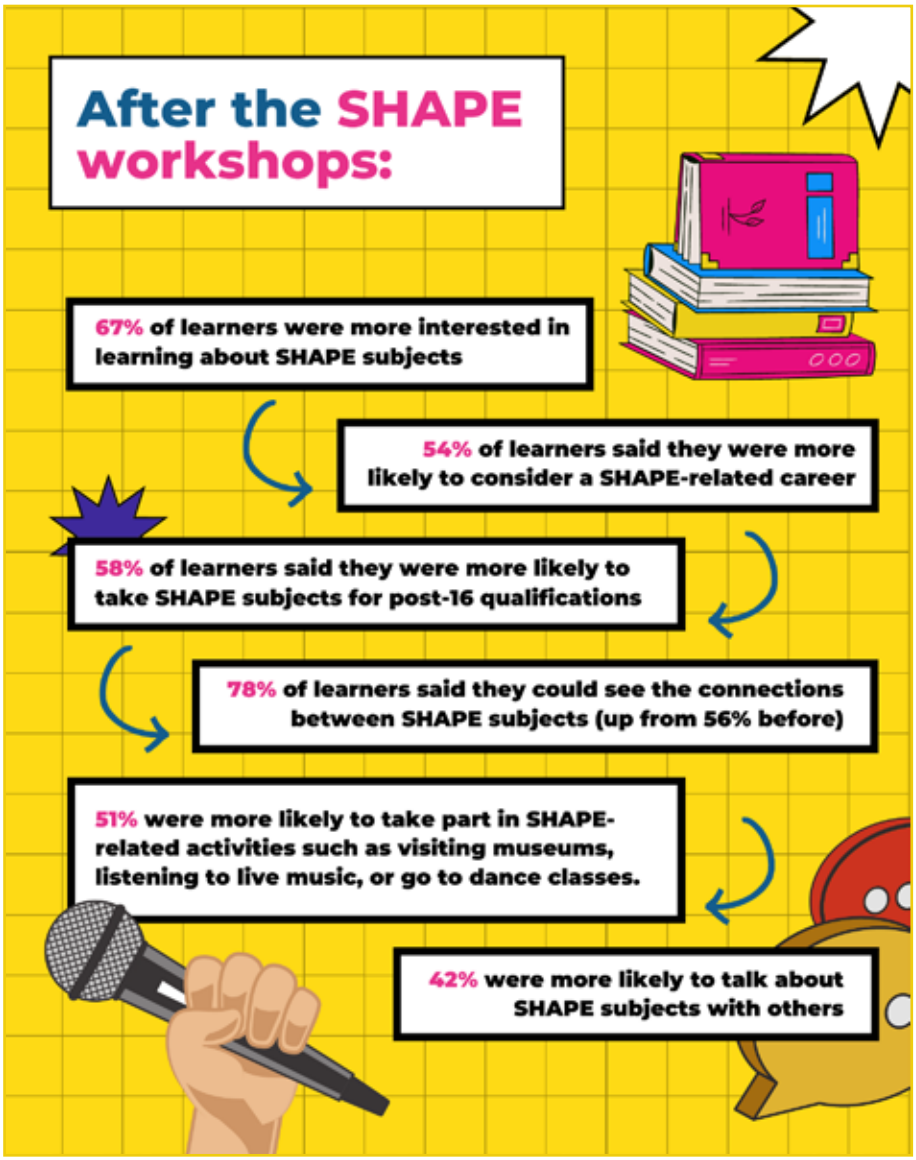
Students' understanding of, and attitudes to, SHAPE subjects were assessed via surveys and interviews before and after the workshops. Once the pilot was complete, the SHAPE in Schools team used this research to evaluate the overall experiences of teachers and learners.

Visibility

SHAPE in Schools aims to make SHAPE subjects more visible in secondary schools, through the creation of resources and training teachers to act as SHAPE ambassadors. Teachers responded very positively about the training experience and resources provided. They demonstrated their understanding of the methods and mindsets at the heart of the SHAPE workshops, especially how the different subject areas interlink and affect one another. Some teachers also went on to train other teachers to support delivery of SHAPE workshops. The style of teaching was noticeably different from typical teaching styles, with teachers saying they enjoyed exploring OBL as an alternative to more traditional approaches.

Relevance

It was important that the workshops helped learners understand the real-world relevance of SHAPE subjects. Many learners said the workshops helped them to see how different SHAPE subjects interlinked and connected to one another. Many also commented that drawing these connections, as well as the OBL method, had been an enjoyable experience, and a number said they were more likely to opt to study SHAPE subjects in later key stages as a result of the workshops.



Personal connection

A key objective of the workshops was to inspire enjoyment and interest in SHAPE subjects. Many learners and teachers reported that the learners had enjoyed the workshops and that their overall enjoyment of SHAPE subjects had increased. Many learners also felt the workshops helped them understand the connections between SHAPE subjects. Highlights included the opportunity to work as a team, being able to use creativity and design skills, and put their imagination to work.

Why SHAPE in Schools is important

With STEM subjects being promoted by both national and regional campaigns, SHAPE subjects (and their teachers) can feel like they have been side-lined. It is vital to address this by building an appreciation of the importance of SHAPE subjects and help nurture the next generation of talented SHAPE professionals. STEM and SHAPE are not adversaries, but allies, and SHAPE in Schools aims to make this apparent.

In terms of how teachers can promote SHAPE subjects within their schools and classes, adopting the mindset of interconnectedness is an excellent way to begin. Collaboration is key to this. Working with colleagues across subjects can help foster these connections, which can then be transferred to lessons: discussing colour theory in science, sonics in drama, technology in human geography – the links are endless. There is then further scope to create a network between schools, where teachers can inspire and educate one another on the SHAPE mindset and how to apply this within their lessons.

Embracing such efforts can bring big benefits for both learners and teachers. Education shapes the way people think and act, so ensuring that learners enter the wider world with a broad perspective is important. Given the positive response to the pilot programme from teachers and learners, the SHAPE in Schools team is now looking to make the resources widely available so that teachers and learners around the nation can access them themselves. The hope is to garner the support of schools' senior leadership teams and SHAPE subject teachers alike to promote a balanced and interconnected curriculum, where no subjects within SHAPE and STEM are considered in isolation, but as parts of the great societal ecosystem.

Meet some of the experts behind SHAPE in Schools

Julia Black

Strategic Director of Innovation and a professor of law at the London School of Economics and Political Science (LSE) in the UK. Julia is also the 31st president of the British Academy and one of the architects of SHAPE.

Claire Gorrara

Dean of Research and Innovation for Arts, Humanities and Social Sciences at Cardiff University, UK.

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Lucy Jenkins and Tallulah Machin were instrumental in the design and delivery of the SHAPE in Schools pilot programme.

Lucy Jenkins

Project Director of the Modern Foreign Languages Mentoring Project within the School of Modern Languages, Cardiff University. Alongside this, Lucy researches language policy, multilingualism, interdisciplinarity and digital technologies.

"I would like to see learners being exposed to learning experiences that spark a conversation about SHAPE subjects. I want learners to be informed, empowered and excited about SHAPE and to understand that it is relevant to them."

Tallulah Machin

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Education consultant and researcher specialising in the design and delivery of education projects and the development of interdisciplinary learning experiences.

"I would like to see senior leadership actively promoting a balanced and interconnected curriculum; teachers feeling valued and supported so they can work together to show learners the interconnections between subjects; learners excited about all subjects because they see how they fit together and how valuable they are for us as individuals and as a society – linking together their school subjects with the world outside of school."

How can community engagement projects empower STEM students?

In cities around the world, air pollution poses a major risk both to the environment and to human health. This has severe consequences for many people, particularly those in underserved and minority communities. At **Xavier University of Louisiana**, USA, **Associate Professor Morewell Gasseller** leads a community-oriented STEM education project that aims to address air pollution in New Orleans while giving students the skills they need for successful careers in STEM.

Associate Professor Morewell Gasseller

Department of Physics and Engineering,
Xavier University of Louisiana, USA

PROFILE

Fields of research
Environmental Physics, STEM Education

Research project
Developing a STEM education programme that gives undergraduate students vital skills and empowers local communities to tackle environmental problems

Funder
US National Science Foundation
(NSF; Award No. 2044192)

TALK LIKE AN ...

