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A non-profit social innovation hub fostering positive change in underserved communities

BIOSCI TOOLKIT

Inspiring Black and ethnic minority communities to pursue careers in bioscience

DECOLONISING THE CLASSROOM

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ISSUE 24
Confounding expectations

WELCOME

What is expected of you? How encouraged are you by your community to pursue an ambitious career pathway? How are your aspirations affected by society's expectations of you? Your answers to these questions will be influenced by a huge range of factors, including your social and cultural background.

Thinking Minds Ghana is a non-profit organisation aimed at fostering positive change in underserved communities. In a country where literacy rates are far lower for girls than for boys, empowering women to become entrepreneurs is no mean feat. The founder of Thinking Minds Ghana, Seth Panyin Boamah (p 04), tells us about the initiative that is challenging societal expectations to achieve just that.

Based at Brunel University in the UK, bioscience lecturer Dr Chinedu Agwu introduces BioSci Toolkit (p 42), an information resource page set up to support more students – especially those from BAME communities – to think beyond the traditional STEM choices of medicine and engineering and pursue bioscience. As Chinedu explains, expanding the fields where people can envision themselves serves to reduce inequalities in education and diversify the workforce.

From educators moving away from Eurocentric teaching by 'decolonising the classroom' (p 08) to individual researchers going beyond the norm to achieve great success, issue 24 of Futurum highlights many examples of where challenging expectations reaps rewards.

What is expected of you? More importantly, what do you expect of yourself?

THE FUTURUM TEAM

Karen Lindsay
Director

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

Kate Wilkinson, MA

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futurum
Inspiring the next generation

CONTACT

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

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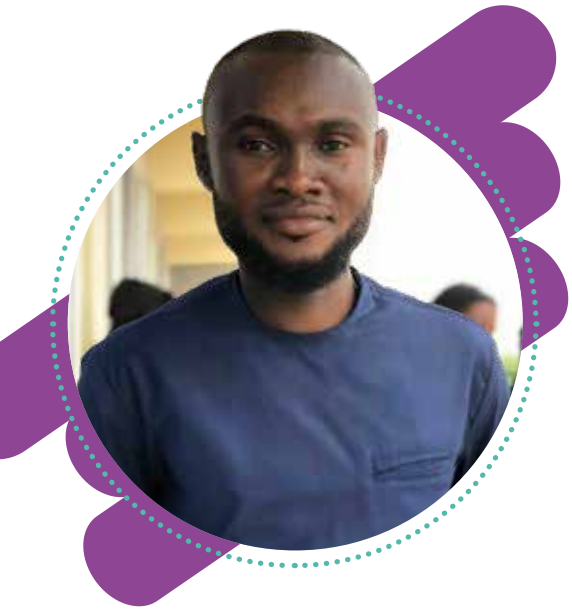
CONTENTS

Research articles

48

Research articles

INTERVIEWS

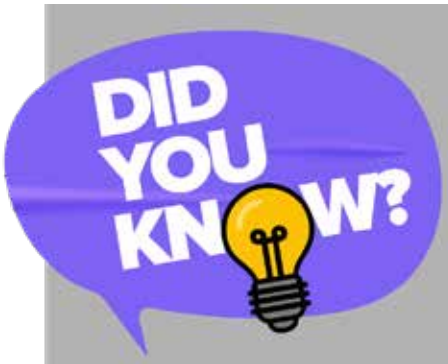


Making Abolo Girls Great

Thinking Minds Ghana is a non-profit entrepreneurship and social innovation hub aimed at fostering positive change in underserved communities. **Making Abolo Girls Great** is one of its initiatives, which is dedicated to empowering Ghana's women street hawkers to become entrepreneurs. Founder of Thinking Minds Ghana, **Seth Panyin Boamah**, tells us more.

About Making Abolo Girls Great (MAGG) Livelihood Empowerment Project

MAGG is a vocational incubation programme for women street hawkers in Ghana. The programme offers entrepreneurship skills training, such as in financial management and record-keeping, to young women in the Manya Krobo District of Eastern Ghana over a six-month period. Gered Gereedschap, a non-profit in the Netherlands, provides the necessary resources for co-working spaces for MAGG beneficiaries.



1. The capital of Ghana is **Accra**
2. Ghana has a population of **32.1 million**
3. **Languages spoken in Ghana are:** English, Dagaare, Dagbanli, Dangme, Ewe, Frafra, Ga, Gonja, Nzema, Twi and Fante
4. **13.7%** of the country's labour force is unemployed, representing over **1.76 million** people.
5. **Two thirds** of unemployed people in Ghana are women
6. Abolo is a sweet, steamed dumpling. Selling abolo on the streets is a **major source of income** for young women in Kpong, a town in the eastern region of Ghana

Sources:
www.bbc.co.uk/news/world-africa-13433790
and Ghana Statistical Service (GSS)

How does Ghana compare to other African nations in terms of unemployment rates?

Africa has the largest youth population, and unemployment rates across the continent go way beyond expected levels. So, unemployment isn't solely a Ghanaian problem, but an African one. In Ghana, about 70% of the population is between the ages of 1 and 35 years and a whopping 38% is between 15-35 years. Considering that Ghana is a developing country, opportunities do not abound.

Is education free in Ghana?

For now, basic education is free but it comes with multiple challenges. Funding education in a developing country is difficult. Not only that, but there are certain resources and materials that beneficiaries of free education need, such as books and uniform. So, you still need the support of your immediate family to be able to take advantage of government-funded education.

Then there is the fact that young women with children find it very challenging to go to school. Before they can complete their own education and pursue their dreams, they need some form of livelihood to support their children.

What are the employment challenges for women and girls?

Literacy rates for girls are far lower than for boys because educating girls is not widely accepted in African culture. There is a perception that boys will be more industrious than girls, and that girls will get married and have children. As such, there are many more boys than girls enrolled in schools in Ghana. It is also more likely for girls to drop out of school

Apprentices in the cosmetology unit learning how to braid using mannequins © Thinking Minds Ghana

than boys, especially in rural communities. This is because girls in rural communities are more vulnerable to sexual exploitation and may fall pregnant. They often experience poverty, and if female students don't have the resources they need for school, they start to feel inferior and unable to continue their education.

Another challenge is that women are largely dependent on men because, in many rural communities, economic empowerment of women is considered improper. For these reasons, women experience higher rates of unemployment.

What can girls do without an education?

Girls who are 15 years old or older can do what we call a traditional apprenticeship. This is where they learn how to sew, cut hair and do other vocational activities. Nevertheless, traditional apprenticeships aren't always accessible due to the high cost of training, indefinite training periods, absence of training manuals and lack of payment or stipends for trainees. Then there are the unscrupulous practices, which lead girls to doing household chores like washing up or cooking in madams' homes. Traditional vocational apprenticeships are, essentially, a blanket replication of modules that don't take into consideration the socioeconomic and cultural setup of so many marginalised women.

Another drawback is that many of these apprenticeships start at 7 am and finish at 6 pm. The majority of young women aged 18-20 will have dropped off the educational ladder because they have had children. Many are victims of sexual exploitation and therefore become single mothers. This is why street hawking is so common among girls and young women.

What is a street hawker?

A street hawker is a person who moves around the city selling inexpensive wares, such as food, electronics or household items, to passers-by. In Ghana, there are huge numbers of street hawkers and many are women with children. Street hawkers work in shifts. For example, one group might work on Mondays and Tuesdays, while another will work on Wednesdays and Thursdays, etc, so they won't receive a full week's pay. Another problem is that the wares they sell on the street don't belong to them. They sell these items for someone else, taking a small commission from the sale. As you can imagine, the money they make is very little and, often, it can't sustain them or their children. So, many become involved in social vices.

What does Thinking Minds Ghana offer?

In the absence of tailor-made programmes for young people, we realised that we could offer apprenticeships to street hawkers. We had planned to work with existing apprenticeship providers, but realised they weren't suitable for our ideas so we set up a skills and entrepreneurship training centre and

> **"Literacy rates for girls are far lower than for boys because educating girls is not widely accepted in African culture."**

Graduation ceremony for the first cohort of the MAGG project © Thinking Minds Ghana

> ***I'm very proud of the fact that, when the local community believes in initiatives like ours, anything is possible. We've been able to show people that local community challenges can be solved with local resources.***

MAGG project participants model garments and hairstyles they have created © Thinking Minds Ghana

created an accelerated, six-month apprenticeship programme. Apprentices start at 7 am and are finished by 1 pm, which means they can work alongside their apprenticeship. We teach fashion design and cosmetology, which is the study of beauty treatments.

How is the programme funded?

That's a bigger challenge. We started with community philanthropy, letting the local community know that it has a role to play in lifting street hawkers' standards of living. We met people, explained what we were doing and were able to secure some funding. But it's not enough to keep up with the work we do, so we work with volunteers like myself. I've been volunteering for the past 4-5 years. We have a team of about 8 people and we volunteer our time to ensure that this programme continues.

How many young women has your programme supported so far?

We've trained people in different areas but, with respect to skills training in fashion and cosmetology, it's currently 55.

What are you most proud of so far?

Firstly, I'm very proud of the fact that, when the local community believes in initiatives like ours, anything is possible. We've been able to show people that local community challenges can be solved with local resources.

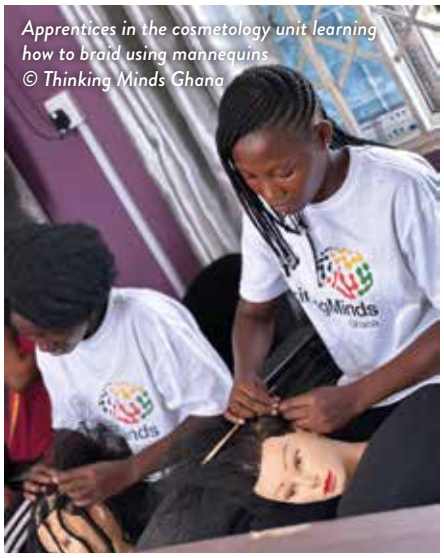
Secondly, I'm glad that we've been able to train 55 young people through our programme, empowering them with vocational skills as well as entrepreneurship training.

We also work on lots of other initiatives besides MAGG. For example, we are a member of the UNESCO Media and Information Literacy Alliance (MIL). We have reached more than 3,000 young people, empowering them to define their information needs, develop skills for accessing information and interpret that information correctly.

What are some examples of apprentices' achievements after graduating from MAGG?

When our apprentices start training, they are very timid, but midway through the training, they gain confidence and they don't want to go back to working on the streets. After completing their training, we have examples of apprentices starting their own businesses – for example, hairstyling from the comfort of people's verandas.

In our training school, I see students who have experienced a lot of stress and trauma. They have been subjected to abuse, sexual exploitation and human trafficking. As street hawkers, they are more like slaves, making money for other people. Their eyes are opened when they go through our training programme; their aspirations are high. They want to continue to an intermediate course and leap higher



Apprentices in the cosmetology unit learning how to braid using mannequins © Thinking Minds Ghana

Hairstyling practical © Thinking Minds Ghana

on the educational ladder to pursue their dreams. To see somebody, who thought they were hopeless and didn't believe that they could make anything, find a sustainable means of living is very rewarding.

What is your vision for Thinking Minds Ghana?

My vision is for Thinking Minds Ghana to become a modern enterprise and social innovation hub that trains at least 250 young women every year.
I would like to call on people who believe in what I'm doing, people who believe that disenfranchisement, cultural barriers and gender shouldn't be barriers to girls accessing education or achieving their dreams. I want to call on these people to come on board and support Thinking Minds Ghana, to give us the financial means and resources we need.

We have had applications from young women who want to have an opportunity to be on our apprenticeship programme but, because of our limited resources, we're only able to support a small group at a time. We have taken the first and second cohort young women. If we get the support we need, we'll be able to increase our offering and make an even bigger impact.

Hairstyling practical
© Thinking Minds Ghana

Meet Seth

Seth has a BSc in Materials Engineering from Kwame Nkrumah University of Science and Technology. He founded Thinking Minds Ghana in January 2019 and became co-lead of 10 Billion Strong Ghana Hub, a movement of leaders committed to building a better future, in May 2023.

Did you want to be an engineer when you were growing up?

Growing up, I was very technical and creative. I liked putting things together and knew I wanted to build things, so, right from the start, I thought about becoming an engineer.

Why did you found Thinking Minds Ghana?

As much as I love engineering, I'm also very inquisitive. Everywhere I went, I was always looking for solutions to problems. My engineering background has helped me a lot. You become analytical, it makes you want to solve things, so now I'm into social engineering!

Training in the fashion and design unit
© Thinking Minds Ghana

> ***"I want to remove gender barriers to education and employment, and serve people who are deprived of education for reasons that may be cultural or incidental."***

Do you have another job alongside Thinking Minds Ghana?

As I said, I volunteer my time for Thinking Minds Ghana, so I also have a shop that I personally run. I'm also involved in data collection for research institutions.

What do you see yourself doing in 5 to 10 years?

In 5-10 years, I see myself in a position where I am influencing government policy on gender inclusion, especially in relation to job creation and education policies. I want to remove gender barriers to education and employment, and serve people who are deprived of education for reasons that may be cultural or incidental, by deploying a gender lens on recruitment, programme design and content.

What do you have to do now to start influencing government policy in the future?

Over the next few years, I'd like to return to education and study social enterprise, business creation and educational policy. With these qualifications, and through the work I'm doing, I'll be able to advise the government.

Connect with Seth and Thinking Minds Ghana

- **linkedin.com/in/seth-panyin-boamah-b5231877**
- **linkedin.com/company/thinking-minds-ghana**
- **facebook.com/ThinkingMindsGhana**
- **thinkingmindsghana.org**

Decolonising the classroom

Current teaching methods in many nations across the globe tend to stem from Eurocentric traditions, which can be at odds with the communities and experiences of the students and teachers involved. Based at the **University of Saskatchewan** in Canada, **Dr Geraldine Balzer** is advocating the introduction of alternative methods and materials that give a broader worldview. These can support the deconstruction of the systemic ills of colonialism, helping upcoming generations to appreciate diversity and address injustices.

Dr Geraldine Balzer

Department of Curriculum Studies, College of Education, University of Saskatchewan, Canada

Fields of research
Social justice teaching, decolonisation, reciprocity

Research project
Collaboratively developing a social justice pedagogy that aims to deliver inclusive, decolonised teaching methods and materials

Funder
Social Sciences and Humanities Research Council of Canada (SSHRC)

PROFILE

Glossary

BIPOC — Black, Indigenous and people of colour

Canon — a collection of books treated as the genuine 'truth' (originally in religious contexts)

Cognitive dissonance — the perception of contradictory information and the effect this has on the mind

Colonisation — the settling among, and establishing control over, Indigenous Peoples and their lands

Critical literacy — the ability to find embedded discrimination or prejudice in media

Decolonisation — the process of freeing a system or institution from the effects of colonisation

Eurocentric — a tendency to interpret the world in terms of European values and experiences

Indigenous — inhabiting a land since before the time of colonisation

Marginalisation — treatment of a social group or person as unimportant or without power

Patriarchal — describing a society or system controlled by men

Pedagogy — the method and practice of teaching

Socratic circle — a method for facilitating student discussion, where students sit in a circle, facing each other

Trope — a recurring metaphor or symbol

A key aspect of colonialism involves taking the values and practices of the colonisers' culture and imposing them on those of the colonised. This inevitably leads to inequities. As well as introducing systems that can run counter to the needs and experiences of the colonised, it also establishes a power structure with the colonisers at the top. Colonialism continues to cast a shadow over many nations of the world, perpetuating injustices. At the University of Saskatchewan, Dr Geraldine Balzer is working to address these injustices through one particularly powerful tool: teaching.

"Current and traditional pedagogies grow out of Eurocentric educational traditions," says Geraldine. "In the Canadian context, these evolved from the British and American educational systems." Such systems prioritised literature from their respective traditions, which were principally authored by white men from wealthier backgrounds. "This set of literature became known as the school canon," says Geraldine. "The school canon validates specific ways of existing in the world, centres on white middle- and upper-class values, and normalises a hierarchical, patriarchal structure."

Impacts

The use of the school canon when teaching literature leaves many students feeling their own experiences are going unrecognised. "The most significant impact for students is that they do not see themselves represented in these texts," says Geraldine. "In the school canon, the central characters are usually white and male. Any other characters are rarely in positions of power or autonomy." For instance, female characters are typically secondary, fulfilling traditional roles such as caregivers, while BIPOC characters are often in subservient roles. "If racism is ever confronted,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such as in texts like *To Kill a Mockingbird* by Harper Lee, the white saviour trope emerges," explains Geraldine. "Any stories of marginalised individuals are typically through the lens of trauma, with these individuals in the role of victim."

The establishment of these roles within literature implies that these are the only roles that do and 'should' exist in the real world, cementing perceptions of existing power hierarchies as the right and proper way of doing things. This has effects at the personal level. "If learners only see themselves represented in these traditional roles, it is difficult to imagine themselves in other roles," says Geraldine. "It is not only students, but also women or BIPOC teachers that can also feel marginalised by the school canon."