ENVIRONMENTAL PHYSICIST

Arduino — a small, simple computer that is simplified to a single board and commonly used for teaching purposes

Desiccant — a substance that absorbs moisture, leaving the surrounding area dry

Environmental injustice — the differences in how groups of people are affected by environmental issues. Underserved or minority groups tend to be at greater risk from many environmental problems, such as air pollution

Particulate matter (PM) — tiny solid particles or liquid droplets in the atmosphere

STEM — science, technology, engineering and mathematics

In 2016, a young entrepreneur from the UK made headlines by selling jars of fresh, countryside air. Customers could choose from the 'naturally filtered and unblemished' air of Somerset, the 'pure and splendid' air of Yorkshire, or the 'vibrant and flavoursome' air of South Wales. The scheme was surprisingly successful and the company, Aethaer, is still active today, selling most of its products to East Asian countries such as China and South Korea.

Although this may sound like a practical joke, Aethaer's success is based on a serious issue. In many Chinese cities, air pollution poses a real threat to human health. In fact, according to the World Health Organization, air pollution in China is responsible for around 2 million deaths every year. It is no surprise, then, that some people are willing to pay up to £80 for a single jar of fresh air.

Unfortunately, there is no evidence to suggest these jars of air have any health benefits. And even if they did, most people cannot afford to spend their hard-earned money on a few breaths of clean air. That is why Aethaer reinvests all its profits into anti-pollution initiatives such as anti-pollution face masks and an air quality monitoring app.

Monitoring air quality is a vital step in the process of reducing air pollution. It is important to identify areas of low air quality so that measures can be put in place to reduce pollution. ECOSTEM is one such air quality monitoring scheme, run by Associate Professor Morewell Gasseller, an environmental physicist at Xavier University of Louisiana, alongside Dr David Brooks and Dr Timothy Glaude. Undergraduate students taking part in ECOSTEM learn how to build and deploy sensors that monitor air pollution. They use the data from these sensors to conduct their own research projects to investigate air quality in New Orleans, and they work closely with high schools to deploy the sensors around their local community.

Through ECOSTEM, Morewell, David and Timothy help students develop important practical skills and help the local community learn about, and protect themselves from, the dangers of air pollution and particulate matter.

What is particulate matter?

Particulate matter refers to any solid particles or liquid droplets in the air. "Some particles, such as dust, dirt or smoke, are large enough to be seen with the naked eye when they become concentrated," says Morewell. Other particles are so tiny that they can only be detected using specialist equipment such as electron microscopes.

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Particulate matter is categorised according to the size of the particles. "PM10 refers to particles smaller than 10 micrometres," explains Morewell, "while PM2.5 refers to particles smaller than 2.5 micrometres." A micrometre is a thousand times smaller than a millimetre, so these particles can be inhaled by a person without them noticing.

"Any type of burning or dust-generating activities produces particulate matter," explains Morewell. "This includes traffic, construction and agriculture." Particulate matter poses serious health risks, especially in cities where these microscopic particles accumulate.

Why is air quality an issue for communities around Xavier University?

Xavier University is located in the heart of New Orleans, Louisiana's most populated city. Many underserved and minority communities in Louisiana are disproportionately affected by environmental issues. This is known as environmental injustice and is a pressing issue in New Orleans. "Of the many environmental injustices facing underserved and minority communities around Xavier, air quality is at the top of the list of significant problems," says Morewell.

The health risks posed by air pollution are numerous. Scientific studies have linked particulate matter to a variety of health problems, primarily affecting the lungs and heart, including asthma, breathing difficulties, irregular heartbeat and premature death for people with heart or lung disease.

What do ECOSTEM students do?

ECOSTEM students build particulate matter sensors based on a prototype Arduino (an open-source hardware and software electronics platform) system designed by David. Through this process, students learn practical skills in electronics, such as soldering circuits, and in computing, such as programming the Arduino system for environmental monitoring.

> **"OF THE MANY ENVIRONMENTAL INJUSTICES FACING UNDERSERVED AND MINORITY COMMUNITIES AROUND XAVIER, AIR QUALITY IS AT THE TOP OF THE LIST OF SIGNIFICANT PROBLEMS."**

They also learn how to identify and evaluate sources of particulates and the importance of environmental monitoring for addressing health issues, and they develop problem-solving skills as they overcome practical challenges. For example, the humid environment of New Orleans caused some of the electronics to fail, so students added desiccants to the sensors to keep them dry. These hard and soft skills set ECOSTEM students up for future careers in STEM.

Once built, ECOSTEM students deploy their particulate matter sensors around New Orleans, including across the Xavier University campus and at local high schools. Timothy coordinates the high school involvement in ECOSTEM, in which high school teachers participate in training workshops to learn how to incorporate the air quality data into their classes. ECOSTEM students visit local schools to teach high school students how to use the particulate matter sensors to monitor the air quality in their neighbourhood. Not only does this increase community awareness of air pollution, but it also enables younger students to get involved in locally relevant, practical science projects. Morewell hopes these experiences will inspire young people to pursue careers in STEM and empower them to address the issues that impact their community.

ECOSTEM students also conduct research projects by analysing the data collected from their air quality monitoring network. This includes investigating the spatial and temporal variations in particulate matter around the Xavier campus and across New Orleans. These data show that air quality can vary dramatically, even between places that are only a few miles apart. "This is the main reason that we advocate for a high density of these sensors to be deployed in the Greater New Orleans area," explains Morewell. The more sensors there are, the more understanding and awareness residents will have about how their neighbourhoods are affected by air pollution. This is particularly important for low-income and environmentally at-risk communities.

The importance of ECOSTEM

Xavier University is committed to supporting a more just and humane society. The ECOSTEM project is an extension of this commitment that uses education and research to serve its local community. "By focusing on community environmental issues, ECOSTEM provides the motivation that is essential to increase undergraduate participation in STEM fields," says Morewell.

Empowering students to pursue careers in STEM will be key to solving many of the world's problems, including air pollution. But community engagement is just as important as scientific research. At the heart of the ECOSTEM project is the aspiration to give young people the skills and opportunities they need to take science into their own hands and protect their own communities.

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About *stem education*

For many students, STEM subjects can be a challenge. Even on a good day, the intricacies of particle physics and inorganic chemistry can be difficult to grasp. But science, technology, engineering and mathematics are key to understanding the world around us and to addressing the problems we face, so it is important to inspire the next generation of socially engaged STEM students.

If you have a passion for a particular STEM subject, the chances are that you had a teacher who inspired you. This is the art of STEM education – transforming complex theories and concepts into experiences that students not only understand, but also enjoy.

Why are practical, community-oriented STEM projects important?

"ECOSTEM gives high school teachers the opportunity to infuse their lessons with data collection from real-world scenarios that affect the communities where their students live," says Timothy. Providing students with learning experiences that are relevant to their lives and their communities makes learning more meaningful. Most people find it easier to retain new information if it is given context, especially if that context is something they can relate to on a personal level. "It is always exciting to see the passion in students when they believe they are working on a project that actually matters," says Morewell.

This is the key aspect of ECOSTEM. It teaches its students about electronics, environmental physics and social health issues in the context of their local communities. Research has shown that involvement in such projects not only increases student engagement but can encourage students to consider STEM-related careers.

Why is STEM education important?

"STEM education is a gateway for creating critical thinkers and it plants the seeds for the next generation of innovators," explains Morewell. Students learn how to solve problems and how to apply their skills and knowledge to new situations. "I want to impart this education to our children for the future of all humankind," he says.

Meet *Morewell*

Growing up in Zimbabwe, my favourite subject was history. At first, I wanted to know about Zimbabwean history but, when I went to secondary school, I started learning about world history, and I loved the subject even more!

I wanted to study physics and chemistry, but I was very bad at maths and I realised maths is key to understanding physics and chemistry. So, a fellow student coached me in maths, and I started doing well in both physics and chemistry. Eventually, I won a prize as the top physics student, which was a big surprise to me and all my friends!

Initially, I studied general science at the University of Zimbabwe, before focusing on physics, then doing a master's in applied physics. I moved to the US to do my PhD in experimental condensed matter physics. I used scanning probe techniques to study nanoscale systems and structures. After several short teaching positions at two universities in the US, I landed my dream teaching job at Xavier University of Louisiana.

I have always believed that research programmes should provide opportunities for undergraduates to make contributions to society. While teaching an Earth science class, I saw the opportunity to link my research with what I was teaching my students. This started my focus on applied environmental physics research. I am motivated by the fact that what I am doing matters to the community I live in and appeals to the students I serve.

Until a few years ago, I was an experimental condensed matter physicist to the core. I wanted to discover things that had not been discovered before. However, I gravitated towards applied physics, such as environmental physics, and I have since found that to be very rewarding. I can research things that benefit the community right now.

> "I AM MOTIVATED BY THE FACT THAT WHAT I AM DOING MATTERS TO THE COMMUNITY I LIVE IN."