Ongoing injustices of colonialism

The far-reaching impacts of colonialism persist to this day all around the world. "We can see the ongoing effects of colonialism in low access to education for women in Afghanistan and Iran, the lack of voice for Indigenous Peoples in Australia, and the ongoing Israel-Palestine conflict, to name a few," says Geraldine. Canada's colonial past also continues to hold a heavy influence over how the country operates, despite an ever-evolving demographic. "Mobility and immigration mean that the diversity in our classrooms is changing constantly," says Geraldine. "History teaching has emphasised the immigration of Europeans to Canada, but little attention has been given to the influx of immigrants from Asia, or to Canada's historic Black communities."

While Canada promotes itself as highly multicultural, this does not address the unequal power structures that continue to exist and support Eurocentric values. This is why active decolonisation efforts are needed. "Decolonisation exposes these power structures, examining the roots of discrimination and oppression with the goal of building a more equitable society," says Geraldine. "In the classroom, decolonising pedagogies provide paths for teachers to introduce multiple perspectives to their students, support their discussions of access to power, and illustrate the ways that oppressive structures persist."

> **"The school canon validates specific ways of existing in the world, centres on white middle- and upper-class values, and normalises ahierarchical, patriarchal structure."**

Barriers

However, the introduction of such pedagogies comes up against some significant challenges. Current constructs are well-established, making change difficult, and this applies to schools as much as any aspect of society. Schools typically follow a rigid curriculum, promote teachers as a source of invulnerable authority, and even keep classroom layouts restrictive. "School architecture is part of this colonising process, as the physical structures constrain the kinds of activities that teachers can implement," explains Geraldine. "For instance, small group discussions such as Socratic circles are difficult to organise in spaces with individual desks."

Furthermore, noisy classrooms – which are inevitable when multiple learning-based discussions are taking place – are typically frowned upon. Pressures on time and resources, as well as the school's own culture and lack of support for new approaches, can often act as barriers to moving away from the school canon. "Teachers are discouraged from trying new things if they are not validated in their efforts," says Geraldine. "Additionally, accessing the budget necessary to purchase new resources can be a major barrier."

Teacher inquiry groups

With these barriers in mind, Geraldine has been working collaboratively to bring alternative pedagogies into classrooms. She ran a multi-year research project (one of eight such projects that took place across Canada), working with a group of teachers to understand their experiences and to support their efforts to introduce alternative pedagogies into the classroom. "We met regularly to discuss strategies of literature, beginning with postcolonial theory and the necessity of discomfort," says Geraldine. "We discussed how literature needs to represent the people within our classrooms and to tell stories that counter traditional narratives." The project provided the funds needed to purchase sets of classroom books, including titles suggested by the teachers, creating a 'library' that the teachers could borrow from.

As the project progressed, discussions turned from theory and literature towards pedagogical strategies, students' responses to the literature, and teachers' own personal development. "The inquiry group was a place to test ideas among colleagues who had become friends," explains Geraldine. "Some of us developed a workshop for the European Literary congress in Spain, and others attended a final symposium of the larger research group from all eight sites." This symposium offered the opportunities to share experiences and successes, exchange recommendations for literature, and celebrate the research journey. Geraldine went on to co-author a book chapter with some of the teacher participants.

Indigenous *communities*

Geraldine's project involved working with people from a wealth of backgrounds, including Indigenous Peoples. One school served a significant Indigenous population, in a community adjacent to First Nation reserves. Prior to this research project, Geraldine has a long history of research with Indigenous communities. "Since 2007, I have worked with Indigenous communities in Guatemala," she says. "During that time, the focus of my research shifted from examining how the worldviews of Canadian youths changed following learning opportunities in Guatemala, to how these study tours impacted host communities."

Geraldine's findings were profound: the communities perceived these learning efforts as another extractive industry, one where researchers gained information for their own purposes, but the community saw little benefit. "We have been trying to change this by engaging members of the local community in the development of the research project itself, including the gathering of data along with analysis and validation," says Geraldine. "Our aim is to develop an ethic of reciprocity focused on co-creation of knowledge."

Key *findings*

Teachers reported students responded positively to the selection of postcolonial literature that they were presented with. "For instance, through reading texts by Afghan author Khaled Hosseini, students were able to see Afghans as people they could relate to – they were no longer 'the other'," says Geraldine. "When reading the memoir of Ishmael Beah, including recounts of his time as a child soldier in the Sierra Leone Civil War, students responded with frustration at not having known this event had happened." Such conversations led to analysis of Canadian news and media, including which global events received airtime and which were rarely mentioned, and how these choices related to political power structures.

Other texts covered experiences closer to home. "Students also read texts by Canadian Indigenous writers, empowering Indigenous students to speak up about their experiences and express pride in who they are," says Geraldine. "These pieces of literature provided counter stories to dominant narratives, ensuring the voices of diverse members of the community are heard and that unfair power dynamics are exposed."

Facilitating *discussions*

Making these discussions happen is not as simple as just giving the students different books to read; it also involves changing the structure of lessons. "First, a culture of respect needs to be established where all voices are valued and questions can be asked without judgement," says Geraldine. "This involves teachers being models for questioning and curiosity, and admitting their own lack of knowledge." This introduces a degree of vulnerability for teachers, but this can bring its own benefits through empowering students to feel their voice is equal to that of the teacher.

Geraldine's group often changed the layout of the classroom itself. "A non-hierarchical form like sitting in a circle, or even removing desks altogether, can help shift power structures," says Geraldine. "Many teachers use an Indigenous talking circle, to ensure that students can express their opinions without being interrupted. This involves an object such as a stick or rock being passed around, with only the holder of the object permitted to speak."

Teachers also help coach students in how to use language to present possibly controversial opinions in non-confrontational ways, which can be a powerful skill for facilitating change. All these efforts help build trust among students and with the teacher, which, with time, can help students to speak up, challenge ideas of the status quo, and point out fallacies in societal assumptions. "Such methods help combat racism and other oppressive structures through gentle and inclusive means," says Geraldine. "They enable students to become, as author bell hooks would say, 'enlightened witnesses' of the world."

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Critical *literacy*

Every piece of literature has a social context, and understanding these contexts is a necessary part of appreciating the viewpoint of the author and how it fits into the wider system and the injustices held within. "Critical literacy helps students to understand that texts, and our interpretations of these texts, are always socially constructed," says Geraldine. "They are never neutral." Learnings in how to spot these social constructs in texts can be readily applied to the real world. After all, social constructs are at the heart of the power structures that govern our society.

Rather than directly challenging students' own beliefs or backgrounds, which could be a deeply uncomfortable and potentially counterproductive experience, literature provides an avenue more removed from the individual. "Literature is a safe path into these conversations because it doesn't begin by examining students' own social contexts, but lets them see these structures through stories and make the links to their own lived experience themselves," says Geraldine. "Exposure to different perspectives enables them to make connections to issues close to home and ask hard questions about the structure of their own community, media coverage of events, and advertising tactics." Such critical analysis inevitably leads to the recognition of systemic inequities – and recognition is the first step towards tackling them.

Displacement *of power*

Overhauling teaching techniques and texts can take students and teachers alike out of their comfort zone – but this is not a bad thing. "Change is usually precipitated by discomfort, so a pedagogy of discomfort brings about change," says Geraldine. "The trick is finding the level of discomfort that creates the cognitive dissonance needed to affect change, without causing so much discomfort that people resist and double down on their held beliefs." Geraldine refers to Megan Boler's 'pedagogy of discomfort', which involves students critically examining their own ideological assumptions – an uncomfortable but rewarding task, which can also be valuable for personal development.

Being able to identify power imbalances and their colonial origins can help people advocate for directed change. "Colonised people have been constructed as inferior to colonisers, and this power imbalance fosters classism and racism that perpetuate societal inequities," explains Geraldine. "Decolonising pedagogies expose the roots of these imbalances and reveal how language can be used to perpetuate these systems."

Teachers as advocates *for social justice*

Adolescents are still making sense of the world, forming worldviews that will become more cemented and difficult to challenge later in life. This means that teachers have an important role to play in guiding the perceptions of upcoming generations, which will inform the decisions they make throughout their lives and careers. "Most adolescents are looking for things that aren't fair, so helping them understand the context of injustices in their communities is a good place to begin," says Geraldine. "Teachers can look for places where injustice prevails and draw their students' attention to it."

Once students are aware of these injustices, the next step is to give them the tools to address them. "While solving global problems such as the refugee crisis is out of reach, there are often opportunities for students to champion justice within their own communities," says Geraldine. "For instance, advocating for women in student governance, or making playgrounds more accessible may be goals that are possible for students to achieve." This encapsulates the 'think global, act local' mantra that informs advocacy work around the world. "Most importantly, teachers need to be models for enabling change," says Geraldine. "Being an advocate of social justice necessarily involves strategies to make the world a more just place."

How are coercive psychiatric practices experienced by First Nations communities?

While psychiatric services are designed to help people with mental health issues, they do not benefit everyone, and many people are held in psychiatric facilities against their will. Not only are people from Indigenous communities more likely to be held in psychiatric facilities, but mental healthcare approaches based on Western ideas of health and illness do not provide suitable healing for people with different worldviews. At the **University of Ottawa** in Canada, **Professor Emmanuelle Bernheim** and **Professor Eva Ottawa** are investigating the effects of coercive psychiatric practices on Manawan community members and helping them develop their own well-being and territorial programme.

Professor Emmanuelle Bernheim

Professor Eva Ottawa

Faculty of Law, University of Ottawa, Canada

PROFILES

Fields of research
Social justice, mental health, law

Research project
Investigating coercive psychiatric practices against Manawan community members and co-creating community-aligned well-being services

Funder
Social Science and Humanities Research Council of Canada (SSHRC)

Talk like a ...

social justice researcher

Atikamekw Nehirowisiwok — a First Nations people, who live in the Manawan community

Coercive — the use of force or threats to get someone to do something against their will

Colonise — to settle among and take control over Indigenous Peoples and their lands

First Nations — Indigenous Peoples of Canada

Medicine wheel — a symbol in various First Nations cultures representing the interconnections between all living things

Miromatisiwin — an Atikamekw Nehirowisiwok term meaning 'to have a good life with the world around us' or 'to live a life of balance and harmony'

Ontology — the philosophical study of the nature of existence

Psychiatric — related to mental illness

Sedentary — staying on one place

If, due to the state of their mental health, someone is considered to be a danger to themselves (or others), they can be admitted to hospital and kept there against their will. While this confinement is designed to protect the person concerned, it can have severe negative consequences on them. What is more, research from Australia and New Zealand has shown that people from Indigenous and marginalised communities are disproportionately subjected to coercive psychiatric confinement, highlighting how such practices are exacerbating social inequalities.

"The only Canadian study on the subject, conducted in the 1990s, showed that on average, First Nations people in Canada are held in psychiatric hospitals for twice as long as other patients," says Professor Eva Ottawa, a member of the Manawan community and a specialist in Indigenous law at the University of Ottawa. She is working with Professor Emmanuelle Bernheim, a civil law and social justice researcher, to investigate the impacts of coercive psychiatric practices on members of the Manawan community. They are also working with community members to develop well-being approaches that align with community values and worldviews.

Manawan mental health challenges

The Manawan community is located 250 km north of Montreal, in the Canadian province of Quebec, and is home to around 3,000 Atikamekw Nehirowisiwok. "The Atikamekw Nehirowisiwok consider themselves intrinsically linked to *notcimik*, the forest universe, which has shaped their way of life," explains Eva. Before colonisers arrived in the region, the Atikamekw

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Nehirowisiwok lived a nomadic lifestyle, moving around their ancestral territory according to the six seasons and sustaining themselves through hunting and trapping. The violent impacts of colonisation included the creation of the Manawan reserve in 1906, which forced the Atikamekw Nehirowisiwok to adopt a sedentary lifestyle on the small area of land allocated to them by the Canadian government.

Today, the Manawan community faces numerous mental healthcare challenges due to a lack of mental health services. Most hospitals or crisis centres have specific rooms to ensure a patient's safety during a mental health crisis, with caregivers on duty at all times to monitor them. However, there is no crisis room in the Manawan Health Centre and there is not always a doctor or psychiatrist on site. This means community members cannot always access local services during certain crisis situations. "Vulnerable people have nowhere to turn during mental health crises," says Emmanuelle. Instead, they are forcibly hospitalised. However, psychiatric confinement is resented by those who experience it, who view it as a coercive, rather than caring, measure. In 2020, 39 people from the Manawan community were transported by the police to the emergency room of the hospital in Joliette (185 km away). "The overuse of such practices against members of the Manawan community is a clear case of systemic discrimination," says Eva.

Uncovering coercive psychiatric practices

Emmanuelle and Eva's research is focused on involuntary admission to emergency rooms and psychiatric wards as a form of coercive psychiatry. To investigate the issue, they are collecting data from multiple sources covering all stages of the process. "We want to document police and hospital practices alongside community members' experiences," says Emmanuelle. "This involves compiling medical records, conducting interviews with health professionals and police officers, and meeting with individuals who have been forcibly hospitalised and their families."

> **"First Nations people in Canada are held in psychiatric hospitals for twice as long as other patients."**

While the research is still in its early stages, the team has already noticed a worrying lack of follow-up care for psychiatric patients. "It appears that several individuals have simply ended up on the streets after being discharged from the hospital in Joliette and left to find their own way back to the Manawan community," says Emmanuelle. Once discharged, patients are not offered further mental health counselling.

Differences in perceiving the world

To address mental health needs, it is essential to understand how people perceive themselves and their place in the world. However, the diagnosis and treatment of psychiatric conditions follow Western views of medicine and do not accommodate Indigenous worldviews.

"The Atikamekw Nehirowisiwok subscribe to the concept of *miromatisiwin*, meaning 'to have a good life with the world around us' or 'to live a life of balance and harmony'," says Eva. This ontology, or theory of being, is very different to that found in Western cultures, where humans are considered separate from their surroundings. "The Atikamekw Nehirowisiwok ontology encompasses a vision where values, experiences and relationships are a core part of reality. This way of being encompasses a sense of responsibility towards others, both human and non-human."

These differences in the ideas of our place in the world inevitably lead to fundamentally different approaches to life. The lack of interconnection between self and others in Western mental healthcare makes it unsuitable for people with different theories of reality. Emmanuelle and Eva's project aims to document practices and experiences related to the use of involuntary admission in the Manawan community and to support the community in the development of wellness services.

Miromatisiwin services

Together with the Manawan community, Emmanuelle and Eva are co-developing an array of *miromatisiwin* wellness services, which embed Atikamekw Nehirowisiwok knowledge. These therapies will draw on Atikamekw Nehirowisiwok ontology linking individual health to territorial health. "The Manawan Health Centre has already experimented with a mental health support programme that encourages close contact with the land," says Eva. "It includes ceremonies with community elders, allowing beneficiaries to undertake the sacred journey of their lives thanks to the medicine wheel, and promotes daily use of the territory through traditional activities such as hunting and trapping, to help bring about personal balance."

Emmanuelle and Eva hope that the community-led *miromatisiwin* services will improve mental health and well-being among Manawan community members, reducing the number of people subjected to damaging coercive psychiatric practices.

About *psychiatry and law*

How have psychiatry and law been used as colonial tools?

The frameworks behind Western notions of psychiatry are rooted in colonial values, which put them at odds with the values of Indigenous cultures. "For example, the classification of 'normal' and 'abnormal' behaviours in psychiatry is based on the cultural standards of colonisers, not of Indigenous communities," says Emmanuelle. "By prioritising the supposed 'rationality' of Western medicine over the 'superstition' associated with Indigenous approaches to mental health, psychiatry imposes a Western view of illness and healing." Consequently, in colonised countries around the world, people from Indigenous communities and marginalised groups are more likely to be subjected to coercive psychiatric practices that white individuals. And people who experience coercive psychiatric practices are also more likely to have problems with criminal justice and child welfare systems, suggesting such psychiatric techniques are focusing more on control and punishment than therapy.

In theory, everyone should be equal under the eyes of the law. However, in practice, law is commonly used as a tool for systemic marginalisation. "The legal field is largely monopolised by the elite," explains Emmanuelle. Limited access to legal education means that most legal professionals come from wealthy backgrounds, leading to a rift between the experiences of legal practitioners and those of people caught up in legal systems. "Legal professionals do not understand the complexity of the social issues at play," says Emmanuelle. "Additionally, people subject to legal orders are disproportionately poor, and become further impoverished due to legal decisions made against them."

How can people working in psychiatry and law improve social justice?

The systemic inequalities in psychiatry and law may seem entrenched, but many people are working to make these systems more equitable for all. "Psychiatric and legal professionals must acknowledge the wisdom of the individuals they serve and recognise that communities have the knowledge to develop valid options for themselves," says Emmanuelle. "It's important that they ask themselves why the most educated and privileged members of society are the ones making the decisions that affect others, without considering their situations."

Pathway from school to *psychiatry and law*

- If you are interested in psychiatry, it would be useful to study science, mathematics and psychology at school. You will then need to study a psychiatry medical degree at university. Check the requirements for the country you want to work in, as every healthcare system is different and requires different qualifications.
- If you are interested in law, it would be useful to study English, history and philosophy at school. You will then need to study a law degree at university. Check the requirements for the country you want to work in, as every legal system is different and requires different qualifications.
- If, like Emmanuelle and Eva, you want to study psychiatry and/or law as a researcher, rather work as a psychiatrist or lawyer, then you could study a degree in psychiatry, psychology, law, philosophy or political science.

Explore careers in *psychiatry and law*

- Psychiatrists are health professionals who diagnose and treat mental health conditions. They may work in hospitals, private clinics, schools or prisons. Learn more about psychiatry from the Canadian Psychiatric Association: **www.cpa-apc.org**
- To gain experience in psychiatry, look for work experience or internship opportunities at health centres or with mental health organisations.
- There are many career opportunities in law. For example, lawyers represent clients during legal proceedings, judges and magistrates oversee court cases, politicians create a nation's laws, and law researchers investigate how legal systems influence society. Learn more about the legal profession from the Federation of Law Societies of Canada: **www.flsc.ca**
- "Engage in law-related activities while at school, such as mock court competitions and debates," advises Emmanuelle. "Gain first-hand experience of ordinary legal issues by volunteering with organisations that assist marginalised individuals."

Meet *Emmanuelle*

I've always loved books, and reading and writing are my passion. When I was younger, I wanted to be a writer, so I went to university to study literature but soon realised that literature studies weren't for me.

I switched to studying law because I didn't know what else to do. While I didn't enjoy the technical aspects of law enough to pursue a career as a lawyer, I was captivated by my first experience of conducting fieldwork for law research. That was when I understood that I wanted to spend my career researching the sociology of law, in partnership with marginalised communities and individuals.

> ***My research has led to changes in legal practices.***

Through my work, I uncover the structural issues behind psychiatric and legal practices related to social inequalities. I want to understand how and why the legal mechanisms meant to protect the rights of the most vulnerable people can result in blatant violations of these rights. I aim to expose how legal systems are used to marginalise, impoverish and stigmatise individuals and communities who are already marginalised.

My research has led to changes in legal practices, the development of new rights information documents that are now available in courts, and the inclusion of social workers in community legal clinics, and it has been cited in legal decisions regarding mental health rights.

In my free time, I enjoy spending time with my family and friends. I love activities such as hiking, cooking, playing with my dogs, and, of course, reading.

Emmanuelle's *top tips*

If you're interested in social research, build connections with community organisations as it's essential to consider the knowledge and concerns of community members when developing research projects. It is also important to engage with political debates and social movements, as well as building scientific knowledge.

Meet *Eva*

I have always been a curious person. I love learning and sharing what I learn with everyone, young and old. I particularly enjoy visiting *kokoms* (grandmothers) and *mocoms* (grandfathers) in my community.

When I was younger, I thought that 'law' was inaccessible and intimidating. However, I discovered that I needed an understanding of law to serve my community. The Atikamekw Nehirowisiwok are in the process of negotiating a territorial and self-governance treaty with the Canadian federal and provincial governments, and I became a researcher for the Commission on the Atikamekw Constitution. I was shocked to discover that the technical terms of a Western constitution had no resonance among the Atikamekw Nehirowisiwok, so I decided to study law so I could explain the terms of the future Atikamekw Nehirowisiwok treaty to my community.

My family taught me to always help vulnerable people, which is why I am passionate about improving access to justice for marginalised communities. For me, it is important to contribute to the well-being of everyone.

When I'm not working, I like spending time with my family and children. I enjoy a range of creative activities, such as beading, sewing and drawing. I also love reading, watching movies, travelling and visiting friends. I have many hobbies, so I'm never bored!

Eva's *top tips*

Take time to know yourself, discover your 'gifts' and seek out the lessons that will allow you to flourish and contribute to the well-being of everyone. Be creative to stay connected to the teachings of our elders.

The Atikamekw Nehirowisiwok have a close relationship with their environment © Thérèse Ottawa, CC BY-SA 4.0

How can trade unions prevent mental health issues at work?

The mental health of workers has been deteriorating in recent years, and workplaces are often ill-equipped for dealing with these issues. At the **University of Montréal's** School of Industrial Relations in Canada, **Dr Mélanie Dufour-Poirier** is studying the role of social delegates in the Quebec Federation of Labor (FTQ). These union-appointed people help address workers' mental health issues. Mélanie's research focuses on developing strategies to prevent the causes of mental health problems in the workplace, which relies on the collective contributions of all stakeholders to achieve primary prevention.

Dr Mélanie Dufour-Poirier

Associate Professor, School of Industrial Relations, University of Montréal, Canada

Fields of research
Industrial relations, unionism, mental health issues, primary prevention, union-management relations

Research project
Studying the role of social delegates for addressing and preventing workplace mental health issues caused, among other factors, by poor work design

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PROFILE

Talk like a ...

labour relations researcher

Labour relations — the research field that studies the relations between management and workers in workplaces

Longitudinal study — a research study that involves collecting data over an extended period of time

Primary prevention — interventions that prevent harm from occurring in the first place, rather than treating harms that have already occurred

Social delegate — an individual in a workplace (appointed by a trade union) who listens to workers' issues and directs them towards relevant services and, where necessary, advocates for improved work design

Stakeholder — a person with an interest in an issue

Trade union — an organised association of workers formed to protect their rights and interests in workplaces

Work design — the content and organisation of a person's employment activities and relationships, i.e., how work is carried out in a workplace

Injuries that occur at work are not only physical, but also psychological. "Psychological injuries in the workplace, specifically those linked to work design, have been increasing throughout the world for many years," says Dr Mélanie Dufour-Poirier from the University of Montréal's School of Industrial Relations. "My research aims to uncover links between work design and the prevalence of certain mental health problems, for example, work-related strain such as anxiety and depression." The increasing mental distress of workers arises from numerous causes, including poor working conditions, unrealistic working demands, poor work-life balance and loss of meaningful working communities.

Trade unions can play a key role in addressing and preventing these issues. However, preventing mental health issues in the workplace requires a collective approach, with workers and management working together to address the causes of psychological injuries at their source.

The importance of social delegates

One innovation of the Quebec Federation of Labor (FTQ) union organisation was the creation of the Social Delegates Network in 1983. These workers address colleagues' mental health concerns and try to prevent mental health issues at work by advocating for improved work design, among other things. "Social delegates deal with distress at work, often caused by the work itself," explains Mélanie. "In some cases, they also collaborate with management and workers to amend working practices, enhance working communities and improve management styles." In doing so, social delegates contribute to primary prevention of mental health issues, by addressing the causes of problems.

"Social delegates listen to their colleagues' mental health concerns and provide referrals (to psychologists, social workers or lawyers) to prevent crisis situations," explains Mélanie. "Since the creation of the Network, social delegates have provided support for issues such as addiction, debt, harassment, depression, emotional burnout and suicide." As many of these problems may be caused by issues at work, it is important to change workplace cultures and working practices to improve the mental health of workers.

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Social delegates play an important role in workplaces because employers often lack the capacity to deal with such sensitive and complex issues. While social delegates are not specialists or therapists themselves, as colleagues of the people they help, they understand the context of problems in the workplace. For example, they understand the organisational and management culture in the company, which helps them empathise with workers' concerns and address the causes of problems.

However, being a social delegate is often not easy. "The psychological burden of the role is challenging, as social delegates are responsible for people's welfare," says Mélanie. In many cases, their role is separate from traditional trade union structures, making it difficult to officially define and placing frustrating limitations on their abilities to help colleagues. Social delegates often face a lack of recognition for their work, leaving them feeling they are a low priority. These challenges have the potential to diminish the impact and transformative scope of social delegates' actions. "Breaking taboos and prejudices around mental health is necessary for employers, trade unions and workers to appreciate the role of social delegates in the workplace," says Mélanie.

Studying the impacts of the FTQ's social delegates

Mélanie uses qualitative methodologies to study the role of trade unions and social delegates in protecting workers' mental health in the Canadian province of Quebec. "My longitudinal research spans over thirteen years," she says. "It is based on individual interviews, group discussions and document analyses." Few studies have investigated how trade union innovations are addressing workplace mental health over such a long time period. "My colleague, Dr Jean-Paul Dautel, and I will soon be complementing this qualitative study with a quantitative survey to gain more in-depth knowledge of the mental health problems experienced by workers in Quebec and further afield, and how employers and trade unions can address them," says Mélanie. "We hope to work with trade unions, workers and employers to build a primary prevention programme that promotes better work design to prevent mental health issues."

> **"Mental health must be considered as a fundamental right at work."**

Not only does the long timeframe of Mélanie's research provide a rich dataset of changing attitudes towards trade unions and workplace mental health, but it also has allowed her to build relationships with social delegates. "Dealing with trade unions requires building solid relations of deep trust," she says. "Conducting interviews should be considered a gift in any research process and researchers must treasure the experience." Mélanie has worked with trade unions in several countries, establishing her reputation as an expert in her field and building relationships with the people she works with.

The ©Trans-faire tool

The COVID-19 pandemic disrupted how people worked across the world, and this included how social delegates performed their responsibilities. "The pandemic seriously compromised their ability to act on behalf of workers, at a time when many were experiencing higher psychological distress due to social distancing, the challenges of remote working and global uncertainty," says Mélanie. "Many social delegates quickly found solutions to these problems so they could provide their services remotely."

With her former colleague, Dr Francine D'Ortun, Mélanie developed the ©Trans-faire tool (a play on the French words for 'transfer' and 'to do') to collect and share these solutions among social delegates, so they could benefit from a communal knowledge base. "The ©Trans-faire tool enables social delegates to voluntarily describe their experiences, as well as the innovations they have developed," says Mélanie. "This collective exchange of knowledge, skills and expertise helps everyone."

Mission for the future

Mélanie believes there is still much to be done to protect and improve mental health in the workplace. In particular, it is important to build systems that prevent psychological injuries before they occur and to consider mental health issues as organisational, not only individual, problems. "Workplaces in Quebec tend not to implement systems of primary prevention that include the active and voluntary participation of all stakeholders," she says. "Primary prevention would require strong collaboration among employers, social delegates (when present), trade union representatives and employees, all of whom must contribute to discussions about work design. Only a collective approach will prevent injuries to mental health." This might require changing how work is organised, conditions for employees and administrative procedures. Mélanie and her colleagues, Dr Nicolas Chaignot Delage and Dr Jean-Paul Dautel, are currently investigating this idea by conducting a large, comparative study of workers in the aerospace industry in Canada and France.

Currently, social delegates are highly useful for addressing workplace mental health issues, but lack the power to prevent these issues from arising. "This requires employer support and open discussions," says Mélanie. "Giving social delegates the tools to perform their role as advocates against distress in the workplace could transform them, and trade unions more generally, into true agents of change when it comes to preventing mental health issues. Now, more than ever, mental health must be considered as a fundamental right at work and a reflection of social justice and industrial democracy in society as a whole. All stakeholders must fight for it as such."

About *labour relations*

'Labour relations' broadly refers to the relations between management and workers in workplaces. It involves considering of a wide range of social, economic and psychological factors, and understanding how these relations can improve working conditions and, therefore, quality of life. Mélanie explains more about her field:

"**Labour relations is a multidisciplinary academic field.** It studies employment relationships, worker-management relations and the labour market as a whole. It also studies the interactions and interrelations between employers, employees, trade union organisations, employer organisations, and the state. For me, the phenomenon of unionism and collective representation of workers, unionised or not, is of special interest.

"**I have investigated union representation in Canada, Chile, Mexico, Peru and the Philippines.** My main finding was that there is no such thing as a 'Global North' and 'Global South' when it comes to how unions approach workers' rights, but rather that any differences are anchored in local and regional contexts. Issues need to be studied on a case-by-case basis to be fully understood. Despite having less resources available, trade unions in less developed countries display very interesting initiatives. These organisations are a source of inspiration to me, and should be an inspiration to trade unions in so-called developed countries.

"**There are many careers available in labour relations.** Organisations can employ psychologists, behaviour specialists and human relations specialists. Other opportunities include trade union representatives, law specialists, labour economists, labour sociologists, public policy specialists and advisors, as well as an array of researchers, practitioners and consultants in these fields."

Pathway from school to *labour relations*

- Relevant subjects to study at school can vary widely, depending on your ultimate career goals. Examples include business studies, politics, psychology, sociology, communications, computer studies and mathematics.
- At university, Mélanie suggests taking modules in labour relations, which can focus on unionism, collective bargaining, collective representation and grievance processes. Other areas of focus can involve human resources management, organisational behaviour, labour sociology, labour law, labour economy, methodology and public policies.

Explore careers in *labour relations*

- Mélanie recommends talking with researchers, practitioners, consultants and union representatives in different sub-fields of labour relations that interest you, so you can discover what different roles involve.
- Mélanie suggests exploring the websites of societies devoted to labour relations, including l'Ordre des Conseillers en Ressources Humaines Agréés (**www.ordrecrha.org**; in Quebec), the Chartered Professionals in Human Resources (**www.cphr.ca**; in Canada), the Canadian Association of Industrial Relations (**www.cira-acri.ca**) and the Society for Human Resources Management (**www.shrm.org**; globally), all of which provide educational materials and careers information.
- The FTQ's social delegates website has a wealth of information (in French) about the history and mission of the network: **www.ftq.qc.ca/reseau-dentraide-des-delegues-sociaux-et-des-deleguees-sociales**
- The Canadian Union of Postal Workers has information about the role of social stewards: **www.cupw.ca/en/member-resources/social-stewards**

Mélanie's mental health advice *for students*

Take time for yourself! Being able to work and study effectively requires doing enjoyable things, exercising and a good balance between your studies and social life. Don't forget that your brain also needs to rest, not just your body. And don't feel guilty when you decide to rest and enjoy free time for yourself. I often get my biggest research epiphanies when I'm doing something other than endlessly straining my brain!

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Meet *Mélanie*

When I was younger, my career aspirations were constantly changing! I wanted to be an astronaut, a veterinarian, an astrophysicist, an interpreter, an ambassador… My challenge was to choose something! I loved reading, which allowed me to discover endless sources of knowledge and new ways of thinking.

I have always been intrigued by the complexities concealed in human interactions. I have also always wanted to contribute to the well-being of humanity – to help achieve social justice, democratic thinking and our place in the natural world.

> ***I want my work to advocate for a better world for future generations.***

I used to be a union representative, and my own experience of seeing people suffering from psychological distress at work inspired me to focus on studying labour relations and the role of social delegates.

I love being able to fight for high-level ideals. I want to see industrial democracy and equality among workers – and on a wider level, social justice across humanity in general. I want my work to advocate for a better world for future generations.

I have worked with many very inspiring people during my career. Some have suffered a great deal and, in some nations, have even been tortured and jailed because of their social justice activism. I think these experiences have helped my personal growth to being a better human being, as well as convincing me of the importance of fighting for these ideals. I dedicated my PhD thesis to all these people.

Free time is important for mental health. I enjoy reading, Pilates, meditation, walking in nature and spending time with my precious son and my family, cherishing life.

Mélanie's *top tips*

1. Focus on your own strengths and what makes you different and wonderful. Don't compare yourself to other people.

2. Follow your heart and try to find what Japanese people call 'Ikigai' – your purpose in life.

How can photography help refugee men talk about mental health?

Refugees face many threats to their mental health, from the trauma of being forced to leave their home, to the loneliness, financial insecurity and discrimination they may face in their new country. At the **University of Victoria** in Canada, **Dr Nancy Clark** has been working with Syrian refugee men to explore their experiences of resettling into life in a new country. The team is using photography to understand Syrian refugee men's experiences of integration, employment and affects to their mental health.

Dr Nancy Clark

Director of Social Justice Studies, School of Nursing, Faculty of Human and Social Development, University of Victoria, Canada

PROFILE

Fields of research
Social justice, refugee mental health, community-based participatory action research, social determinants of mental health, forced migration, intersectionality

Research project
Exploring Syrian men's mental health and participation in labour employment: a community participatory arts-based project

Funder
This article draws on research supported in part by the Social Sciences and Humanities Research Council of Canada (SSHRC)

Since the Syrian civil war began in 2011, more than half of Syrians have been displaced from their homes, creating one of the largest refugee crises in modern times. While most Syrian refugees live in surrounding countries, including Turkey, Lebanon and Jordan, over 44,000 have settled in Canada. Not only must refugees deal with the trauma of being forced to leave their homes, but they must then overcome the challenges of adapting to life in their adopted country. The process of resettlement has many challenges, such as integrating to a new culture, understanding the language, and finding employment, housing and social support.

At the University of Victoria, Dr Nancy Clark is working with Syrian refugee men to understand their experiences of accessing employment and effects on their mental health and well-being during resettlement in Canada. She is using community-based participatory action research and photovoice methods to uncover how their employment status impacts their mental health.