I am a member of the GLOBE Program (Global Learning and Observations to Benefit the Environment), an international science and education initiative that provides students worldwide with the opportunity to participate in environmental data collection. I help the GLOBE team design air quality monitoring protocols and I mentor high school students around the world (e.g., Saudi Arabia, Oman, Czech Republic, Argentina and Thailand) as they conduct environmental science research projects.

In my free time I love to play tennis. I also enjoy watching TV shows with my wife, Pauline, and playing chess and mind games with my two boys, Takudzwa and Anashe.

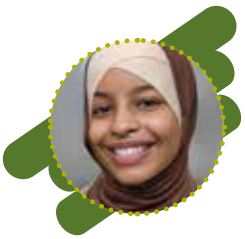
Morewell's *top tips*

1. Be curious about the world around you.

2. Figure out what you're really passionate about.

3. Persevere and don't give up.

Meet some *ECOSTEM students*



Ranaar *Hashi*

I enjoyed the hands-on learning approach in ECOSTEM, which allowed me, a kinaesthetic learner, to explore environmental issues in an engaging way. Learning about environmental issues while working with community members allowed me to develop a deeper appreciation for the world and a feeling that I have positively impacted my community.

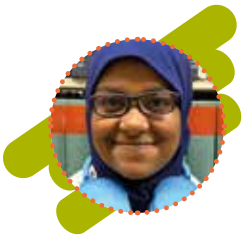
ECOSTEM helped me gain skills that are necessary for many STEM-related fields, such as problem-solving, critical thinking, data analysis and scientific inquiry. I hope to work in a STEM-related field, so ECOSTEM has opened a variety of opportunities for me.

Jade *Ravare*

ECOSTEM gave me a head start on learning skills such as programming, conducting research and working with a research group. As a public health student, my research focuses on respiratory issues, specifically asthma and how PM2.5 affects the New Orleans community.

ECOSTEM has given me amazing opportunities. Public health is such a broad field, so being able to gain experience this early in my educational career is fantastic. I also never thought I would have the opportunity to be a mentor to high school students and to be engaged in the New Orleans community.

I hope to pursue a master's degree in environmental science and policy, where I can make a positive change to the world.



Hiba *Abdelazizz*

During ECOSTEM, I enjoyed building the particulate matter sensors. I especially liked learning how to use Arduinos and gaining practical skills in soldering the circuit components together.

After graduating, I plan to study for a master's degree in mechanical engineering. I then hope to work for NASA or Microsoft.

Ghefua *Yembu*

Participating in ECOSTEM has enriched my awareness of the environment and of the factors affecting it. I really enjoyed presenting the research data at workshops and the festival of scholars.

I aspire to become a data scientist. I hope to make data more relevant for and easily understood by those who need it, by using different analytical tools and methods.

"STEM EDUCATION IS A GATEWAY FOR CREATING CRITICAL THINKERS AND IT PLANTS THE SEEDS FOR THE NEXT GENERATION OF INNOVATORS. I WANT TO IMPART THIS EDUCATION TO OUR CHILDREN FOR THE FUTURE OF ALL HUMANKIND."
Dr Morewell Gasseller

Deducing how Antarctica will respond to climate change

Antarctica holds a huge volume of ice – enough to raise global sea levels by 65 metres if it all melted. This means it is vitally important to understand how the Antarctic Ice Sheet is likely to be affected by rising global temperatures. **Dr Denise Kulhanek,** at the **Christian-Albrechts-University of Kiel** in Germany, **Dr Brian Romans,** at **Virginia Tech** in the US, and **Dr Molly Patterson**, from **Binghamton University** in the US, are collaborating to make these predictions by delving deep into Antarctica's geological past.

Dr Denise Kulhanek

Professor of Marine Micropalaeontology,
Institute of Geosciences,
Christian-Albrechts-University of Kiel, Germany

Affiliated with Texas A&M University and Binghamton University, USA

Field of research
Marine Micropalaeontology

Dr Molly Patterson

Assistant Professor, Department of Geological Sciences and Environmental Studies, Binghamton University, SUNY, USA

Field of research
Geology

Dr Brian Romans

Associate Professor of Sedimentary Geoscience,
Virginia Tech, USA

Field of research
Geology

TALK LIKE A ... GEOSCIENTIST

Albedo — the proportion of light that is reflected by a surface

Computerised tomography (CT) scanner — a device (used in medicine as well as research) that uses X-rays to create images of the insides of something

Geoscience — the study of the Earth's structure and composition, its history and its systems

Ice sheet — a huge mass of ice covering a large area of land or ocean

Micropalaeontology — the study of microscopic fossils

Phytoplankton — plankton that photosynthesise, mostly single-celled plants

Plankton — tiny organisms that drift in the sea or freshwater

Orbital forcing — the effect on the Earth's climate as the planet changes the tilt of its axis and the shape of its orbit around the Sun

Sediment — material that collects on the land or in the sea, often over millennia. In this case, the team studies sediments deposited on the seafloor

Sediment core — a long, vertical sample of sediment

Historians look to the past to help understand our present and future. This is true not just for human history, but also geological history. We are living through a time of rapid climatic change, but it is no easy task to work out what this means for the processes that underpin our planet. Through examining the geological record, scientists can look to previous times in the Earth's history where the climate changed, to help make predictions about the changes we are likely to see in coming decades.

"Even though past climate events are not exactly the same as today's situation, we can still learn a lot by studying how Earth systems responded to change in the past," says Dr Brian Romans from Virginia Tech. "You can

Joint research project
Studying the behaviour of the Antarctic Ice Sheet under past climates, especially through analysis of the microscopic fossils, composition and geochemistry of the sediment from sediment cores

Funder
US National Science Foundation (NSF)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think of our planet's history as a set of countless 'experiments' run by nature that we can compare to present and future conditions."

In the context of climate change, a lot of research focuses on the Pliocene epoch, from 5 to 2.6 million years ago, which was the last time the atmosphere held similar levels of CO_2 to today. "The environmental conditions of the late Pliocene provide a geological analogue to current projected atmospheric CO_2 levels and global mean temperatures," explains Dr Molly Patterson from Binghamton University. These historic conditions were primarily driven by a process called orbital forcing, which is when changes in the tilt of the Earth's axis and its orbit around the Sun have effects on the climate. This process happens very gradually (over tens of thousands of years), in stark contrast to the rapid climatic changes being driven by human actions today, but nonetheless provides a useful comparison point.

The Antarctic Ice Sheet

The research team is looking at the Antarctic Ice Sheet, which, due to its massive size, has a significant influence on the world's current climate. "The Antarctic Ice Sheet controls ocean currents and atmospheric circulation, and we are already seeing changes to these systems as melting occurs," says Dr Denise Kulhanek from Christian-Albrechts-University of Kiel. "It also holds a huge amount of water, so even if a small amount of it melted, it would have drastic impacts on low-lying areas around the world." The ice sheet has covered the continent of Antarctica for 34 million years – since a long time before the Pliocene – and the team is interested in understanding how it has responded to climatic changes since it first formed.

While a relatively straightforward relationship between climate and ice might be imagined, as higher temperatures lead to more melting, the reality is far more complex. "There are many processes that contribute to ice sheet melt," says Denise. "One process we are looking at is how the warming of waters surrounding Antarctica can melt the ice sheet from the bottom up." Other processes include direct melting from the Sun's energy hitting the ice's surface. Given that this energy varies daily and seasonally, the ice can undergo repetitive freezing and thawing, which can crack the ice sheet and lead to dramatic collapses of sections. "Additionally, particles such as soot can land on the ice and reduce its albedo," says Denise. "As the ice becomes darker in colour, it absorbs more energy, causing more melting." On the global scale, water has a much lower albedo than ice, meaning that the more ice that melts, the more energy is absorbed, creating an accelerating effect.

> **"YOU CAN THINK OF OUR PLANET'S HISTORY AS A SET OF COUNTLESS 'EXPERIMENTS' RUN BY NATURE THAT WE CAN COMPARE TO PRESENT AND FUTURE CONDITIONS."**

Filling knowledge gaps

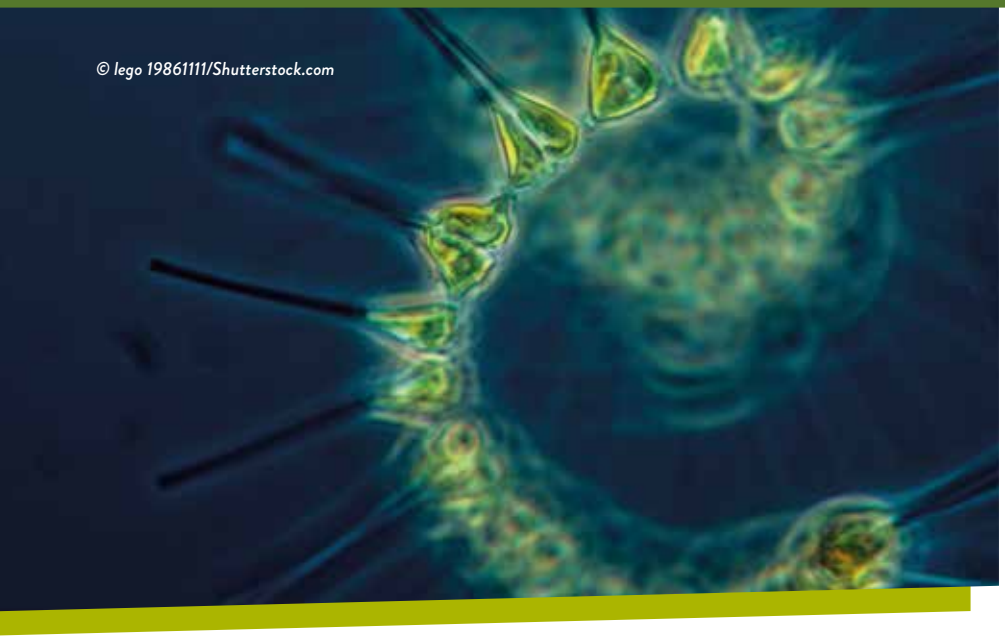
"While we know, generally, that a warming climate leads to ice sheet melting, it's difficult to predict how fast this will happen," says Brian. "Will it take decades, centuries or millennia?" Uncovering this relationship involves some sophisticated modelling. "Because these processes typically take place over very long timescales, we have to rely on models by expressing these processes as mathematical formulas," explains Denise. "To test these models, we compare them with geological records, and then calibrate the models accordingly." Currently, these geological records are far from complete, so filling in these knowledge gaps is an essential task in order to develop more accurate models – which is exactly what the team is working on.

The team is focusing on an area of Antarctica known as the Ross Sea, which is particularly sensitive to climate changes. "We're investigating how this part of the ice sheet responded to the relatively warmer climate of the Pliocene, especially the interactions between the ice sheet and ocean currents," explains Brian. "Changes in ocean currents can bring warmer water into contact with the ice, which can accelerate melting." Molly is working on comparing the team's findings to results from an adjacent area of Antarctica, to understand how different parts of the ice sheet respond to climate change. "I aim to find out the most important natural mechanisms that drove ice sheet instability during the Pliocene, and use these findings to make projections about likely instabilities in coming decades and centuries," she says.

Techniques

A lot of evidence about the Earth's past can be extracted from sediment cores. Over millennia, sediment builds up on the seafloor, capturing bits of evidence, such as different chemical compositions and microscopic fossils, that give an insight into past environments. In particular, the team is interested in using sediment cores to examine the extent of the ice sheet at different times. "When the ice sheet advances, it bulldozes the sediment, leading to unconformities in sediment cores – 'missing time', in other words," says Denise. "We can compare sediment cores collected at different sites to see where these gaps occur, and we then know when the ice sheet was present in a certain area throughout its history."

Prior to the team's efforts, there were very few cores taken from the Ross Sea. "The cores were taken from specific places and at different water depths, to get the most complete records of past ocean-ice sheet interaction," says Brian. "In particular, they give us information on globally important deep-ocean currents, and how these currents affected the ice sheet." PhD student Natalia Varela is studying these cores using an instrument called a laser particle analyser to accurately determine the size of tiny particles within the sediment cores. The current affects the size of deposited particles as well as other characteristics, so measuring these means that the strength of the current over time can be extrapolated.



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> **COLLATING ALL THESE DATA WILL FORM A STRONG FOUNDATION OF EVIDENCE, ALLOWING US TO LEARN MORE ABOUT PAST CLIMATES AND THE FUTURE OF OUR OWN.**

Denise's work focuses on the fossils of marine plankton within sediment cores, which can be examined under a microscope to yield a wide variety of important information. "They can be used to date samples, given that different species have evolved or died out over time," says Denise. "They also give us information about water conditions, since different plankton species prefer different temperatures, nutrient levels or salinities." Denise also uses geochemical techniques, especially X-ray fluorescence scanning, a non-destructive method that uses X-rays to determine the elements present within the sediment.

What comes next?

Each laboratory within the project is collecting different datasets that will ultimately be pulled together into a final product. "We have different equipment available to us," says Denise. "For instance, I had access to a CT scanner to scan the cores, while Molly's lab has equipment to study grain size and X-ray diffraction." Molly also has expertise in statistical analysis, a big asset to the team, while Brian and Natalia have skills in reconstructing ocean current behaviour.

Brian and Natalia have found that deep-ocean currents were more active in the warmer Pliocene, relative to the cooler climate that followed. "This result is interesting as it tells us that this type of ocean circulation was still happening when it was warmer," says Brian. "However, our results also indicate an unusually warm episode when the ocean current shut down abruptly." This implies there may be a 'threshold' temperature, which once exceeded, leads to the current disintegrating – important information for predicting our climate future.

The next step is to combine this finding with the evidence being gathered by Denise and Molly, and their teams. "We are working to combine data from sediment cores on sediment grain sizes, geochemistry and other properties," says Denise. "Once we have this complete dataset, we can divide the sediment into different 'packages' with similar characteristics, helping us pair them up with the broader processes that led to their formation." For instance, sediment properties such as a yellow colour, high silica concentrations, and low concentrations of magnetisable minerals generally correlate with high concentrations of certain phytoplankton species. "A high productivity of phytoplankton in the surface water above a sediment suggests the area was not covered by thick ice, as they need access to sunlight to photosynthesise," explains Denise. "We can interpret this as a potentially warmer interval in geological time." Collating all these data will form a strong foundation of evidence, allowing us to learn more about past climates and the future of our own.

About *marine micropalaeontology*

Micropalaeontology is the study of past organisms' microscopic remains. When we think of fossils, it is dinosaurs and other large animals that spring to mind first, but, in fact, the vast majority of fossils are tiny organisms not visible to the naked eye. Studying these microfossils can tell us a lot about the Earth's past. As well as a window into past biodiversity, they provide clues about past climates and more local environmental qualities.

Our oceans are filled with phytoplankton: microscopic marine algae that use carbon dioxide to produce oxygen, in much the same way as the plants we find on land. "There is an emerging area of research into how changes in atmospheric CO_2 affect phytoplankton," says Denise. "This is important to understand because as phytoplankton absorb carbon themselves, they in turn affect the climate, so changes in their populations could mitigate or accelerate climate change."

Once again, turning to the fossil record can help us understand this relationship. "Phytoplankton produce organic molecules that can be preserved in the fossil record," says Denise. "Some of these can be used to understand past climate, because their composition changes as ocean temperature or atmospheric CO_2 changes." There are growing opportunities to learn more about these molecules and what they can tell us about the past and future.

Denise works closely with many scientists, to share resources and expertise and, ultimately, to produce cohesive research. "Collaboration is one of the best things about science!" she says. "I used to hate group projects at school, but, as a research scientist, I have realised the importance of working together." Because Denise is on a different continent to Brian and Molly, such collaborative efforts are not necessarily straightforward. "We use online tools like video calls and live documents, which we all became experts at using during the pandemic," she says. "We also have to take time differences into account, not to mention the changing circumstances and commitments of team members. The main thing is to stay in touch and be supportive."

Meet *Denise*

When I started university, I wanted to be an archaeologist. I always really liked history and learning about past cultures, as well as the Indiana Jones movies! During my first semester, I took a physical geology class and loved it. I followed with a class in historical geology, which taught both the physical evolution of the Earth's continents, as well as the evolution of different organisms. The professor was an amazing educator, and the subject matter was fascinating. I was hooked and changed my major to geology.

Even after finishing my undergraduate degree, I didn't really know what I wanted to do. I took a master's degree examining how tiny plankton evolved following the mass extinction event that killed the non-avian dinosaurs, which was fascinating. I then got an internship and, later, a job in the oil industry, which uses micropalaeontology to determine the age of rocks in oil wells. While the work was enjoyable, I didn't like the industry, and I missed research and teaching, so I quit and took on a PhD, including participating on two research cruises, the second to Antarctica. I really enjoyed sailing and carried on working with these expeditions as a staff scientist for eight years. I then secured a professor position in Germany, which is where I am now.