A key aspect of this project is that Syrian refugee men are active research collaborators, rather than research 'subjects'. Historically, research has treated marginalised communities as objects for study, rather than working with them to find solutions to problems. Nancy's research team includes peer researchers (Syrian refugee men who are helping to lead the project), research participants (Syrian refugee men who are sharing their experiences of employment and mental health during resettlement), employment and settlement counsellors from Options Community Services (a not-for-profit

Talk like a ...

community-based participatory action researcher

Discrimination — unfair treatment due to a person's race, nationality, religion, gender, disability, age, etc.

Mental health — a state of well-being in which a person realises their own abilities, can cope with the normal stresses of life, can work productively and can contribute to the broader community

Gendered — socially constructed roles based on a person's gender or sex

Immigrant — a person who has moved to a different country

Integration — the process of 'fitting in'

Masculinity — societal ideas of what characteristics and behaviours men should have

Peer researcher — a member of a research team who has lived experience of the issue being studied

Photo-elicitation — a research method that uses photos to stimulate discussions

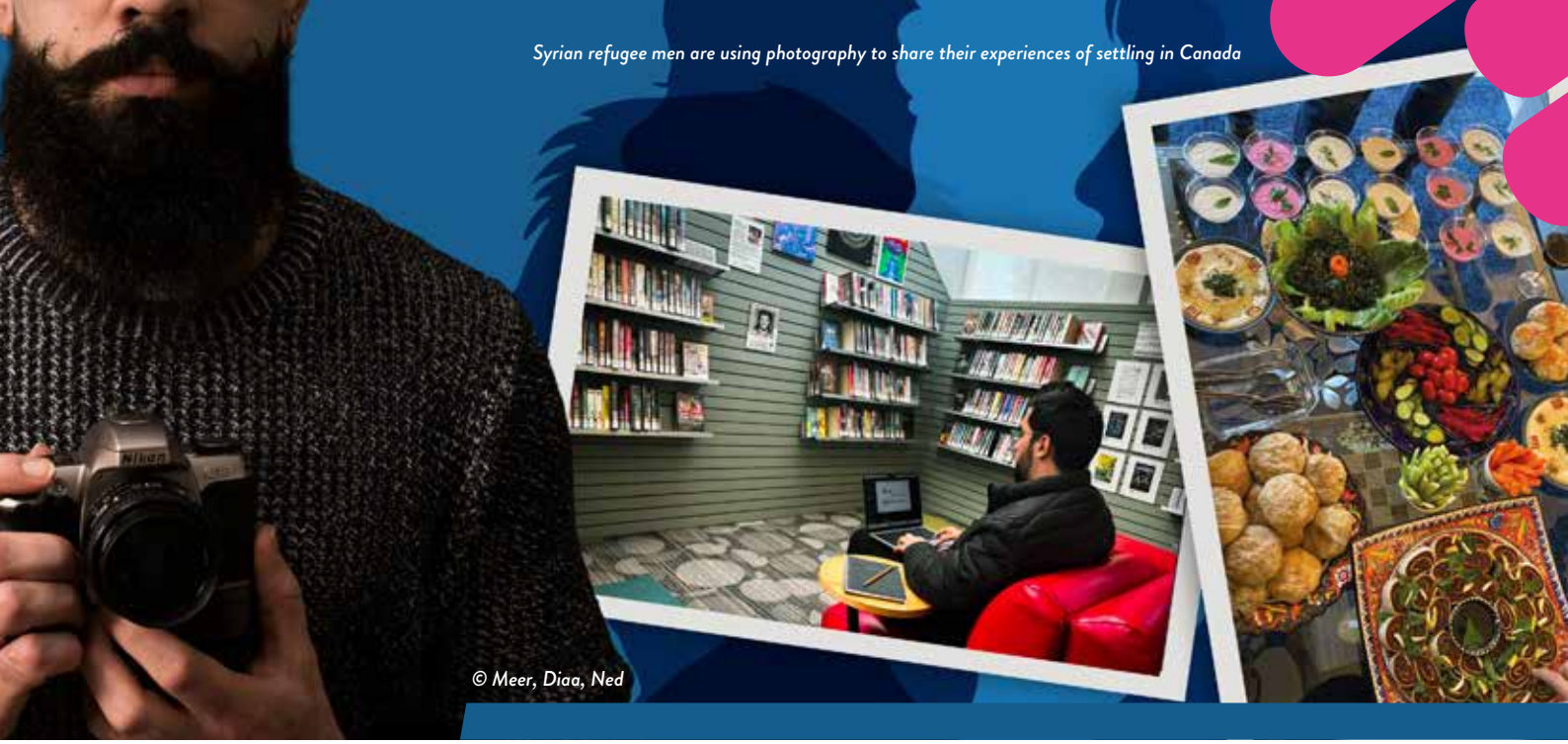
Photovoice — a research method in which participants take photos to translate their experiences into knowledge and to promote action

Refugee — a person who has experienced forced migration as a result of war, climate change, persecution or other factors, and who requires protection

Resettlement — the formal and informal processes of an immigrant's integration

Social determinants of mental health — social, economic, gender, education or other factors which influence an individual's mental health

Underemployed — working in a job for which a person is overqualified



Syrian refugee men are using photography to share their experiences of settling in Canada

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organisation that provides support to immigrants in Canada), mental health specialists and academics.

What challenges do Syrian refugee men face in Canada?

"Syrian refugee men face many challenges during resettlement in Canada," says Nancy. "Our research shows that they experience language barriers, stress, time pressures, isolation at work and difficulties in finding a sense of cultural belonging and identity." Culturally, the need to provide for their family is a high priority for Syrian men, but finding well-paid work is not easy for newcomers. While many of the men involved in the research project had highly skilled careers in Syria, including in civil engineering, architecture and dentistry, they have been unable to continue working in these roles in Canada. This may be because Canadian employers do not acknowledge their experience, skills and qualifications, or because they are excluded from work opportunities due to discrimination.

"This means many Syrian refugee men cannot work in their occupation of choice," explains co-investigator Dr Carla Hilario. "Instead, they are forced to take low-skilled minimum wage jobs for which they are often over-qualified, such as driving delivery trucks or working on factory assembly lines." Among Syrian refugees in Canada, those with higher levels of education report having lower job satisfaction and poorer mental health, as they are more likely to be underemployed.

As the jobs available to them are low paid, many Syrian men are forced to work multiple jobs to make ends meet. This leads to additional challenges as refugee men attempt to adapt to their new life in Canada, and working long hours reduces the time available for integration efforts and activities that promote mental health. "Refugee men are less likely to attend English language classes than refugee women, due to the gendered pressure to earn an income," says research assistant Muna Zaidalkilani. Without the opportunity to learn the local language, integration into the local culture and community becomes much harder, and better-paid jobs remain out of reach.

> **"Syrian men are the knowledge holders. We decide how we want our stories to be told."**

"Economic integration is a key social determinant of mental health," says research assistant Eli Verdugo. "Studies have found clear links between low income, financial insecurity and poorer mental health, highlighting the need for refugees to have access to meaningful work."

The power of photography

Encouraging people to talk openly about their vulnerabilities is difficult at the best of times. "Cultural ideas of masculinity make it particularly challenging to discuss Syrian men's mental health issues," Nancy says. "That was why we turned to photovoice methods."

To initiate discussions about mental health, the Syrian refugee men involved in the project took photos representing their experiences of employment and mental health in Canada. Many took photos while travelling to or from work, often of sunrises and sunsets, highlighting the long hours they work. Photos of things that help the men relax and relieve stress, such as hikes and picnics with family and friends, were also common. These photos became a starting point to encourage the men to talk about their lived experiences during photo-elicitation interviews, by drawing out what the photos represented and meant to them.

"Photovoice methods give a voice to social justice issues through the power of photography," explains peer researcher Meer Mahmoud. "Such methods are particularly valuable for helping people express complex concepts, such as mental health." As a participatory research process, photovoice is a form of storytelling that aims to equalise the power balance between researchers and community members. "Syrian men are the knowledge holders," says peer researcher Ned Izdden. "We decide how we want our stories to be told."

What has the team discovered?

Although the men in the project came from different religious backgrounds, ages and educational levels, there were common themes in their photos. These reflected the similar barriers they have all faced when accessing employment and integrating into Canadian society, and the similarities in things that supported their mental health during their resettlement.

"Loneliness was a common theme, both within and outside work environments," says peer researcher Elias Moses. The men miss friends and family back in Syria, as well as the cultural and social aspects of their lives in Syria before the war. Some feel excluded in their jobs in Canada, as colleagues and employers discriminate against them due to their lack of English or their accent. The greatest sense of connection and support comes from family and social networks, through new friendships, religious communities and connections with family and friends left behind.

"The men wanted to develop a digital storybook that can be given to employers and employment counsellors, to share their voices and experiences in the hope of influencing more inclusive workplaces and better employment opportunities," says Nancy. The team hopes this research will lead to improved employment for refugee men, who have a gendered responsibility for providing for their families, while integrating into a new culture.

About *community-based participatory action research*

Community-based participatory action research (CBPAR) is a research framework that focuses on equity and social justice, aiming to give a voice to communities and work towards positive social change. "CBPAR involves fostering meaningful participation from all involved," explains Nancy. "We advocate for an inclusive process that leverages the strengths of all participants, with the end goal of positive social change." In practice, this involves actively engaging community members in all aspects of the research, from developing research questions and deciding on data collection methods to analysing results and disseminating findings.

Why is it important that people with lived experiences are involved in research about the issues that affect them?

Nancy explains that for research to make a meaningful change, it is important to include people with lived experiences as much as possible. "Our peer researchers were essential for the project!" she says. "They played an integral role in understanding Syrian men and culture, addressing language barriers and building trust."

As Syrian men who have settled in Canada, Ned, Meer and Elias brought their personal experiences to the project. "We act as a vital link between the research team and our participants, offering essential support and guidance throughout the research process," says Ned. As Elias explains, "We have shared backgrounds with the participants which helps build trust, which is crucial for collecting authentic and meaningful data." Ned, Meer and Elias helped recruit research participants from the Syrian community in Canada, conducted the research interviews, provided interpretation and translation services, and supported the men.

"Many researchers forget that community members are knowledge holders," says Nancy. "They bring unique knowledge and perspectives that can improve both the research process and its impact." Peer researchers are, therefore, essential for meaningful CBPAR. "Policy interventions often lack the voice of the people affected by the issues they are trying to address," says Nancy. "We want to ensure that our research respects the voices of the Syrian refugee men involved and provides meaningful outcomes for them." Through the research process, the men all developed relationships with each other, fostering connection and community.

Why is it important that CBPAR is tailored to the needs of the community?

CBPAR should be culturally tailored to the preferences of the individuals involved to ensure it is inclusive. "For example, our workshops always involved food," says Nancy. The team purchased food from a nearby Syrian bakery to share with the men, which created a sense of community among the team. "We also had to consider that some men had to pray at the nearby mosque during the day, so we allocated breaks in the workshop schedule to accommodate this." As reciprocity is a key aspect of CBPAR, all participants were compensated for their involvement in the project, with the team paying for their travel and childcare support during the workshops and interviews.

Meet *the team*

Dr Nancy Clark

Project leader

When I came to Canada as a young child, I experienced severe racism and discrimination. As a Palestinian immigrant, my father struggled to continue his degree in political science when he arrived in Canada, and instead spent most of his life working as a labourer, painting houses. Both my parents were unable to work in their chosen fields, and I saw the toll this had on their mental health and well-being. As a result, I have devoted my professional career to supporting those who do not 'fit in', specifically people who experience forced migration and are affected by social determinants of mental health.

I studied nursing because I was interested in health and helping people who are marginalised. After years of working as a community mental health nurse, I am passionate about getting to the root causes of mental health issues and uncovering the factors that support mental health.

I was inspired to investigate the gendered experiences of migration because most refugee research focuses on women. While working with Karen refugee women from Myanmar and Thailand, I realised that men's experiences of immigration were very different. Having access to meaningful employment is especially important for men's mental health due to masculine ideals and pressures of providing for their families. Resources and support should be equally accessible to the whole family.

I hope to make a significant contribution to advancing health equity for refugees. I intend to advance my research in addressing the social determinants of refugee mental health and, importantly, I aim to improve health systems and services.

Dr Carla Hilario

Co-investigator

I was inspired to study nursing because of my mother, who had multiple health issues. But also because I wanted to understand how I could improve people's experiences of health and illness. As a health researcher, I have examined the social context of mental health for young immigrant men in Canada. I am excited to be part of this project as it aims to support the mental health of refugee men, and I am motivated by the potential impacts it will have on individuals.

I contributed my experiences and expertise in qualitative and arts-based methods to this project. In my previous research, I have used photo-elicitation and participatory videos to explore mental health issues.

I really enjoy seeing the photos that the Syrian men took. These photos illuminate the conditions they face and highlight aspects of their lives that influence their mental health.

Eli Verdugo

Research assistant

I am a master's student studying the social determinants of health. I joined this project because I believe that community-based research is key to addressing inequalities. It is essential for understanding the experiences of different populations, especially those who have historically been marginalised, such as people with forced migration experiences. I believe this study has the potential to raise awareness of the experiences of Syrian refugee men and to promote change.

Getting to know the study participants has been hugely rewarding. Although I don't speak Arabic, it has been wonderful to connect with the men and to enjoy Syrian food and music together. Seeing their photos and listening to their stories has been very moving, and I believe that if we can raise Syrian refugee men's voices then we can change the perspectives of employers and service providers in Canada to better support them.

I founded La Paz es Diversa, a community support group and non-profit organisation, to promote LGBTQ2+ rights in my hometown of La Paz and in the wider state of Baja California Sur, Mexico. As a queer person, I am passionate about providing safe spaces and support for queer youths. As a researcher, I hope to increase knowledge about LGBTQ2+ issues that helps my community and contributes to public policy changes.

Muna Zaidalkilani

Research assistant

I have spent many years serving refugees as they settle in Canada. Having noticed that there is a critical gap in the provision of mental health support for refugees, and witnessed the implications of this, I was eager to join this project as it provides the opportunity to address this critical need.

It has been rewarding to see how we have created a safe, non-judgemental space for Syrian men to share their stories and express their creativity, and to learn how it has fostered a profound sense of belonging among the men.

Canada has become my new home, and I relish the natural beauty, freedom, high quality education and ability to make a positive impact that I have access to here. However, I miss the warm camaraderie of the people in Jordan, the singing birds, my mother's Palestinian home-cooked food and the breezes of our region.

Many refugees are forced to take low-skilled minimum wage jobs © Taleb

Elias Moses

Peer researcher

I believe in the power of research to drive positive change and to improve the lives of marginalised communities. I was motivated to join this project as it focuses on human rights and disrupting negative narratives, which aligns with my values of promoting inclusivity and social justice.

The personal connections I've formed with the Syrian men participating in the research have been my highlight of the project. It has been incredibly rewarding to build trusting relationships and hear their stories. It is also inspiring to witness the potential impact of our research on policies and services aimed at supporting refugees, and it's gratifying to know that our work could lead to positive changes in the lives of many people.

I work as a settlement and employment counsellor with Options Community Services, where I provide practical guidance and support to newcomers as they navigate the challenges of finding employment, accessing resources and adapting to a new culture. It is rewarding to support people in their resettlement journey as they become active contributors in their new community.

Meer Mahmoud

Peer researcher

As a Syrian refugee man who has settled in Canada, I was excited to join a research project that investigates the challenges I face in the labour market. I was also motivated to use photography as a medium to communicate and document the stories that Syrian men want to share.

I am passionate about photography, and one of my roles in the project was to teach photography skills to the participants. This was the first time I have had the chance to use photography and art to address real-life problems, which I find inspiring.

The sense of community and connection created among the project participants has been a highlight for me, as I really miss the connections and community I left behind in Syria. I also enjoy listening to the stories and learning about the experiences of men who come from the same place as me.

Ned Izdden

Peer researcher

Having personally experienced the challenges of settling in Canada, this research project resonates deeply with me. It has been eye-opening to witness the shared challenges faced by members of the Syrian community, regardless of their educational background, career or religion. Gaining insights into the current economic difficulties in Canada has deepened my understanding of these struggles, and it has been enlightening to recognise that understanding these problems is the first step towards finding viable solutions.

My feelings about Syria are complex and deeply rooted. When I came to Canada, I hoped to leave behind the trauma and memories of my past. I was eager to start anew, and I tried to distance myself from the Syrian community. However, I've come to realise that, like an olive tree, my roots run deep in my homeland. Uprooting myself may risk losing a vital part of my identity. I can't escape my enduring connection to the Syrian community, as I share in its struggles, aspirations and dreams.

> ***"Like an olive tree, my roots run deep in my homeland."***

In Canada, I cherish the freedom to express myself, pursue my passions and engage with diverse cultures, and the natural beauty that surrounds me brings immense joy. But I yearn for my family, my neighbourhood, my city and the nostalgic memories of my life in Syria.

The Community Advisory Board for the Syrian men's photovoice project © Meer

Options *Community Services*

"Options Community Services is a multiservice agency that provides a range of services and support to underserved and marginalised communities," says Jenny Lam. This includes mental health, employment, education, housing and language learning support to help immigrants settle into their new life in Canada. This research project was developed in partnership with Options, which provided the space for hosting workshops, helped recruit participants and shared the knowledge and expertise of staff who work closely with Syrian men to help them achieve their employment goals in Canada.

The involvement of the Options team has been essential for the project's success, and the Options team members themselves have also benefited from participating in the research. "I enjoyed the opportunity to be part of a project that focused on a very specific population," says Iris Solorzano. "This allowed us to reflect on ways to use culture to support Syrian men as they overcome trauma and proceed on their resettlement and employment journeys." As Jagjit Gill highlights, it was enlightening to hear the stories shared by the participants: "I have enjoyed seeing the growth that Syrian men have accomplished through their resettlement journey."

Many photos represent things that bring the men joy © Taleb

"The knowledge gained from this research project will help our employment and settlement staff better understand the challenges faced by Syrian refugee men and customise our support accordingly," says Rima Moubarak. Diana Delgado is committed to creating new services to better support refugee men as they settle into life in Canada. "As a woman, it was empowering to validate that fact that men also need support," she says.

The workshops took place at Options Community Services, located in the traditional territories of the Semiahmoo, Katzie, Kwikwetlem, Kwantlen, Qayqayt and Tsawwassen First Nations. The Truth and Reconciliation Commission of Canada exposed the terrible legacy of the Indian Residential School System and the on-going trauma for survivors. The ongoing legacy of colonisation has impacts for refugees and other newcomers who have also been forced away from their homes and given minimal options to build a new life.

The team's *top tips*

- Remember that diversity is a strength. Appreciate and respect the cultures around you, and embrace your own cultural roots with pride, as they are an essential part of who you are.
- Take care of your mental health. Remember, it's okay to ask for help, so reach out to professionals or support groups if you ever need support.
- Continuously strive to become a better version of yourself, and surround yourself with people who believe in you, motivate you and make you think critically.
- Don't fixate on a rigid plan. Instead, be curious and flexible, follow your intuition and be ready to explore new areas of life.
- Take control of your destiny. Aim to be a decision-maker in your life's journey, rather than a passive follower.
- If you are embarking on a resettlement journey, seek support from community organisations, settlement agencies and fellow newcomers to help you adjust and adapt, and take advantage of any resources and services that will help you achieve your potential. Take time to find local not-for-profit organisations where you can develop social support systems to practise your language skills and develop friendships.

The heroines of heavy metal: how are female artists challenging genre norms within the music industry?

Music has been a fundamental form of human expression for thousands of years. We use it to tell stories to each other, to make sense of our emotions, and to articulate moments of cultural significance. Over the years, music has evolved and diversified into countless different genres, each of which conveys the cultural values of the musicians within it, as well as the people who consume it. At the **University of Ottawa** in Canada, **Professor Lori Burns** has been investigating how artists develop new ways of working within genres to express themselves freely and transform cultural conventions.

Professor Lori Burns

School of Music, Faculty of Arts,
University of Ottawa, Canada

PROFILE

Field of research
Popular music studies

Research project
Investigating how female vocalists are impacting the genre of heavy metal music

Funder
Social Sciences and Humanities Research Council of Canada (SSHRC)

Talk like a ...

popular music researcher

Disruptive divas — trail-blazing female musicians who have revolutionised the genres in which their music participates

Gatekeeping — using a position of power to control which artists are given opportunities

Genre — a category that is used to identify music based on its style, origins and cultural influences

Identity — the distinguishing features of an individual's personality, ethnic and racial background, gender and sexual orientation and physical characteristics that they consider to be a fundamental part of who they are

Misogynistic — negatively prejudiced against women

Spectogram — a visual representation of sound frequencies

The desire to be seen, understood and accepted for who we are is a fundamental part of human nature. For many of us, expressing ourselves is not easy, especially if we have not yet found our own voice or others make it difficult for us to use it.

The avenues through which we find self-expression are as unique and varied as we are, ranging from the art we create and the food we cook to the stories we tell and the conversations we have with strangers.

Music is a form of self-expression that resonates with a lot of us. Even if we do not play an instrument or write our own songs, listening to music can often help us understand those thoughts and feelings that we struggle to express or articulate ourselves. Through music, we can find expression for how we feel, who we are, and where we belong.

The beauty of music is that it helps us connect with our feelings and beliefs and, by extension, with other people who share the same feelings and beliefs. This sense of harmony and communion with fellow music fans helps to create tight-knit communities, where musicians and fans alike build a set of common values.

But what happens if these music communities exclude certain types of people and identities? "One of the challenges for popular music expression is that genres rely upon conventions that exclude some people from taking part," explains Professor Lori Burns, a music analyst from the University of Ottawa's School of Music. "Many genres of music are grounded in exclusionary practices in which a particular identity is dominant, which can leave people of different identities feeling unwelcome and unheard." With her current focus on heavy metal music, Lori is investigating how musicians can break down genre-defining rules and find new ways of expressing themselves.

Why is music so powerful?

"Music has a tremendous cultural reach," says Lori. "People can access music through many different channels – from radio stations, streaming platforms and social media to concert venues and festivals. With this level of accessibility, everyone can listen to music and focus on the styles and genres that most appeal to them."

"The music itself – no matter what style and genre – arises from culture and expresses social values," continues Lori. "It is important that members of society are able to make sense of the cultural and societal values that are being voiced through the music." This is particularly important because music has the power to influence how we feel about and communicate our identity.

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How are genre and identity intertwined?

The array of musical genres that we have today arose from the ways in which different cultural groups and individuals felt the need to express their experiences. For example, hip-hop originated in the South Bronx, a poverty-stricken district in New York City in the US. During the late 1970s, in an effort to escape the violence of a rampant gang culture, members of these largely African-American communities turned to music.

"Composers, performers and producers are human beings whose experiences and perspectives play a part in the musical stories they tell and how they tell them," explains Lori. "To succeed in a genre, artists must find a balance between shaping their expression to respect the conventions of the genre they are contributing to, while also communicating something of their own identity." This can make things difficult for artists who want to express themselves through a genre that does not conventionally align with their identity.

What is gatekeeping?

"The conventions that are associated with genres function like rules that are not always acceptable to break," says Lori. "If a musical artist's identity or manner of musical expression sits outside of these rules, that identity might not be understood or endorsed." For example, Black female artists have often found it challenging to break into certain popular genres.

Some individuals in the music industry are in positions of power. For example, artists and repertoire (A&R) executives decide who gets signed to a music label, and booking agents choose which artists play on certain shows. Gatekeeping occurs when these people pick and choose who gets signed to their label or who plays their show based on an artist's identity, rather than their music. This can further solidify the link between genre and identity, preventing musical genres from evolving.

> ***"The conventions that are associated with genres function like rules that are not always acceptable to break."***

How is the genre of heavy metal evolving?

Typically, heavy metal music has been seen as a predominantly white, male and heterosexual form of expression. "The messages within metal music often focus on male perspectives," says Lori. "The images in album artwork, posters and music videos are sometimes misogynist in their depictions of women."

For years, the majority of metal musicians have been men, and only a handful of women have been successful within the genre. "All of this is changing," says Lori. "Now, there are women in all aspects of metal production and performance, although they remain a small percentage." Lori has spent the last few years studying and analysing how the metal genre is being influenced by an influx of female musicians.

How are female artists breaking the mould of heavy metal?

In the past, female metal artists have been expected to squeeze themselves into the conventional styles and images of the genre. "However, there are ways to challenge these norms," assures Lori. "There are spaces – sound spaces and visual spaces – that women do not typically occupy." By going against the grain and entering these spaces, women can drive innovation within the metal genre.

"For instance," continues Lori, "the harsh vocal space is becoming more available to female vocalists, but it can still surprise listeners to hear heavy metal singers Tatiana Shmayluk or Floor Jansen deliver vocals in a deep growling register." As listeners, we become accustomed to hearing women perform in certain styles. When these expectations are challenged, the effects can be transformative.

"Cammie Gilbert is a brilliant vocalist and composer who does not adhere to a single set of genre conventions," says Lori. "Based on her skills and expressive abilities, she is pushing contemporary metal music into new sounds, styles and messages." For example, Gilbert's band, Oceans of Slumber, released a cover of 'Strange Fruit', a song originally by Billie Holiday, a US jazz singer, in 1939. The song deals with issues around racism, a topic that has not typically been discussed within the metal genre.

How have pioneering female artists influenced music?

Lori has spent her career studying ground-breaking female artists, who she likes to call disruptive divas. "The disruptive divas I have studied over the past 30 years have all changed the sounds and images of the popular genres in which they have recorded their music," she explains. "They have used their voices to tell new stories, develop new modes of expression, resist societal norms, pave the way for new understandings, speak out against injustice, and proclaim the urgent need for equity."

What is next for Lori's research?

Lori is currently writing a book about female-fronted metal music with her son, Patrick Armstrong. "This book is taking an innovative form and offers a new model for interpretive research on women artists," Lori explains. "I would like to complete this project and then turn to the genre of punk rock, which is another important space for female voices."

About *popular music studies*

Music has been an integral part of human culture for thousands of years. In fact, the earliest evidence of humans creating music comes from a 45,000-year-old bone flute that was found in a Slovenian cave. Since then, music has evolved into countless forms and genres, from religious chants and sea shanties to electronic synth-pop and hardcore drum and bass.

With such an immense range of styles to consider, the potential scope of musicological research is practically endless. Often, musicology is split into three categories; historical musicology, which considers the origins and evolution of music throughout history, systematic musicology, which includes technical aspects of music such as musical theory, and ethnomusicology, which explores how and why different cultures create music.

How does Lori conduct her research?

"I analyse song lyrics, music, video images and live performances. I begin with a thorough analysis of each individual element, and then I interpret the ways in which these layers intersect," says Lori. Looking at these different layers – and how they relate to each other – enables her to explore the messages that are being expressed in popular music culture.

She also uses visualisation tools to interpret the sonic features of recorded music. "A spectrogram analysis of a recorded track reveals how the pitch frequencies (notes in different registers), timbres (sound qualities), and dynamics (levels of intensity) are articulated in and through the musical gestures," explains Lori. "A spectrogram allows me to 'see' the music in real time."

What is rewarding about being a musicologist?

Lori is constantly collaborating with students and other scholars. For example, she is currently editing several books that include chapters written by other people. "This activity alone puts me into scholarly discussion with over 100 researchers from around the world," says Lori.

As well as working with other scholars, Lori spends a lot of time on her own research, analysing and interpreting songs, videos and artists. "I continue to be grateful for this creative and instructive vocation," she says. "It is rewarding to witness how the field of music continues to evolve over the years."

What research topics will be available to the next generation of musicologists?

Aspects of identity such as gender, sexuality and race are constantly being discussed in our society. Music is one vehicle through which we can have these conversations. Musicologists will spend a lot of time tracking how these conversations are expressed through music and the influence that music has on how society views identity.

"With new forms of media and communications becoming available," says Lori, "it is easier both to create innovative and reflective materials to share with the world and to have access to these new perspectives." Researchers may study how these new platforms extend the influence that music has in conversations about identity.

Pathway from school to *popular music studies*

- Studying music is not just about learning how to play an instrument; music students also learn about music theory, the history of music, and the context of music in society and culture.
- Lori encourages students to cast a wide net and listen to a range of music: "Try not to study only what you like, but rather expose yourself to music of all varieties."
- "Once in the process of studying a particular music," says Lori, "learn the language that is used in relation to that music so that you know how to speak about it and participate in a solidly grounded critical interpretation."
- See a range of live music events, from open mic nights to local gigs, to orchestral concerts. This can be a great way to find new music and get chatting to people who share your interests.

Explore careers in *popular music studies*

- Whatever area of music study you are interested in, there will be global, national and local societies that publish journals, host events and build research opportunities and communities. Some examples include the Society for Musical Analysis (**www.sma.ac.uk**), the British Association for Music Therapy (**www.bamt.org**), and the International Musicological Society (**www.musicology.org**).
- Find some music magazines or publications that interest you and read their reviews. This can be a good way to start understanding how to think about music critically. Try Pitchfork Magazine (**www.pitchfork.com**), Gramophone (**www.gramophone.co.uk**), or Songlines (**www.songlines.co.uk**) for a range of different genres.

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Meet *Lori*

In my Bachelor of Music undergraduate degree, I had many professors who encouraged and mentored me to pursue a passion for musical knowledge.

Through my own listening and watching practices, I am sometimes exposed to a musical work or genre that compels me to inquire further. It might be the message of the song, a particular form of representation, a performative issue, or a set of narrative materials attached to the song/video/album/concert. Sometimes, the choice to work on a particular example results from collaboration; for instance, when a student or colleague raises a question about a song or video that leads to a mutual decision to pursue the work together.

I usually listen to the music I am currently studying, as well as related music that reflects a similar genre or style. As a result, my listening emphasis changes in keeping with my work. I do enjoy music in my free time. Usually, I discover something that I want to listen to repeatedly. I have never lost my love for listening and responding to the driving patterns and emotional expression of music.

Researchers confront obstacles all of the time, whether they are analytic and critical concerns, difficulties with a challenging assessment of our work, or debates within the scholarly discourse. I always solve problems through consultation and collaboration. The first thing I do is reach out to a colleague and explore the problem.

I am proud of the body of work that I have developed over a sustained career dedicated to the subject of gendered subjectivity in popular music. I am especially proud of the relationships I have formed with students and scholars along the way. My long-standing collaborations with Marc Lafrance (Concordia University), Jada Watson (University of Ottawa) and Alyssa Woods (University of Guelph) have been intellectually stimulating, productive and rewarding.

Most recently, I have been focusing on collected editions of essays which, although very demanding work, is something that I am very proud of. These volumes reflect the themes and critical issues that have been most important to my career, and they are all the result of collaboration and mentoring. These collections explore the topics of intertextuality in popular music recordings (co-edited with Serge Lacasse), popular music video (with Stan Hawkins), analysing recorded music (with William Moylan and Mike Alleyne), the compositional structures of metal music (with Ciro Scotto), progressive rock/metal and the literary imagination (with Chris Anderton), and vivid cover versions (with Mike Alleyne).

My aims for the future are to continue to work with diverse students and scholars and to facilitate critical understanding of music that is culturally significant and transformational.

Detecting deepfakes: how can we ensure that generative AI is used for good?

The field of generative artificial intelligence (AI) is advancing at an astronomical pace. As a result, deepfakes – manipulated pieces of media using generative AI technology and designed to trick their viewers – are becoming more convincing, prevalent and problematic. **Professor Siwei Lyu**, based at **University at Buffalo, The State University of New York** in the US, is determined to halt the advance of deepfake media and ensure that generative AI is used for the good of society.

Professor Siwei Lyu

SUNY Empire Innovation Professor, Department of Computer Science and Engineering, University at Buffalo, The State University of New York, USA

Fields of research
Media forensics, generative AI, computer vision, machine learning

Research project
Developing techniques for detecting and mitigating deepfake media

Funder
US National Science Foundation (NSF)

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PROFILE

Talk like a ...

media forensics researcher

Artefacts — irregularities or uncommon features in manipulated or synthesised media content that expose their unauthentic nature

Artificial intelligence (AI) — computer algorithms that can learn from data and experience to perform tasks which would usually require a human level of intelligence

Deepfake — digital media content created or manipulated using generative AI, most commonly used for images and videos

Disinformation — false information that is deliberately fabricated and spread to deceive or mislead people

Generative AI — a type of artificial intelligence capable of creating a wide variety of data, such as images, videos, audio, text and 3D models

Media forensics — the subfield of AI that aims to detect and mitigate manipulated or synthesised media using AI algorithms

How would you feel if you were scrolling through Instagram or TikTok and came across a video of yourself that you had not created or were even aware of? What if the video showed you doing something you would never do or saying something that you disagree with?

In March 2022, just a month after Russia launched its invasion of Ukraine, a video was released showing the Ukrainian president, Volodymir Zelensky, calling for his troops to surrender. Upon closer inspection, the video was quickly identified as a deepfake, a piece of media modified with generative AI models and designed to trick the viewer.

Luckily, the deepfake of Zelensky was fairly easy to spot as the image of his head and his voice were clearly inauthentic. However, just a year and a half after its release, advancements in generative AI have made deepfake videos much harder to identify. The improving quality of deepfake media is making many people nervous about the potential harm that the technology could cause.

Professor Siwei Lyu, a computer scientist at University at Buffalo, The State University of New York, is a leading expert in the field of generative AI and media forensics. Much of Siwei's research focuses on the detection of deepfake media, although his expertise spans the whole field of generative AI.

What is generative AI?

In order to understand what generative AI is, we first need to clarify what we mean by the term 'AI'. Artificial intelligence, or AI, refers to algorithms and systems that can learn, predict and, in some cases, create. Algorithms and tools that have this creative ability are known as generative AI, and they can be used to fabricate media such as images, videos and audio.

Recent advancements in the field mean that generative AI systems can now learn by analysing photos, audio and videos that are widely available on the internet. As a result, it has become cheaper and

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easier for users to create convincing fake media, created to deceive the viewer, in large quantities. "Since 2015, generative AI technologies have experienced astronomical development, with new methods showing up on a monthly or even weekly basis," says Siwei.