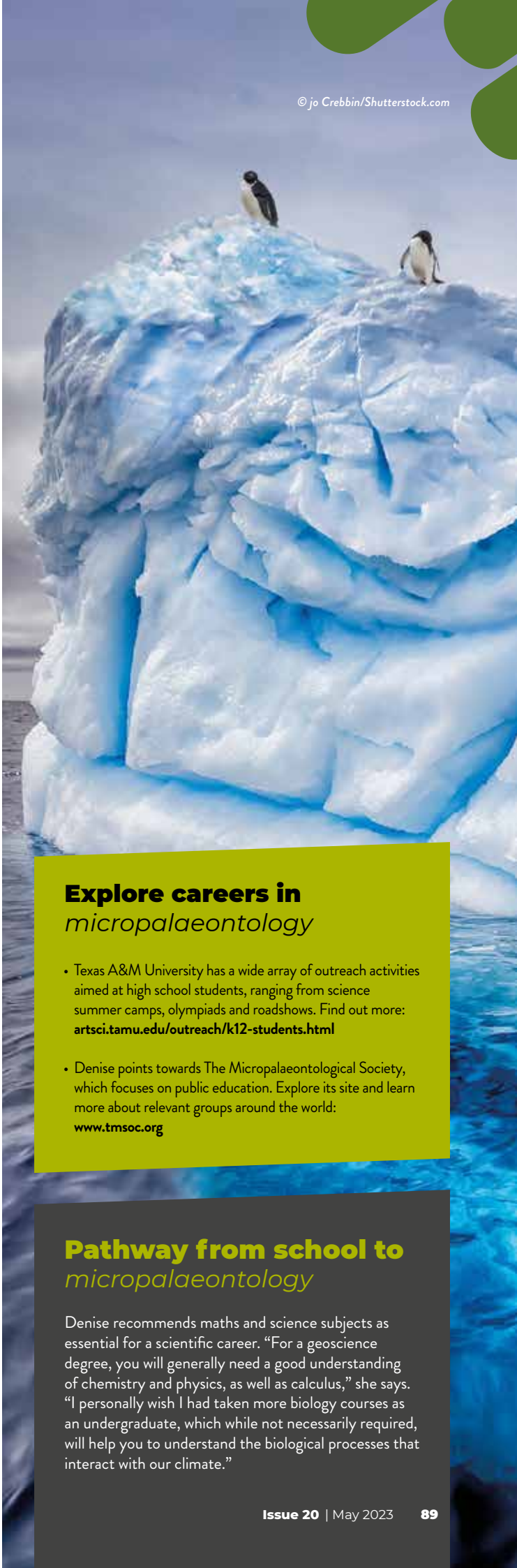
Curiosity about the natural world and how it works is crucial for scientific success. I am also detail-oriented and organised (at least in my professional life!), which helps with conducting and writing up experiments. I am quite a perfectionist, which can actually be an issue sometimes. Often, it's best to just get on with a task rather than worrying if it will be perfect.

There are many things that I love about being at sea for research. Whenever we bring up a new core, we are the first people to ever see it, and we often get surprises and learn interesting things about past climates. I also enjoy the peace and simplicity of these expeditions, free from commutes, chores and the regular annoyances of adult life. While we work a lot, it's free from distractions. Watching marine life and the sea itself is also wonderful.

Being offered my professorship was a proud moment for me. I'm very excited to now train the next generation of marine micropalaeontologists, as well as focus on research.

Denise's *top tip*

If you love science, don't give up on pursuing it as a career, even if you don't feel your grades are good enough. I know many brilliant scientists who were not the best students in their younger days. Even if you don't immediately go to university, there are alternative paths you can take to ultimately pursue a graduate degree.



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Explore careers in *micropalaeontology*

- Texas A&M University has a wide array of outreach activities aimed at high school students, ranging from science summer camps, olympiads and roadshows. Find out more: **artsci.tamu.edu/outreach/k12-students.html**
- Denise points towards The Micropalaeontological Society, which focuses on public education. Explore its site and learn more about relevant groups around the world: **www.tmsoc.org**

Pathway from school to *micropalaeontology*

Denise recommends maths and science subjects as essential for a scientific career. "For a geoscience degree, you will generally need a good understanding of chemistry and physics, as well as calculus," she says. "I personally wish I had taken more biology courses as an undergraduate, which while not necessarily required, will help you to understand the biological processes that interact with our climate."

About *geology*

Geology is the study of the Earth's structure, evolution and dynamics, as well as the resources it holds. This makes it a very broad field, stretching from minerals to climate, from volcanoes to oceans.

Brian sees a full and exciting future for geology. "There's a lot to do," he says. "I think the next generation of geoscientists will be able to learn even more about our planet, through creating new ways to combine and analyse the huge amounts of data that already exist."

Brian and Molly both believe that embracing data science skills will unlock answers to big questions. "Being able to manipulate and analyse large datasets is going to be increasingly important," says Molly. "Learning statistical techniques and programming languages are becoming as fundamental as traditional topics such as mineralogy and structural geology."

Like any area of science, collaboration is of vital importance in geology, especially when tackling pressing issues like climate change. "Just like a detective needs to build their case with multiple pieces of evidence, climate scientists need to generate a range of datasets representing different Earth processes to reveal the whole story," says Brian. "Different specialties are needed for this – no single person knows everything! While team projects bring challenges, such as communication barriers, the rewards are worth it."

To get into marine geoscience, Brian has a couple of book recommendations: *Soundings: The Story of the Remarkable Woman Who Mapped the Ocean Floor* by Hali Felt, and *Vanished Ocean: How Tethys Reshaped the World* by Dorrik Stow. "I recommend soaking up as much information on your own as you can," he says. "These books are good starting points, and there are many more out there depending on your specific interests."

"I THINK THE NEXT GENERATION OF GEOSCIENTISTS WILL BE ABLE TO LEARN EVEN MORE ABOUT OUR PLANET, THROUGH CREATING NEW WAYS TO COMBINE AND ANALYSE THE HUGE AMOUNTS OF DATA THAT ALREADY EXIST."

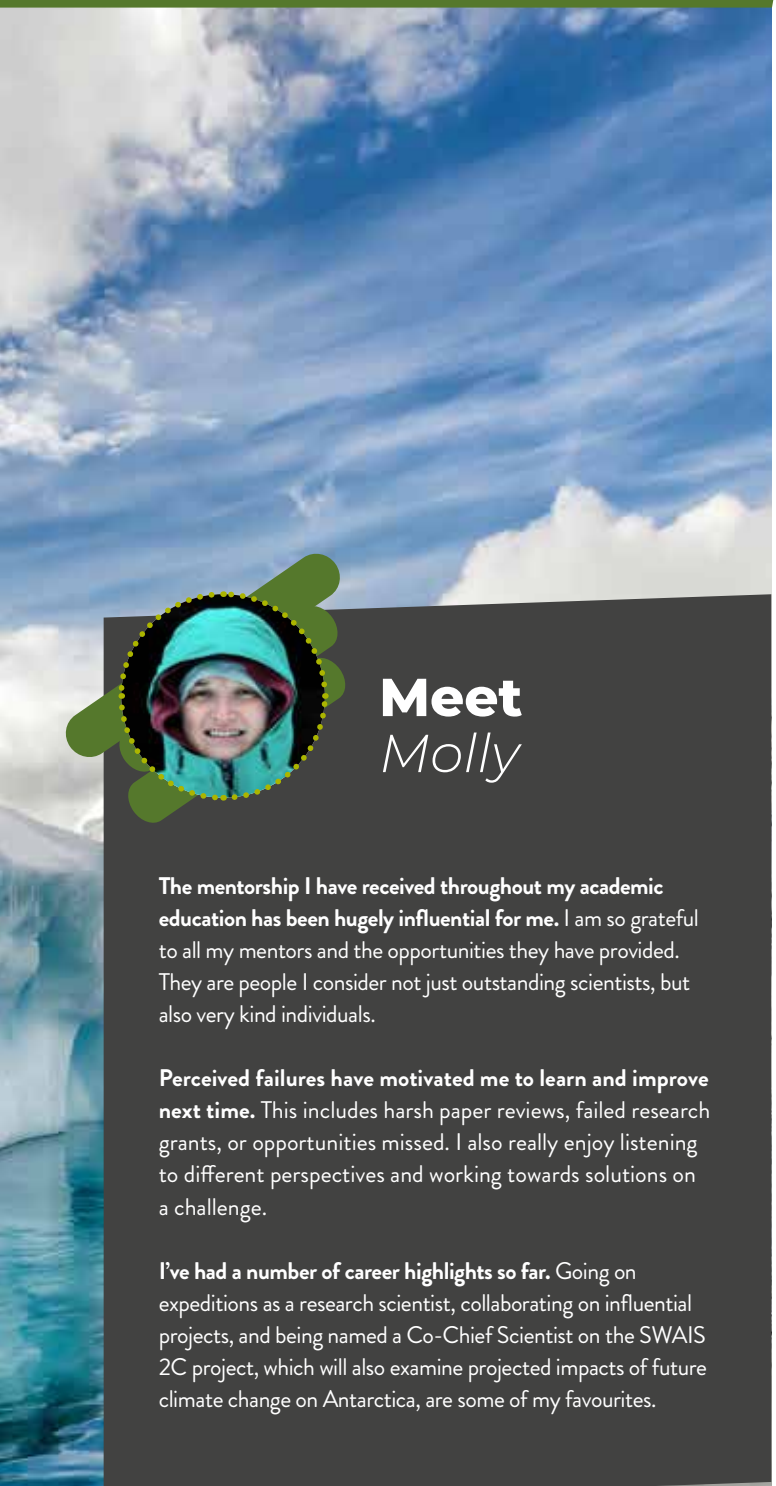
DR BRIAN ROMANS

Pathway from school to *geology*

Brian says that the fundamental sciences of physics, chemistry and biology are important, as geology involves the combination of all three and understanding how processes between them interact. He and Molly agree that mathematical skills, especially statistics and coding, are also very helpful.

Explore careers in *geology*

- The Time Scavengers site provides a wealth of resources about the connections between fossils and climate, pioneering research in the field, and links to educational opportunities: **timescavengers.blog**
- Virginia Tech's Department of Geosciences has its own museum, which hosts an array of outreach and education events, as well as a fascinating geological collection: **geos.vt.edu/museum-of-geosciences.html**
- According to the US Bureau of Labor Statistics, the average salary for geoscientists is around $85,000.



Meet *Molly*

The mentorship I have received throughout my academic education has been hugely influential for me. I am so grateful to all my mentors and the opportunities they have provided. They are people I consider not just outstanding scientists, but also very kind individuals.

Perceived failures have motivated me to learn and improve next time. This includes harsh paper reviews, failed research grants, or opportunities missed. I also really enjoy listening to different perspectives and working towards solutions on a challenge.

I've had a number of career highlights so far. Going on expeditions as a research scientist, collaborating on influential projects, and being named a Co-Chief Scientist on the SWAIS 2C project, which will also examine projected impacts of future climate change on Antarctica, are some of my favourites.

With colleagues Jeanine Ash, Jan Sverre Laberg and Laura De Santis, Molly Patterson (right) examines one of the Ross Sea cores during IODP Expedition 374 (Photo by William Crawford, IODP JRSO)

Meet *Brian*

I received an undergraduate degree in geology and did okay, but I didn't really know where to go next. I ended up working in the oil industry and quickly realised that I would need a graduate degree to work on more interesting things. My master's degree and PhD both involved a lot of fieldwork, and I fell in love with sedimentary geology as a field of study.

Going to sea is a different type of fieldwork but is still about discovery. I'll be going on my third expedition (to Greenland) soon. I love the idea that the deceptively simple observations and measurements that we make can tell us so much about our planet's history.

Curiosity is a key attribute for any scientist. In my opinion, you need to be genuinely curious and interested in scientific problems to make progress. I've seen plenty of smart people who simply weren't interested in their work, which made it challenging for them to advance. Follow what you're curious about and acknowledge that this may change over time.

There is bad advice out there. One piece I hear sometimes is that you should seek to work with the most successful and accomplished people, even if they are unkind and the work is unenjoyable. I'm so glad I didn't follow this advice. Instead, I've decided to work with people who are honest and kind. Life is too short to work with jerks, no matter how successful and famous they are!

My proudest moments come from watching my students succeed. Seeing graduate students who I have mentored and advised complete successful projects, and move on to do what they love, makes me very happy.

> ***"FOLLOW WHAT YOU'RE CURIOUS ABOUT AND ACKNOWLEDGE THAT THIS MAY CHANGE OVER TIME."***

Brian's *top tip*

Be curious about how the world works. Kids have a natural curiosity and a scientific way of thinking, but this can sometimes be lost with the perception that science is just about memorising facts. If you stick with it, you will find that the feeling of discovery and experimentation will return.

Concrete change: the innovative chemistry of sustainable cement

The global cement industry is gigantic, so finding ways to reduce its impact on the climate is essential for a sustainable future. At the **University of Sheffield** in the UK, **Dr Theodore Hanein** and his team are investigating alternative methods for cement production. This includes replacing raw materials with waste products from other industries and reducing the carbon dioxide released during cement manufacture.

Dr Theodore Hanein

Department of Materials Science and Engineering, University of Sheffield, UK

PROFILE

Fields of research
Cement Materials Science, Chemical Process Engineering, Thermodynamics

Research project
Investigating the chemical processes and qualities involved in alternative cement manufacture, and how this could bring benefits to the UK's environmental targets and economic goals

Funder
UK Research and Innovation
(UKRI EPSRC grant reference EP/W018810/1)

TALK LIKE A ...

MATERIALS SCIENTIST AND PROCESS ENGINEER

By-product — unnecessary product produced during a process

Carbon capture and storage (CCS) — the capture and storage of CO_2 emissions to prevent the gas entering the atmosphere

Cement — a powdery substance made from lime and clay, that can be used to make concrete and mortar

Circular economy — an economic system based on the reuse and reutilisation of materials and products

Clinker — the hard product made from processing raw materials, such as limestone and clay, at high temperatures (around 1500 °C). Making clinker is the first step in the conventional cement-making process

Concrete — a building material made of cement, water and aggregates (for example, sand and gravel) that hardens into a stone-like mass

Decarbonise — reduce or eliminate CO_2 emissions from a process

Lime — a powder created by heating limestone, and an intermediary substance in the creation of cement

Limestone — a naturally occurring rock, mostly composed of calcium carbonate, used as a core raw material for the manufacture of cement

Mortar — a material made of cement, sand and water used in construction to bind bricks or stones together

"Cement is the most manufactured commodity in the world," says Dr Theodore (Theo) Hanein, from the University of Sheffield. "Current demand is at 4 billion tonnes every year, which is more than one kilogram of cement every day for every person on the planet!" Cement is vital for society as it is a core material of concrete and mortar, which are essential components in the buildings and infrastructure that surround us. We cannot live without it.

However, all this production has a serious impact on the planet. "Cement production requires vast amounts of natural resources, and is responsible for 8% of our carbon dioxide (CO_2) emissions, which are changing the climate," explains Theo. In line with global climate commitments, governments are investing in ways to reduce CO_2 emissions, and the cement industry is a prime area of interest. "The UK cement industry is set to cut 4.2 megatons (Mt) of CO_2 emissions per year by 2050 — and about half of these savings could be through resource efficiency," he says.

The chemistry of cement

It is the use of resources, especially raw materials, that forms the current focus of Theo's research. "Unlike other manufacturing processes that emit CO_2 through their use of energy, emissions from cement production are mainly from the conversion of the raw material into clinker, a key process in cement manufacture," he says. While some energy-intensive industries can decarbonise through switching to renewable energy inputs, it is not so simple for cement. By far, the most common type of cement produced today – and for the past 200 years – is Portland cement, which relies on the following reaction to begin production:

$CaCO_3$ →	CaO +	CO_2
Calcium carbonate (limestone)	Calcium oxide (lime)	Carbon dioxide

"Not only does this emit CO_2, but almost half of the limestone's solid mass is lost in the process," says Theo. "The UK cement industry uses about 12.5 Mt of limestone every year, so we're interested to see if this natural raw material can be substituted with by-products from other sectors." This could be by-products from steel manufacturing or mineral mining, or even the reprocessing of old cement from construction or demolition sites. Developing this process would have the double benefit of cutting down the emissions from cement production, as well as using the waste produced by other sectors.

The contamination challenge

The main issue with such reprocessing efforts is that any alternative materials will contain other elements that could change the underlying chemistry of the cement manufacturing process and the end product. "The effects of these contaminants across the service life of the new cement needs to be studied and understood completely to ensure that the cement can be used safely," explains Theo. Cement that has previously been used in construction, for instance, has generally been mixed with other materials, such as sand and gravel, to give it the properties needed, but that can interfere with the repurposing process which needs to be done for the cement to be reused.

A particular project of Theo's, called FeRICH, is investigating this challenge when utilising by-products from steel manufacture. "While these by-products contain the key elements that are essential to cement production, they also have an unusually high amount of iron," says Theo.