Although generative AI is often used to create deepfake media, researchers in the field are convinced that the technology can also be used for good. For example, a new generative AI algorithm is being used to help rehabilitate stroke patients who have lost their ability to speak. The algorithm translates the patient's brain activity into simulated speech that resembles their old voice. Such technology will have a hugely positive impact on the patient's everyday life.

What are the dangers of deepfakes?

Deepfakes can pose significant threats to society. "Personal security risks emerge as deepfakes can be used to fabricate convincing yet false representations of individuals," explains Siwei. "This can lead to reputational damage and psychological distress for anyone whose personal images or videos can be accessed by people using AI to produce deepfakes."

At a wider scale, deepfakes can impact our democratic processes by spreading disinformation. "By creating illusions of an individual's presence and activities that did not occur in reality, deepfakes can influence our opinions or decisions." This can become a particular issue around election time, when people are trying to decide who to vote for based on things they see and read online.

As the field of generative AI continues to develop, deepfakes will become more powerful but so will our methods of detecting them. Siwei compares the situation to developing vaccines to combat a virus. As vaccines improve, viruses evolve new ways of overcoming them, so scientists have to work even harder to develop new vaccines.

How can we detect deepfakes?

Although deepfakes are becoming more convincing, it is possible to detect them simply by looking closely to find artefacts. The generative AI models that create deepfakes are trained on enormous amounts of data, but they have no understanding of the laws of physics or how the human body works. This means that they often make mistakes, which attentive observers can pick up on.

For example, AI models are often trained on thousands of images of human faces downloaded from the Internet however, almost all of the people in these images will have their eyes open. As a result, the simulated people in many deepfake videos do not blink, which is something that viewers can spot relatively easily. Other errors to look out for are missing teeth when someone is talking, hands that have the wrong number of fingers, and the reflections/light flecks in eyes pointing in different directions.

Unfortunately, as generative AI models become more sophisticated, deepfakes are becoming harder to spot, even if you know what to look for. To address this, Siwei has developed tools that can detect deepfakes that even a trained human would struggle to identify.

Whilst genuine videos come directly from the real world, deepfakes have been stitched together from a variety of sources. The process of stitching the deepfakes together is not perfect and often leaves minor inconsistencies or visual errors, known as artefacts or noise, that do not appear in the original media. Siwei likens his detection tools to X-ray scanners that can see inside deepfakes and uncover artifacts that might not be visible to the human eye.

How else can we stop deepfakes?

Detection methods can be effective at spotting deepfakes, but what if we could prevent deepfakes from being created in the first place? "Unlike detection methods, the pre-emptive approach directly obstructs the training or generation of deepfakes," explains Siwei. "One idea is to 'poison' the would-be training data by adding specially designed patterns."

These patterns disrupt the generative AI's training process and cause the AI models to create low-quality deepfakes. For example, one of Siwei's methods deliberately adds unnoticeable patterns into the original media, making it hard for generative AI models to detect faces. This could prevent one of the most common methods of creating deepfakes, which involves inserting someone's face into a video that they did not actually appear in.

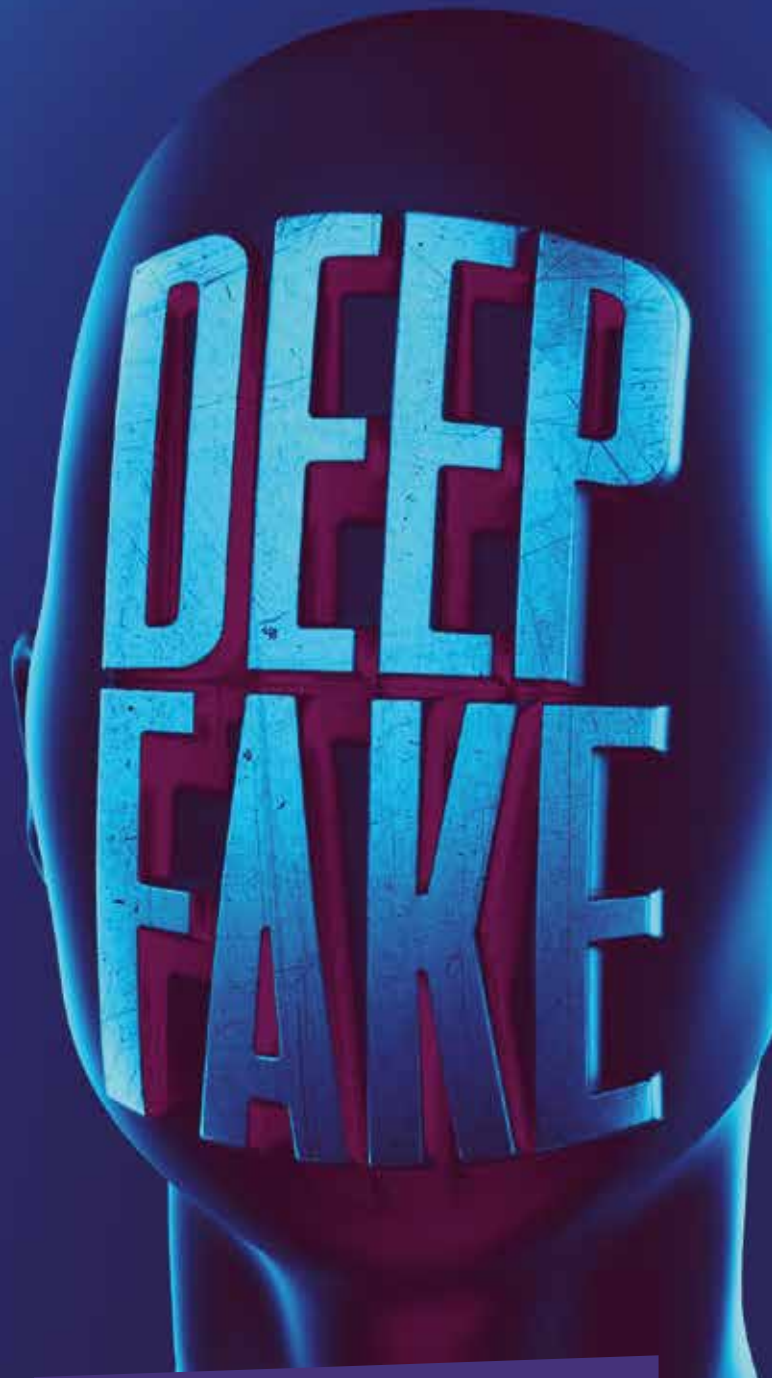
What does the future of generative AI hold?

"Looking into the future, we will continue to see accelerated development of deepfake technology," says Siwei. He predicts that we will see new generative AI models that can create deepfakes that look more realistic and have fewer artifacts. "In the not-too-distant future," continues Siwei, "ordinary users may have access to more easy-to-use and ready-made tools to manipulate media in the same way that they use Photoshop to edit images today."

Although deepfake technology will become more accessible, Siwei is not too worried about the consequences. "I don't think it will necessarily lead to a future of dooming dystopia or an apocalypse!" he says. "Human brains are unbelievably flexible and as we are seeing more synthetic media created with generative AI, our ability to cope with them will evolve." For example, in the early 2000s, spam emails were becoming a huge problem until we learnt how to spot them and developed technologies to help protect us.

"We must continue developing deepfake forensic methods that are more effective, efficient, robust and explainable," says Siwei. In doing so, he, and other researchers like him, will help to halt the progress of deepfake technologies and ensure that generative AI is used for the good of society.

About *media forensics*



The field of generative AI research is growing rapidly as these tools become increasingly powerful and sophisticated. We are always learning more about the potential impacts of generative AI, both good and bad, so there is always new research to be done.

Rewards

"The most rewarding experience of my research is when I see that I can have a real impact on society," explains Siwei. "The unique nature of media forensics puts me in the frontier of one of the most vexing challenges of this century." Siwei often meets with journalists, government officials and members of the public to help them understand the situation and provide expert advice.

"On a more personal level, I like puzzles and games as pastimes," says Siwei, who sometimes imagines that his research in media forensics is a game of cat and mouse that he plays against the people who make deepfakes. "The intention to beat the other party is one important motivation for me to continue exploring my research work," he says.

Opportunities

"The current situation with AI, and particularly with generative AI, has taught us that technologies must be developed with adequate consideration to their potential impacts on humanity and society," explains Siwei. "These tools are going to be woven into the fabric of our lives."

Over the coming decades, we will begin to see the development of 'responsible AI' and 'trustworthy AI'. These new generations of AI will focus on human and social impacts, instead of solely focusing on the technology. "This will create many challenging and exciting research opportunities for the younger generation of computer scientists," says Siwei.

Pathway from school to *media forensics*

- Siwei says a solid foundation in mathematics is critical. In particular, calculus, linear algebra, and probability are vital to computer science.
- More advanced topics such as signal processing, optimisation, and statistical analysis are stepping stones to understanding AI and machine learning.
- Programming is another indispensable skill. You must be able to write code in various programming languages, such as Python and Java, and think using programming terms.

Explore careers in *media forensics*

- Societies such as the Institute of Electrical and Electronics Engineers (**www.ieee.org**), the Association for Computer Machinery (**www.acm.org**), the International Association for Pattern Recognition (**www.iapr.org**), and the Association for the Advancement of AI (**www.aaai.org**) provide education and careers resources and often have student memberships.
- Joining these societies and taking advantage of their seminars, tutorials and conferences can be a great way to keep up with the latest developments in the field. They are also good for building a professional network and making connections.
- Contact generative AI researchers and scientists and ask them questions, both about their research and their career progression.

Meet *Siwei*

When I was in high school more than three decades ago, I had a classmate who had a CASIO programmable calculator. It had some primitive graphics, and you could program simple games on it, like canon ball shooting. I was immediately fascinated and would work on it for hours, exchanging playing cards and other goodies just to be able to play with it longer. That was my first interest in computer science, and it made me want to write computer programs.

Focusing on media forensics happened by chance. When I started my graduate study at Dartmouth College in 2001, my attention was caught by a lecture given by Professor Hany Farid, who is a pioneer in media forensics. In the lecture, Hany discussed the research that he was working on at the time, which needed a classification algorithm. I happened to be studying a more recent classification method, so, after the lecture, I went to his office and offered to try my method on his problem. Fortunately, my method worked and improved the performance significantly. That was the basis of my first academic paper and the starting point of a long and continuous collaboration with Hany, who supervised my PhD thesis.

My encounter with deepfakes started at a conference I attended with Hany in 2018. Deepfakes were a new phenomenon at the time, and I was instantly interested. Detecting deepfakes falls into my research areas of machine learning and media forensics.

My proudest achievement is that I was the first researcher who understood the significance of combatting deepfakes. I developed the world's first dedicated detection method of deepfake videos by capturing an artifact in 2018.

My career goals are to continue research in mitigation technologies of deepfakes and to train the next generation of researchers to work in this crucially important and exciting research area. I will also put more emphasis on public outreach and education programmes on this topic, to improve society's overall awareness and resilience to the new challenges posed by generative AI.

Siwei's *top tip*

Stay curious — research in computer science can be a lengthy, difficult process. The curiosity to solve a problem is often the only driving force that helps us find the answers.

Meet *Shan*

Dr Shan Jia is a research scientist in Siwei's lab.

Funder
US National Science Foundation (NSF)

I participated in a research project on image restoration during my junior year in college. I really admired the magic of using computer science to solve real-world problems. That experience inspired me to delve deeper into the field.

Participating in an exchange student programme at West Virginia University had a profound impact on me. This experience shaped the research direction of my career, motivating me to contribute to the fields of information security and media forensics.

One of my eureka moments came during my visit to Madame Tussauds Hong Kong. The highly realistic wax figure faces made me realise the potential threat of such 3D face models as face presentation attacks to face recognition systems. This insight led me to research the threat posed by 3D face spoofing attacks and to develop novel detection methods to identify these spoofed faces.

My primary role in Dr Lyu's lab involves conducting research in media forensics and taking charge of media synthesis research projects. Additionally, I provide guidance to graduate students and lead new research initiatives as an assistant lab director.

One of the primary technical challenges I face is ensuring the performance and reliability of our media forensics methods in practical scenarios. This demands enhancing the generalisation ability of our algorithms and effectively addressing potential biases in detection. The field of computer science is evolving rapidly, so ensuring that I'm up-to-date with the latest trends and technologies is both a challenge and a necessity.

I have authored/co-authored 11 academic papers within this role. I have served as a reviewer for over 10 international journals and conferences and co-supervised more than 4 students.

In the short term, I'm focused on contributing to top-tier publications. In the long run, I hope to leverage my expertise to provide effective information security solutions for practical scenarios.

Shan's *top tip*

Nurture authentic curiosity. It fosters strong motivation and critical thinking, which are crucial for doing research.

The amazing complexity of ecological metacommunities

Ecosystems are hugely complex. Every animal, plant, fungus and microbe is interacting with countless others, as well as with their ever-changing environment. Understanding these intertwining relationships is highly challenging, but **Dr Mathew Leibold**, from the **University of Florida** in the US, believes it is possible. He champions the concept of 'metacommunities', which can help us appreciate how ecosystems function and are affected by human activity, and how we can conserve our natural world.

Dr Mathew Leibold

Department of Biology, University of Florida, USA

PROFILE

Fields of research
Community ecology, aquatic ecology

Research project
Using the concept of metacommunities to understand complex interactions of species within ecosystems

Funder
US National Science Foundation (NSF)

Biodiversity describes the variety and abundance of life found on our planet. An ecosystem's biodiversity broadly refers to the makeup of different species found within it. "Biodiversity is beautiful for its own sake," says Dr Mathew Leibold, from the University of Florida's Department of Biology. "Moreover, there is plenty of evidence that high biodiversity is important for maintaining ecosystems that are useful to humans." Benefits of intact ecosystems are countless – they can provide us with food, fresh water, defence against natural disasters, new medicines, and much more.

Every species in an ecosystem interacts with others; predators depend on prey to feed, plants depend on predators to keep herbivore numbers down, and so on. Higher biodiversity leads to a more complex ecosystem, especially as species affect each other in complex webs of interaction, and this complexity is important. For instance, if a species within a complex ecosystem becomes extinct, chances are that there will be other species that fulfil a similar role that can take its place. If a species in a simpler ecosystem becomes extinct, however, this can have knock-on impacts on other species which could eventually lead to the collapse of the whole ecosystem.

Talk like an ...

ecologist

Biodiversity — the variety of life found across a particular area/habitat

Community — in ecology, a group of species that are commonly found together

Dispersal — the movement of individuals or groups away from the area where they were born, to another location where they settle and attempt to reproduce

Ecology — the branch of biology that studies the relationships of organisms with one another and with their environment

Ecosystem — a community of interacting organisms, and their physical environment

Environmental DNA (eDNA) — DNA shed from an organism or 'left behind' in an environment that can be sampled to identify the species in an area

Invasive species — a species that causes harm in an environment where it is not native

Local scale — an area where species could, theoretically, all come into contact together

Metacommunity — in ecology, a set of interacting communities linked by the dispersal of potentially interacting species

Regional scale — an array of local communities that can be suitably bounded and could be larger than a metacommunity but need not be

Pollutant — a substance that is harmful to the environment

Introducing metacommunities

"If we think that biodiversity is important, we need to understand how it is generated and maintained across the landscape," says Mathew. "This means how environmental conditions, interactions among species, dispersal and chance events all interact to determine how species are spread out in a landscape." Historically, much of ecology has focused on understanding these interactions at the local or regional scale, but neither of these approaches provide the full picture. "Considering only one scale doesn't do much to bring all interacting factors together," says Mathew. "That's why the idea of metacommunities arose."

The concept of metacommunities involves considering all possible factors affecting biodiversity in one integrated approach. In ecological terms, a community is a group of species commonly found together – the species that make up a particular ecosystem. A metacommunity is a set of local communities, interconnected by at least one (but often many) species moving between them.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Breaking it down

Mathew encourages initially simplifying the concept to help build understanding. "If we focus only on pairs of species, we can identify elemental ideas," he says. "For instance, we can look at how environmental differences affect species interactions – one of the two species may be favoured under a specific local condition, such as a higher altitude, while the other is favoured by a lower altitude. Think about different plants being found at different elevations on a mountainside."

Adding in immigration and emigration – moving in and out of a local area – adds a level of complexity. "Species often disperse to places where they aren't able to be successful in the long term," explains Mathew. "In this place, they become 'sink' populations, where the species only persists in this area because of immigration of 'source' populations from other areas."

There is also the power of chance. Whether a species survives or goes extinct can depend a lot on luck rather than any specific influence, especially at the local level. "In some cases, species may be so similar that they are ecologically identical, and it is random chance that keeps them in the system for long periods of time," says Mathew. "Eventually, chance may drive one or the other of these similar species to extinction."

And finally, there are the species interactions themselves. Interactions between species at one locality can affect what happens elsewhere, as ecosystems are connected by dispersal.

These dynamics are well-understood in isolation, but the issue is that all of these effects are happening, all the time, to a broad array of constantly interacting species. "Considering only pairs of species is similar to thinking that we can understand how the brain works by understanding how only two neurons interact!" says Mathew.

Technology opens doors

Historically, the tools have simply not existed to adequately address this level of complexity, but this is now changing. "There are new exciting approaches emerging that make it possible to sample, analyse and think about metacommunities in new ways," says Mathew.

> **"Considering only pairs of species is similar to thinking that we can understand how the brain works by understanding how only two neurons interact!"**

Environmental DNA, or eDNA for short, is one such breakthrough. eDNA involves taking samples from soil or water and extracting DNA that has been 'shed' by species passing through that environment, to build up a picture of the species present without having to directly find them. "This means we don't have to work hard to collect organisms with butterfly nets or mammal traps, for instance," says Mathew. "With eDNA, we can sample more frequently, and in more places, to build datasets that would have been unimaginable in previous decades."

Analysing this data stream (one might call it a 'hose') is the next challenge, but the growth of computational power is making this possible too. "We can develop computational methods that allow us to reveal very complicated patterns in the data," explains Mathew. "The use of artificial intelligence is an especially major development, and its power is improving substantially every month, sometimes every week."

Increased communication and collaboration between scientific fields is also making new techniques possible. "We can borrow methods from physics based on 'statistical mechanics'. These can give us important answers without having to understand all the detailed parameters driving ecosystem dynamics, which can often cancel each other out and end up looking random," explains Mathew. "Working in this area requires some special skills and training, so it is important to collaborate with people with different areas of expertise."

Humanity's relationship with nature

Biodiversity is currently in crisis, with overall wildlife populations estimated to have fallen by around 70% since 1970. "Human activities are changing most, or maybe even all, of the rules and parameters in play," says Mathew. "We can't ignore the effects of these activities when we study ecosystems." Humanity itself is an especially complex species – affected not only by its environment and other species but also by economics, politics, philosophies, culture and many other factors. "If we can identify the core principles of metacommunities and apply them to realistically complex systems in relatively simple ways, we can also include the human perspective," says Mathew. "This could help us be more effective at conserving biodiversity, while also maintaining human welfare."

Mathew has been working on various aspects of this field of human-nature interactions. "One topic is how pollutants are affected by biodiversity," he says. "It turns out that some ecosystems accumulate pollutants that enter from elsewhere, while other ecosystems are pollutant 'diffusers' – pollutants accumulate in organisms at the top of the food chain, namely predators, which then disperse to other ecosystems." Mathew is also studying the effects of multiple invasive species and how their interacting effects can impact ecosystems. "Most previous work has focused on single invasive species, but invasives don't just come one at a time, and we need to understand what happens when many are acting together."

Finally, Mathew has been puzzling over the role of evolution. "Most prior work has assumed that species are static – that they don't change in terms of their ecological function," he explains. "However, we know that this is not necessarily always so." Species adapt to their environment, so including this adaptation within the already-complex metacommunity approach will be important to get the full picture. "The fascinating thing about metacommunity ecology is that it seems to ask new questions at least as fast as we solve them," says Mathew. "But for someone who wants to be creative, this is an amazing area to work in!"

About *ecology*

Ecology is an important field for addressing the ongoing biodiversity crisis and to conserve and restore our most precious ecosystems, as well as to understand how humans affect, and are affected by, the natural world. Mathew explains more about his field.

"The field of ecology is changing quickly, and lots of opportunities are opening. This is partly because understanding ecology is important for protecting biodiversity and conserving ecosystems, and partly because technological developments mean that future ecology will be using new and 'yet to be discovered' methods. Nevertheless, there will always be a need to confirm these ideas with the old-school 'muddy boots' approach, which calls for field experiments and an understanding of natural history.

"I also think that ecologists will have tremendous opportunities to improve policy, through developing a deeper understanding of how natural ecosystems interact with human activities. I'm not totally sure how this will work, but that's up to the next generation to figure out!

"Working closely with other specialists is vital for effective ecology. Personally, I've found that my 'niche' is to learn enough about all the most recent developments to be able to suggest ways to combine them, and then to identify more specialised scientists to collaborate with. It's amazing how interesting and exciting this process has been. For instance, working closely with statisticians is essential to understand the most recent developments in artificial intelligence.

"A strong understanding of mathematics has always been helpful to me. Mathematics is useful to make sure that your arguments are logical. Ecology is complicated enough that you can't always trust your intuition to make conclusions!

"My main focus now is to incorporate the statistical mechanics approach into metacommunity thinking. I'm working with some brilliant colleagues with experience in the mathematics involved, and I believe we can really make some progress working together."

Pathway from school to *ecology*

- Mathew recommends taking mathematics and biology at school and post-16, as well as ecology if it is available. He also notes the importance of a broad education, saying that new ideas and ways of thinking can come from anywhere – be it philosophy, history, literature, and so on.
- At university, subjects that can lead to a career in ecology include ecology, zoology, conservation biology and environmental science.

Explore careers in *ecology*

- Ecology careers can vary hugely. Ecological scientists carry out research within academia. Consultant ecologists investigate the impact of human activity on ecology, assess the ecological traits of sites and can contribute to policy. Landscape ecologists do hands-on work to manage and monitor ecosystems. Mathew recommends getting a taste of any appealing careers as soon as possible, such as through work experience in labs.
- Mathew recommends looking into the Ecological Society of America (**www.esa.org**), as well as other societies such as the American Society of Naturalists (**www.amnat.org**), the Association for the Sciences of Limnology and Oceanography (**www.aslo.org**), and the Society for Conservation Biology (**www.conbio.org**), depending on your specific interests. All have outreach programmes for young scientists.
- According to Indeed (**www.indeed.com/career/ecologist/salaries**), the average salary for an ecologist in the US is around $73,000 per year.

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Meet *Mathew*

Somehow, I always knew that I wanted to study nature. I have always found the complexity and natural history of organisms beautiful and fascinating. Also, I was fortunate to have a great high school teacher, Miss Velasco, who inspired me to push on to college.

I was so lucky to get connected with an ecologist in my second year of college. I even got paid to do it! But most importantly, I was able to interact with graduate students and my 'boss', which gave me an idea of what it would look like to progress further in an ecology career. I think this is where I learnt what it took to be a scientist.

> ***I will always be exploring how we can use metacommunity ecology to better understand nature.***

Getting the metacommunity idea going was a hugely important experience in my career. The word existed beforehand but descriptions varied, so a colleague of mine suggested that I organise a 'working group' to establish the concept. We invited folks with a variety of approaches, and the ensuing work allowed us to propose a much greater synthesis of ideas than any of us could have individually. I discovered that I enjoyed this kind of interactive and synthesis-oriented work, and that I was pretty good at it.

I am proud to have found a way to balance all my life's priorities. I am true to my family and other 'non-science' things, while also being productive as a scientist and helping to take ecology to a new level.

In the future, I want to find a way to take the basic ideas of community ecology and resolve how they can explain the realistic complexity of natural communities. I will always be exploring how we can use metacommunity ecology to better understand nature.

I think ecology is a crucial science for humans. What we can discover and communicate will define how humans relate to nature. Sometimes nature is pushed aside in favour of economic and social needs, but I believe this ignores the importance of natural ecological processes for the future of our planet and for ourselves.

Mathew's *top tip*

Find a way to get involved with the most creative and interesting scientists you can. This can be through volunteering, work experience or any other capacity you can find.

How can we reduce fat in fried foods?

Deep-fried food is immensely popular. Although embraced worldwide for its deliciousness, its appeal is tinged with health concerns stemming from the significant absorption of oil during the frying process. **Dr Reza Tahergorabi**, an associate professor at **North Carolina Agriculture & Technical State University** in the US, is exploring oleogel as a new frying medium to reduce the fat content in fried foods.

Dr Reza Tahergorabi

College of Agriculture and Environmental Sciences, North Carolina Agriculture & Technical State University, USA

PROFILE

Field of research
Food science, food product development

Research project
Exploring oleogel as a new frying medium to reduce the fat content of fried foods

Funder
US Department of Agriculture (USDA)
This work was funded through the National Institute for Food and Agriculture of the United States Department of Agriculture, Project No. NC.X-311-5-18-170-1 and 1023325.

Talk like a ...

food scientist

By-products — leftover or secondary materials generated during the manufacturing or processing of, in this instance, food

Frying medium — the substance, usually oil, in which food is cooked to achieve frying

Gelling agents — substances, such as natural waxes, that when added to a liquid, bring about a transformation from a liquid to a gel or a semi-solid state

Oleogel — a gel formed by combining oil with a gelling agent

Oxidative stability — the ability of food to resist deterioration due to reactions with oxygen

Shelf life — the duration for which a food product remains safe to eat

Crispy and golden, deep-fried foods can be irresistibly delicious. Unfortunately, eating them in excess is very bad for our health. "There are significant health and quality issues related to deep-fat fried foods," says Dr Reza Tahergorabi, an associate professor at North Carolina Agriculture & Technical State University. "The high oil content means they are calorie-dense and can contribute to weight gain and obesity if consumed in excess."

According to the World Obesity Federation, it is estimated that by 2035, over 4 billion people – more than half the world's population – will be obese. To help combat this alarming rise in global obesity rates, Reza and his team are developing innovative solutions, from edible food coatings to oleogel-based frying mediums. They aim to reduce the fat content of fried foods, while maintaining the taste and texture that make them so enjoyable.

What are edible food coatings?

Edible food coatings are thin layers of 'protective' material applied to the surface of various food items. These coatings serve a dual purpose: firstly, they act as barriers against factors like air and moisture, extending the shelf life of the product. Secondly, they contribute to maintaining the original texture and flavour of the food. These coatings are crafted from diverse natural substances such as proteins, carbohydrates and fats, and sometimes use by-products of food processing that might otherwise go to waste. "The coating used in our previous research is distinctly protein-based, using chicken and fish processing by-products as its principal components," explains Reza. "Its unique feature lies in its ability to function as a protective barrier, significantly reducing the uptake of oil in fried food items while meticulously preserving their sensory qualities." Therefore, these coatings not only help reduce fat in fried food and meet the demand for healthier options, but they also make sure fried products are better for you, without losing their taste and quality.

What are the benefits of edible coatings?

Edible coatings can benefit consumers by reducing fat in fried foods, potentially mitigating health issues like obesity,


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while simultaneously contributing positively to the environment. "From an environmental perspective, this coating addresses the growing concerns surrounding the disposal of by-products generated in the poultry and fish processing industries," says Reza. By using by-products that would otherwise become waste, these coatings promote sustainability and reduce the environmental footprint which is usually associated with the processing of high-fat fried food. "The dual focus on health-conscious choices and eco-friendly practices positions this coating as a significant step towards a more balanced and responsible approach to food consumption and production," explains Reza, highlighting the revolutionary potential of this coating for the fried food industry.

From edible coatings to oleogels

"As we delved deeper into this field and considered the broader implications, we realised that there were more extensive challenges related to fried foods that needed attention," says Reza. "While coatings can reduce fat uptake, they do not address the issue of the frying medium itself, which remains a significant contributor to the fat content in fried products." Taking this into consideration, Reza and his team decided to switch their focus from edible coatings to oleogels. Oleogels, a fascinating innovation in the culinary world, are gels formed by combining oil with a gelling agent, transforming liquid oils into semi-solid or solid structures. These gels have the unique ability to reduce oil absorption during cooking processes. The magic lies in the gel structure itself, which acts as a clever barrier, entrapping and holding the oil, rather than allowing it to be absorbed by the food.


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> **"By shifting our focus to frying mediums, we are taking a more holistic approach to tackle the issue of excessive dietary fat intake in fried foods."**

"Our current research builds on our understanding of the role of coatings in fat uptake reduction and extends this knowledge to address the broader challenge of reducing oil absorption during frying," explains Reza. "By shifting our focus to frying mediums, we are taking a more holistic approach to tackle the issue of excessive dietary fat intake in fried foods." This will be key for developing healthier food options that not only cater to consumer preferences but also contribute to the global effort to combat rising concerns related to obesity and associated health issues. By exploring innovations in frying mediums, such as oleogels, Reza and his team offer solutions that go beyond surface-level interventions, potentially revolutionising the way fried foods are prepared and consumed.

What has the team found so far?

Oleogels show great promise as frying mediums due to their impressive qualities, including the ability to reduce fat in fried foods, sustainability, and the preservation of texture and taste. "In our study, we successfully structured canola oil into oleogels using wax from the carnauba plant, and these oleogels demonstrated remarkable potential in reducing fat uptake and enhancing the oxidative stability of deep-fried chicken breast samples," explains Reza. More specifically, when compared to regular canola oil, the chicken fried in the oleogel not only contained much less fat but also demonstrated enhanced freshness over time and improved texture. These findings herald a promising shift in the realm of fried food preparation, pointing towards a healthier and more sustainable culinary future. As oleogels emerge as potential game-changers, their ability to simultaneously address dietary concerns and enhance gastronomic experiences opens up exciting possibilities for reshaping the way we indulge in fried delights.

Reza's goal is to show that oleogels have the potential to be used as edible coatings, eventually protecting against harmful substances that can form during frying. "Our ongoing work will continue to explore the capabilities of oleogels in mitigating the formation of undesirable and toxic compounds during deep-fat frying, leading to innovative and healthier solutions for the food industry and consumers," says Reza. Through their innovation, Reza and his team are helping to redefine fried food, offering a healthier and safer choice for consumers, while contributing to the evolution of sustainable practices in the food industry.

About *food science*

Food science is the study of the physical, chemical and biological aspects of food. It involves understanding how food is produced, processed, preserved and distributed. Food scientists work to ensure food safety, quality and nutrition, while developing and improving food products.

"One of the significant challenges is the ever-evolving nature of the industry. Researchers must adapt to changing consumer preferences, emerging technologies and sustainability concerns," says Reza. This adaptability is crucial and reminds food scientists to not only stay updated on the latest trends and technological advancements but also collaborate across disciplines (e.g., nutrition, technology and environmental science) to develop innovative solutions for the ever-changing demands of the industry.

Despite the challenges, food science is a very rewarding career. Working in this field can expose you to cutting-edge technologies, such as biotechnology, in which problems of food supplies, malnutrition and environmental issues are being addressed. "Ultimately, the field of food science offers the satisfaction of making tangible contributions to a fundamental aspect of human life, our relationship with food, while continually embracing innovation and improvement", explains Reza.

Looking to the future, the next generation of food scientists will find a wealth of research opportunities awaiting them in this rapidly evolving field. "These include enhancing alternative protein sources, ensuring food safety, reducing food waste, and contributing to a healthier and more sustainable global food landscape, impacting nutrition, security and the environment," says Reza.

Pathway from school to *food science*

- "In high school and beyond, a focus on biology, chemistry and mathematics is essential," says Reza. If your school also provides courses in food science, these classes will provide foundational knowledge about the science behind food.
- Reach out to a nearby food testing laboratory or a local food company. It might offer opportunities for shadowing or short-term internships.
- "In college or university, pursuing a bachelor's degree in food science, nutrition, biology, chemistry or a related field is an excellent starting point," says Reza. "Additionally, courses in microbiology, biochemistry, food engineering and food safety provide a well-rounded education for a successful career in food science."
- Summer internships provide hands-on experience in food science. "North Carolina A&T State University's Research Apprenticeship Program (RAP) (**www.ncat.edu/academics/summer-sessions/summer-camps.php**) is designed for high school students," says Reza. "The students work under the direction of top-notch research scientists and conduct independent research projects."

Explore careers in *food science*

- "Once you have obtained a degree in food science or a related field, gain practical experience and explore career opportunities through internships," advises Reza.
- "Join professional organisations such as the Institute of Food Technologists (**www.ift.org**)," says Reza. "Stay informed by reading food science journals and exploring relevant websites and blogs. Some useful websites include Food Technology magazine (**www.ift.org/advertising-and-sponsorship/ftm-media**), Food Safety News (**www.foodsafetynews.com**), and Food Business News (**www.foodbusinessnews.net**)." These provide a variety of learning resources which can keep you informed about the latest trends, research findings and innovations in the food science.
- According to PayScale, the average annual salary for a food scientist in the US is $72,000.

Meet *William*

William Oyom Sikapa
Postgraduate student, College of Agriculture and Environmental Sciences, North Carolina Agriculture & Technical State University

Research interest
Food science

I was inspired to pursue food science research after an undergraduate internship with the Food Research Institute (FRI) and Anheuser-Busch InBev SA/NV, a brewing company in Ghana. An internship is a great way to learn about an industry and meet people with similar research interests to you.

Adaptability and resilience are the two most appropriate terms to sum up my academic path. Even though I tend to be proactive, a few obstacles and positive human interactions have been essential to my scientific journey.

Dr Tahergorabi served as a co-advisor during my master's study in China, which strengthened our relationship, resulting in my current role as his PhD student.

In Dr Tahergorabi's lab, I double up as a graduate research assistant and a lab manager. I conduct experiments, collect and process data for conference presentations and publications, and oversee the inventory and maintenance of lab equipment, chemicals and supplies. There is always lots to do!