"FeRICH aims to replace natural raw materials used in traditional Portland cement by upcycling iron-rich by-products, but our understanding of the reactions that take place when we do this is still incomplete." The introduction of iron leads to the production of calcium (alumino)ferrites (compounds made from iron and one or more metallic element), such as $Ca_2(Al,Fe)_2O_5$. Theo is interested in learning what this means for the qualities of the end product, especially its durability and how it reacts with water.

"The FeRICH project will establish the best cement-making conditions to achieve maximum efficiency in both production and performance," says Theo. "Calcium (alumino)ferrites containing contaminants (also known as dopants) could, potentially, also give the cement electromagnetic properties, and we'll be examining how this could bring benefits or disadvantages to the end product." By establishing these traits of ferrite-rich cement, the project can help reduce the environmental impact of both the cement and steel industries in the UK. This would also increase their economic competitiveness in the global market, bringing a boost to the UK and, as other nations follow suit, the rest of the world's cement and steel industries.

CO_2 and the circular economy

While these processes can help increase the efficiency of cement production, the production of CO_2 as a by-product remains inevitable. To address this, a lot of investment is taking place into carbon capture and storage (CCS) technologies, and Theo has developed CCS technology to separate CO_2 from limestone without it being released as a gas. "CCS may be able to capture CO_2 from the exhausts of cement kilns, but we need to find a safe way to then store it," he says. There are various projects around the world that are finding ways to pipe compressed CO_2 underground or underwater – for example, into empty oil or gas fields (areas where these natural resources have been found and extracted for use as a fuel). However, Theo thinks that using chemical reactions to change the CO_2 into something else is likely a better solution. "Currently, the safest and most developed method of CCS is probably via mineralisation," he explains. This involves the reaction of CO_2 with other materials to produce solid minerals. "It would be most beneficial if the generated minerals could be reused in the construction or mining industries, to avoid the storage of large amounts of material."

A running theme across a lot of Theo's research involves connecting different sectors and finding ways where the waste products of one can be a valuable resource for another. This feeds into a broader emerging concept known as the circular economy. Currently, much of our economy is based on linear processes: we extract a raw material, process it and use it, and then discard the waste products. This is a serious problem for several reasons. For one, the world's resources are finite, and for another, waste takes up space and releases contaminants into our environment and atmosphere. Finding ways to break this trend, through repurposing one industry's waste as the raw materials of another, simultaneously solves the issues of extraction of the materials and the disposal of waste. It is a key concept for a truly sustainable future. "The UK is working towards having a circular economy, but we're certainly not there yet," says Theo. "We need to redesign our processes for sustainability and to accelerate industry take-up." Theo is taking a key role in this, using his innovative research to further understand and scale up the uptake of novel cements across the UK.

About *materials science and process engineering*

We have used the Earth's resources to build the infrastructures that underpin our society, but the way we use these materials needs a major overhaul to ensure a sustainable future. Investigating the chemical and thermodynamic processes behind manufacturing – and, in particular, how to make these processes more efficient and circular – forms the core of Theo's research. He explains more about his field and its importance.

"To make any device, structure or product, you need the right materials. Materials science involves learning about what things are made of, and what properties make them behave as they do. It also involves applying this knowledge to improve these processes and properties.

"Materials science and process engineering requires the integration of various fields. We incorporate knowledge from chemistry, physics, mathematics and biology with chemical engineering to help address society's most pressing challenges.

"I find my research highly rewarding because it feels important. I am contributing to developing sustainable materials and processes, helping to solve the most pressing challenge of our time: climate change.

"Most of our processes were not designed with sustainability or the circular economy in mind. We need to redesign and develop new processes for an environmentally friendly world. Sticking-plaster methods such as CCS are useful for the short term, but, in the long term, we need to re-engineer our processes and society as a whole for true circularity."

Pathway from school to *materials science and process engineering*

- At school and post-16, subjects such as physics, chemistry and mathematics are favourable to go on to a relevant degree.
- Theo recommends university courses or modules in materials science and engineering, chemical engineering, product design engineering, computer science, environmental engineering, chemistry and physics.

Explore careers in *materials science and process engineering*

- The University of Sheffield's Department of Materials Science and Engineering hosts a variety of open days, summer schools and other STEM activities aimed at secondary school students. Find out more: **www.sheffield.ac.uk/materials/department/schools-outreach**
- The Institute of Materials, Minerals and Mining (IOM3) has a variety of outreach materials for students of all ages and their teachers, including inter-university-run learning opportunities and a virtual science laboratory: **www.iom3.org/careers-learning/schools-outreach.html**
- According to Check-a-Salary, the average salary for a materials scientist in the UK is around £35,000 per year.

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Meet *Theo*

My undergraduate degrees were in chemistry and chemical engineering. I then spent a summer interning in a cement manufacturing plant, before taking on a master's degree in advanced process integration and design. It was my master's project that really inspired me to follow the career path that I have.

Failure and mistakes are essential for development, especially for scientists. They're an inevitability, but every setback presents an invaluable learning opportunity. Obstacles will come, but never give up.

> ***MY PROUDEST CAREER ACHIEVEMENT WAS WHEN I WAS AWARDED THE UKRI FUTURE LEADERS FELLOWSHIP.***

The worst advice I have been given is to not be myself. Since then, colleagues, friends and family convinced me to follow my own ambitions, and this has been essential to my career.

My proudest career achievement was when I was awarded the UKRI Future Leaders Fellowship. On the theme of "Green, Circular, and Smart Cement Manufacture", I'll help lead research in low-carbon cement production. I also aim to use this research to influence UK policy and write standards for new innovative cements. Furthermore, I can use this platform to help mould other future leaders in my field.

Theo's *top tips*

1. Surround yourself with people who motivate you.
2. Be true to yourself.

Controlling machines from afar

Industrial machines are at the heart of today's economy and society, but training people to use them is a challenge. It is not possible for many students to be physically present to operate such machines, including learners in rural areas or those without access to transportation. Based at the **Community College of Allegheny County (CCAC)** in the US, **Dr Justin Starr's** PRAISE-ET programme is changing this by providing remote access to industrial and scientific equipment, making mechatronics more accessible than ever.

Dr Justin Starr

Endowed Professor of Advanced Technology, Community College of Allegheny County, Pittsburgh, Pennsylvania, USA

PROFILE

Field of research
Mechatronics

Research project
Providing Remote Access to Industrial and Scientific Equipment for Engineering Technologies (PRAISE-ET)

Funders
US National Science Foundation (NSF), Division of Undergraduate Education (award number: 2055714)

TALK LIKE A ...

MECHATRONICS ENGINEER

Hydraulic system — a system that uses pressurised fluids to drive its movements

Logic controllers — a computer adapted for the control of manufacturing processes

Mechatronics — a field that combines the studies of electronics and mechanical engineering

Simulation — a model that mimics the behaviour of something real

The rise of machines has brought countless benefits to society as we are able to make and process things that would never be possible by human hands alone. However, as machines become increasingly sophisticated, the skills needed to operate them become increasingly specialised. A shortage of such skills is a real concern, especially for emerging industries such as renewable energy technologies and autonomous vehicles. A lack of technicians with the right experience could significantly inhibit their progress and development.

Development of these skills requires real, hands-on experience. "When receiving training in fields like manufacturing, learning how to properly use equipment is essential," says Dr Justin Starr, Endowed Professor of Advanced Technology at the Community College of Allegheny County (CCAC). "It's not possible to work with advanced robotic systems, programmable logic controllers, or hydraulic systems without first-hand experience operating and controlling these devices."

Place-based learning

Due to the nature of industrial and scientific equipment, the challenge with this training is that it has to be 'real'. Learning the theory from a textbook is not enough. "Historically, this training has been limited to people who can attend in-person training sessions," says Justin. "But this isn't easy or even possible for many. For instance, people from rural communities, working parents and differently abled individuals."

To solve this issue, Justin is working on systems to enable students to operate real-life machinery from anywhere with an internet connection. The project, Providing Remote Access to Industrial and Scientific Equipment for Engineering Technologies (PRAISE-ET), is using a wealth of clever technologies to make the process as close to an in-person experience as possible.

PRAISE-ET

"Making labs compatible with a remote access format involves making extensive modifications to incorporate the unique features of a remote control scheme," says Justin. This might involve linking up buttons to be electronically – rather than physically – activated, installing robotic arms to operate levers or hydraulic systems, and installing cameras and other equipment necessary for the sensory experience.

"We are one of the only projects that tackles this challenge," says Justin. "We use a variety of equipment such as collaborative robots, 3D printers and custom control interfaces." Such systems have allowed students in remote locations to learn how to operate sophisticated machines and enabled students to operate different machines in other places.

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"In a remote robotics class, students in Pennsylvania were able to control a robot located in Missouri and gain experience with different equipment to the one used in the college," says Justin. "Elsewhere, in introductory 3D printing classes, lessons normally available to a few dozen in-person students were instead accessed by hundreds of online students, who could all earn industry certification."

Simulation limitations

Would it not be easier to build a computer programme with all the same controls as the machine, so students can 'pretend' to use it without needing to actually operate any machinery? "For many years, simulation has been touted as an effective training tool, but it doesn't come close to a real experience," says Justin. "For instance, while a simulated programme may be able to replicate the buttons on a keypad, it doesn't involve the tactile feel of different controls, or the sounds associated with things going smoothly – or not."

There are also challenges in anticipating the range and randomness of potential failures when programming a simulation. "Fault simulators often replicate failures in ways that are too predictable and struggle to truly simulate intermittent errors," says Justin. "Students will learn to identify the patterns of the simulation and are ill-equipped to recognise truly random faults caused by physical issues in the real world."

Sensory aspects

Remote access technologies do not rely on simulations; they involve students actually operating the physical machine, albeit from a distance. "A truly effective remote access tool will enable a student to control a piece of equipment as effectively as if they were there in person," says Justin. However, the experiences of being physically there, as opposed to working from afar, will inevitably be different, which is why Justin is working on clever technologies to make the two experiences as alike as possible.

Transmitting the 'feel' of the machine's operation is crucial and is something that simulations cannot do. "These remote access systems should provide multiple sensor data streams to learners," says Justin. "This includes visual data from cameras, audio feeds, haptic (touch-based) feedback and other sources of information." Combining all these inputs helps learners get a deeper understanding of a piece of equipment: how it responds to different inputs, what different sounds, vibrations and moving parts mean, and how to identify if something is going wrong.

CCAC worked closely with a partner company to develop a custom hardware interface to provide this critical functionality. That company, RealBotics, has pledged to make hardware developed under this grant available to other colleges and universities at an extremely low cost. RealBotics founder and CEO, Christopher Quick, commented that "developing this hardware fills a critical role that dates back to the time when I was a student. Working with CCAC will help us make this technology available to users around the world."

Safety

Despite their drawbacks, simulations do have one advantage: safety. If a simulation is incorrectly operated, nothing bad actually happens. When real machines are involved, something going wrong can have real-world impacts. People in the same location as the equipment could be injured, or the machine might need pricey parts replacing. "Enabling students to control expensive, heavy, rugged pieces of equipment via the internet is inherently challenging," says Justin. "Establishing safety protocols to protect people and equipment is vital."

The introduction of an internet connection also raises its own unique issues. "Systems must be hardened to protect from hackers, as well as other faults," says Justin. "For instance, lag or poor-quality data transfer might make it harder to respond correctly in real-time." Solving these issues requires an alliance of many different specialities, from mechatronics to cybersecurity, but the benefits of such a system are clearly demonstrable.

Linking up

Justin is also passionate about making such technologies available for everyone. "All of the lessons, support materials and code we've developed are available to institutions at no cost," he says. "We're hoping that our hard work to make remote access technology more available will be used by institutions around the world." Unique collaborations have already sprung up between CCAC and other universities, which has opened up opportunities for students to explore transfer options when they finish their studies at CCAC. "We believe these guided pathways and informal learning experiences are critical to encouraging students to continue their education, even if they're enrolled in career-oriented programmes," says Justin.

Equipping students with skills for careers in industry is always at the forefront of Justin's mind. Unsurprisingly, the COVID-19 pandemic accelerated a lot of the technologies necessary for such systems. "The pandemic led to many manufacturing facilities transitioning to distributed teams for maintenance," says Justin. "While one person might be physically there, their teammates can support by dialling in remotely." The rise of remote access communication, and operation of tools themselves, has paved the way for accessible training methods.

This development has been integrated into the PRAISE-ET programme. "We work closely with the Advanced Manufacturing Business and Industry Leadership Team (BILT) to ensure that our developed technologies align closely with regional needs," says Justin. The BILT has helped recommend further modifications, such as ways for students to remotely collaborate on machine operation, and the integration of augmented and virtual reality. "Companies are also invested, such as by donating equipment to allow for the design of custom remote-access equipment," says Justin. The programme aims to expand to a number of partner institutions, to create the next generation of skilled technicians and engineers who are fully equipped for a rewarding career in industry.

About *mechatronics*

Mechatronics is an interdisciplinary branch of engineering that combines mechanical and electronic engineering systems. Its broad aim is to integrate different types of engineering to study and develop fields such as robotics, computer science and manufacturing. It has strong practical applications and is driving the progress of technological developments and rollouts. Justin explains more about his field and why it will be ever-more critical in the future.

"Mechatronics is at the core of advanced manufacturing. It's awesome to work in a field that's being used every day by companies critical to the national economy. The skills that our students learn can be deployed immediately. This is in contrast to many other fields, where there's a lag between advancement and application. Innovations in materials science, for example, may not be used in products for many years. The lag for mechatronics is almost nothing, which means there's never a dull moment.

"While many of us think of artificial intelligence (AI) as a tool for the future, it's rapidly becoming part of our lives. We're already seeing the deployment of advanced AI tools like ChatGPT and Stable Diffusion. Today's technicians will be working with AI in the next three to five years, so knowing how it works and how to use it will be a huge benefit for careers.

"Documenting your work is important, even if you only consider it your hobby. Make a digital portfolio to showcase your work, interests and passions to future employers. Even projects you do for fun show a lot about how you acquire knowledge and solve problems – they are just as important, if not more so, than your school assignments."

Explore careers in *mechatronics*

- The CCAC welcomes visitors for lab tours and shadowing current students, and provides opportunities to use their technologies. It also offers low-cost training in programming, 3D printing, robotics and introductory mechatronics. Find out more and get in touch: **www.ccac.edu/workforce-and-community/index.php**
- The CCAC has a mechatronics programme for high school students, providing an introduction to the field along with industry-recognised certification: **www.ccac.edu/academics/programs/manufacturing-skilled-trades-and-transportation/mechatronics-technology/mechatronics-program-in-high-school.php**
- According to Talent.com, the average mechatronics engineer salary in the USA is $100,000 per year.

Pathway from school to *mechatronics*

"Mechatronics is an integrative field, so knowing a bit about lots of things will be tremendously valuable," says Justin. He recommends studying mechanical systems, electronics and physics as the core of 'traditional' mechatronics. In addition, he says that learning coding and app development will be critical to use software to automate tasks and advance the field.

"I WANT TO BE VIEWED AS SUCCESSFUL BECAUSE THE PEOPLE AROUND ME ARE SUCCESSFUL. BEING SOMEONE WHO FACILITATES SUCCESS MAKES OTHERS WANT TO WORK WITH YOU."

Meet *Justin*

I was always a collector and tinkerer. When growing up, I liked taking things like old TVs and seeing if I could fix them. I ended up saving a lot of old components and built up a really useful set of electronic supplies. I also enjoyed music, reading and travelling to new places.

I had no idea what I wanted to be when I was younger. I fell into engineering, in fact. When I was an undergraduate student, I took a year off from studying to work for a startup that made sewer inspection robots. I loved the intersection of technology and business and returned to the company many years later to work as the Chief Technology Officer and, ultimately, sell the business. These experiences in industry have been vital to becoming an effective educator in the field.

If something seems impossible, just keep trying. If you don't have the funds for a project, apply for a grant or work with local resources. Most importantly, be nice to people and help them succeed. Teamwork is essential to solve the most challenging issues in any workplace.

I believe in sharing the credit for success. Whenever projects go well, I try to let others take the credit. I want to be viewed as successful because the people around me are successful. Being someone who facilitates success makes others want to work with you.

I was honoured to be named an Engineering Unleashed Fellow for my work integrating Entrepreneurial Minded Learning into the mechatronics curriculum. I'm also proud of the work of the CCAC on a number of projects linking learning with industry, and we've successfully involved local employers to guide curriculum updates for our mechatronics programme. We've also provided high schools with advanced manufacturing equipment, to produce a pipeline of students from an early age.

In my free time, I enjoy hiking and spending time with my wife and young son. I also restore computers from the 1970s and 80s, and tinker with old Volvo cars.

Justin's *top tip*

Never stop learning. The pace of technological progress is relentless. Working in mechatronics involves staying on top of these developments. If being on the cutting edge excites you, then mechatronics is an extremely rewarding field.

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