Our research on oleogels has enriched my knowledge. It has shown me that even simple techniques can have meaningful impacts on human lives. I have also published a research paper and attended a several conferences through this work.

My proudest career achievement, so far, has been receiving the best graduating graduate student and thesis award. Looking to the future, I am committed to working as a food science researcher – it's a field I'm passionate about.

William's *top tip*

Understand who you want to become, stay obedient and strive towards your goals.

Meet *Shahriyar*

Shahriyar Valizadeh
Postgraduate student, College of Agriculture and Environmental Sciences, North Carolina Agriculture & Technical State University

Research interests
Edible films and coatings, food packaging, nanotechnology, microbiology

I'm driven to study food science by the profound influence of food on our health. My goal is to raise awareness about mindful eating for better health and empower people to make informed dietary choices.

I joined Dr Tahergorabi's lab because our research interests align perfectly. His expertise in food science and our shared focus on promoting healthy diets made it a natural fit.

> ***My goal is to raise awareness about mindful eating for better health and empower people to make informed dietary choices.***

My research's standout moment is finding a method to lower fat absorption. This discovery could combat weight gain, heart issues and obesity, aligning with our aim for healthier outcomes.

I hold a patent for a biodegradable food packaging material, aiming to reduce plastic usage and help the environment. My published papers reflect my commitment to impactful research and sustainability in both academia and my career.

My ambition is to become a food and nutritional sciences professor. I'm passionate about promoting healthy diets through research and education, aiming to positively impact society by sharing knowledge with students.

Shahriyar's *top tips*

1. Follow your passion, stay ethical in research, and focus on aiding healthier lives.
2. Keep learning in this evolving field, and remember the impact of food on us all.
3. Embrace the responsibility to contribute to people's well-being.

Why a career in bioscience could be for you

BIOSCI TOOLKIT

"When you know more, you can do more and be more." That's the motto of **BioSci Toolkit**, a resource that aims to inspire Black and ethnic minority communities to pursue careers in bioscience. **Dr Chinedu Agwu**, a bioscience lecturer at **Brunel University**, UK, and founder of the BioSci Toolkit, explains.

Who or what inspired you to study bioscience?

I wanted to pursue a university course in medicine but didn't get any interviews and ended up studying biomedical science instead. Whilst I started the course on a low note, I grew to really enjoy the course. It appealed to my scientific curiosity and exposed me to the various career opportunities available with a bioscience-related degree.

Why do you think there is a lack of diversity in bioscience and the sciences, more generally?

This is a good question, and it's a multifaceted issue. Contributing factors include a lack of 'science capital', where Black, Asian and minority ethnic (BAME) students may not be exposed to people/role models within the STEM space or have much engagement with science outside of the classroom. The influence parents have in subject choices is also a factor. Parents of BAME students have typically steered their children towards more traditional courses, such as medicine, dentistry and engineering, etc., where the career outcomes are more widely known. However, this is changing over time.

Holiday in Namibia © Chinedu Agwu

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Why should young people consider a career in bioscience?

It's a dynamic and highly relevant sector that requires diversity of thought to best serve the general population. Bioscience directly relates to our way of life and can open many career avenues to suit different interests.

What are some misconceptions about bioscience careers?

Some people think careers in bioscience provide a poor work-life balance, low earning potential and few career opportunities outside of the lab. BioSci Toolkit, alongside many other organisations, is working hard to address such misconceptions through the content we share.

What is the BioSci Toolkit?

BioSci Toolkit is an information resource for prospective and current bioscience students. It was set up to encourage more students into bioscience degrees and careers, especially Black and racially minoritised students, in the hope of reducing inequalities in science education, increase employability and diversify the STEM workforce.

What can people find in the Toolkit?

They can find information about entry requirements for university bioscience courses,

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Graduation photo © knightvisuals

how to write a scientific CV, internship/placement opportunities, general university advice, postgraduate advice, videos from bioscience career professionals and so much more!

What is one piece of advice you wish someone had given you at the beginning of your career?

Get yourself a career mentor! Whilst I have a mentor now, having one sooner could have helped with my decision-making and put me at ease when I felt anxious or discouraged on my career journey.

What is your philosophy in life that helps drive you forward?

I am fearfully and wonderfully made. I don't need to be anything or anyone else, other than what God created me to be. I don't need to compete or compare myself with anyone. I will make my own unique contribution, and this mindset motivates me to keep progressing.

Connect with the BioSci Toolkit

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> **Bioscience directly relates to our way of life and can open many career avenues to suit different interests.**

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Empowering people through health education

To make informed decisions about our own healthcare, we need to understand how our bodies work and the illnesses that can affect them. Unfortunately, diseases can be complicated, and information about them is not always clear or accessible. **Dr Susan Creary** is a paediatrician from the **Hematology, Oncology and Blood and Marrow Transplant (BMT) Clinic** at **Nationwide Children's Hospital** in Columbus, USA. She and her team have created an education programme to spread awareness and understanding of sickle cell trait and what it means for individuals and families who inherit it.

Dr Susan Creary

Hematology, Oncology and Blood and Marrow Transplant (BMT) Clinic, Nationwide Children's Hospital, Columbus, USA

Field of research
Paediatric haematology

Research project
Raising awareness and knowledge of a poorly-understood genetic disorder within minority communities

Funder
US National Institutes of Health (NIH)

PROFILE

Talk like a ...

paediatrician

Health literacy — a person's ability to find, understand and use information relating to their health, to make informed health decisions

Haemoglobin — a protein inside red blood cells that carries and delivers oxygen around the body

Inherited — in biology, things that are encoded in your body and that make you uniquely you. Inherited traits are passed from parents to children by genes

Sickle cell disease — an inherited disease that changes the shape of red blood cells. Red blood cells in someone with sickle cell disease are more likely to get stuck in their blood vessels and are not able to carry and deliver oxygen as they should. It is caused by inheriting sickle cell trait from both parents or sickle cell trait from one parent and another abnormal haemoglobin trait from the other parent

Sickle cell trait — an inherited trait but not a disease. It is caused by inheriting a sickle cell trait from one parent but a regular haemoglobin trait from the other parent. Individuals with sickle cell trait are not likely to suffer any symptoms but can still pass this trait on to their children

The human body is an incredibly complex collection of trillions of cells, proteins, molecules and microbes that are all connected. It is not surprising that when we become ill, it can be a puzzle to understand what has gone wrong and how best to fix it.

Luckily for us, we have medical researchers, doctors and nurses who train for years to understand how the human body works, why things go wrong and how to help us when they do.

It is important, however, that we also understand what is going on inside our bodies, so that we can keep ourselves as healthy as possible. For example, people with diabetes need to know how the disease works so they can maintain and monitor their blood sugar levels. If a patient does not have access to the right information, they are less able to take care of their own health.

Dr Susan Creary is a researcher at the Hematology, Oncology and Blood and Marrow Transplant (BMT) Clinic at Nationwide Children's Hospital. Her research focuses on increasing knowledge and awareness of sickle cell trait. Sickle cell trait makes people at risk of having children with sickle cell disease. Dr Creary explains, "My aim is to deliver health information in a way that anyone, with any level of health literacy, can understand it and use that information to make decisions about their health."

What is sickle cell disease?

Sickle cell disease is a condition that changes the shape of red blood cells. Healthy red blood cells are flexible and round, allowing them to easily move through our blood vessels and carry oxygen around our body. The blood cells of people with sickle cell disease become rigid and C-shaped like a sickle (an old farming tool). These C-shaped blood cells get stuck in blood vessels, preventing oxygen from being delivered to parts of the body as it should. This can lead to many complications, including intense pain and being at risk of certain infections.

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What causes sickle cell disease?

Haemoglobin is a molecule that is inside red blood cells and carries oxygen. Sickle cell disease is a genetic condition that affects haemoglobin. Sickle cell disease happens when you inherit a sickle cell trait from both parents or sickle cell trait from one parent and another abnormal haemoglobin trait from the other parent. This is called recessive inheritance.

A person who has sickle cell trait is unlikely to have any symptoms of sickle cell disease. However, they can still pass the trait to their children, and they are also at risk of having a child with sickle cell disease.

How common are sickle cell disease and sickle cell trait?

"Sickle cell disease affects approximately 100,000 Americans, but millions of people worldwide," says Dr Creary. "Most of these individuals are from underrepresented minority populations[1]." Although the disease can affect people of all racial and ethnic identities, it is particularly common among minority populations such as African Americans and Hispanics.

Sickle cell trait is much more common than sickle cell disease. Nearly 3 million African Americans have sickle cell trait. Despite the significant implications that it can have on future reproductive decisions, more than 80% of these individuals do not know or understand their sickle cell trait status.[2]

Why is it important for people to be tested for sickle cell trait?

"It is important for people to know their status so that they know if they are at risk of having children with sickle cell disease," explains Dr Creary. Although people with sickle cell trait will not suffer from symptoms, they are at risk of having children with sickle cell disease and who can have severe health complications. If two people with sickle cell trait have a child, there is a one in four chance for each pregnancy to be affected by sickle cell disease.

"It is also important to know that a parent with sickle cell trait and a parent with regular haemoglobin traits cannot have a child with sickle cell disease," says Dr Creary. "It is important for parents to know whether they have sickle cell trait before they have children so that they can make an informed decision."

> **"My aim is to deliver health information in a way that anyone, with any level of health literacy, can understand it and use that information to make decisions about their health."**

What are the challenges of teaching parents about sickle cell trait?

As sickle cell trait is unlikely to cause any symptoms, many people carrying the trait may not know they have it or have even heard of it. The difference between sickle cell trait and sickle cell disease is also commonly confused, and many people struggle to understand that they are different.

"Parents of children with sickle cell trait often receive complex information about sickle cell trait and sickle cell disease at a time when they may be overwhelmed by caring for their newborn," says Dr Creary. It is crucial that information is communicated in an accessible way so that parents understand the risks fully. To achieve this, Dr Creary and her colleagues have developed an education programme called SCTaware (sickle cell trait aware).

What is SCTaware?

SCTaware is an education programme that is delivered using videoconferencing. It was created to increase awareness about sickle cell trait among parents at high risk of having sickle cell trait. SCTaware was delivered as a videoconference so that people were able to access the information without having to travel to meet an educator.

The programme aimed to deliver information to parents in an accessible way and with visuals that were easy to understand. "We used tools to ensure that the language, pictures and format of our programme were presented clearly," explains Dr Creary. "The programme also included an educator so that parents could ask questions, confirm that the information they received was clear, and confirm their understanding by teaching back the information that they learnt to the educator."

What are the next steps for SCTaware?

Dr Creary and her team plan to conduct future studies to confirm that SCTaware improves sickle cell trait knowledge. "Our hope is that people are able to use this information to inform their future decision-making and share this information with their children with sickle cell trait, when they are old enough to understand it," says Dr Creary.

[1] *US Centers for Disease Control and Prevention (www.cdc.gov/ncbddd/sicklecell/index.html)*

[2] *Treadwell MJ, McClough L, Vichinsky E. Using qualitative and quantitative strategies to evaluate knowledge and perceptions about sickle cell disease and sickle cell trait. J Natl Med Assoc. 2006 May;98(5):704-10. PMID: 16749645; PMCID: PMC2569269.*

About *paediatrics*

Paediatrics is the branch of medicine that takes care of babies, children and young adults. This field is incredibly broad, reflecting the vast array of factors that contribute to a child's health. For example, neonatal paediatrics focuses on the health of newborn babies, paediatric cardiology focuses on heart conditions that affect babies and young people, and paediatric endocrinology focuses on hormonal disorders such as those that might affect growth or puberty. Dr Creary's research falls into the field of paediatric haematology, the study of blood disorders that affect babies, children and young people.

One field of paediatrics that Dr Creary is particularly excited about is preventive paediatrics. This looks at maintaining and promoting the health of children and young people to prevent complications, rather than waiting for and reacting to complications. Preventive paediatrics focuses on proactive steps that people can take to prevent their children from getting ill in the first place, such as routine check-ups, vaccines and education. "I hope that there are more opportunities for the next generation of paediatricians and researchers to increase effective use of preventive therapies and to implement these proven therapies into care," says Dr Creary.

Pathway from school to *paediatrics*

- You should study science subjects at school and post-16-years-old, particularly biology and chemistry.
- It is also important to have a strong background in writing and ethics, so subjects such as English and philosophy may be useful.
- At college or university, take courses that develop your communication skills and understanding of how the circumstances in which people live, work, go to school, and socialise affect their health.
- In the US, the route to paediatrics will depend on the undergraduate degree you take. It is possible to study for a medical degree after gaining an undergraduate degree in a range of fields. For more information, see: **www.sgu.edu/blog/medical/how-to-become-a-pediatrician-a-step-by-step-guide**
- In the UK, you will need to study a five-year undergraduate medical degree or a four-year postgraduate degree in medicine. For more information, see: **www.healthcareers.nhs.uk/explore-roles/doctors/roles-doctors/paediatrics/paediatrician**

Explore careers in *paediatrics*

- There are many different disciplines within the field of paediatrics, including community paediatrics, child mental health and paediatric emergency medicine. These disciplines are varied, and each requires specialised knowledge and training.
- Internships, work experience and volunteering are great ways to gain experience and boost your curriculum vitae (CV). Find out if your local university or hospital offers any such opportunities.
- To learn more about paediatric haematology specifically, the American Society of Hematology (**www.hematology.org**) and The American Society of Paediatric Hematology/Oncology (**www.aspho.org**) are useful organisations to learn from. They have training opportunities, summer experiences and mentoring programmes.

Meet Dr Creary

I have always enjoyed working with children. In medical school, I became interested in sickle cell disease because it affects every organ system, and I was looking for an opportunity to provide preventive care, rather than just treating complications once they happened. Paediatric sickle cell disease combined all these things into one career.

During my medical residency, I enjoyed my paediatric outpatient clinic because it served many children who were from underrepresented minority groups, and I also learnt that I enjoyed providing care to those with chronic diseases. Sickle cell disease aligned those interests and was scientifically fascinating to me. When I learnt more about the tremendous burdens this disease places on children, adolescents, young adults and their families, I realised that I had a great opportunity to make an impact.

I enjoy identifying the important questions that need to be asked and then designing the studies to try and answer them. It's rewarding to know that the data we collect and the results we share may not only impact the children that I see in my clinic but also other children around the world who are living with this condition.

My proudest career achievements are when I completed my paediatric haematology/oncology fellowship, when I persevered through scientific rejection, and when I have had the opportunity to mentor young investigators in their work.

I hope to continue to expand the work that we are doing to increase knowledge about sickle cell trait and sickle cell disease so that individuals affected by these can make informed decisions about their health.

Meet Chase

Chase Beeman is a genetic counselling student at The Ohio State University. She focuses on family communication of and adaptation to genetic conditions.

I began working in research to gain experience in a medical field before returning to school for an advanced degree in healthcare. This was an exciting opportunity to help improve care and health outcomes for individuals with sickle cell trait and sickle cell disease. This work inspired me to pursue a career as a genetic counsellor.

I was the research coordinator and educator on SCTaware. I enrolled participants, provided the education, and tracked study progress. I also helped lead writing efforts for scientific manuscripts.

Learning how to be a sickle cell trait educator was a big challenge. This was a completely new skill for me, and it required me to learn a lot about sickle cell trait, sickle cell disease, genetic counselling, and health literacy. It taught me the importance of accessible and understandable patient education.

A highlight of the programme was seeing its impact on improving participants' knowledge and confidence with complex health information. I look forward to seeing this programme evolve to reach a wider audience. I hope to see it inform future research on ways to improve sickle cell trait education.

As a soon-to-be practising genetic counsellor, I am excited to build a career in haematology genetics. I'd like to develop a clinical practice, counselling patients with inherited blood disorders.

Meet Dr Mary Ann Abrams

Dr Mary Ann Abrams is an assistant professor at The Ohio State University College of Medicine and primary care paediatrician at Nationwide Children's Hospital.

I became a physician because medicine was so interesting and a wonderful way to help people. Throughout my medical training, I saw members of the health care team talking to patients using complicated words. Later, as a pediatrician, I led Reach Out and Read where we shared with parents the joy of reading aloud. All this led me to health literacy to help improve safety, quality, equity, and patient/family-centred care.

I helped plan, write, design and evaluate SCTaware to make sure we included plain language and 'teach-back' – explaining back using their own words. I trained people who delivered SCTaware, so using plain language and teach-back came naturally to them.

It has been great to see SCTaware being useful, acceptable and beneficial to parents. It helps make health care more equitable, safe and high-quality. And it's great that people I worked with are now health literacy champions!

I also use health literacy to work with teams to improve outcomes for babies born with cystic fibrosis or certain neuromuscular conditions. I partner with quality improvement to improve care for children with asthma on using their medicines; with dentists to make sure everyone knows when, how, where and why to come for dental care; and with psychiatrists caring for young people with depression. I also work with health equity and trained interpreters for patients with other languages or cultures, so all patients and families understand information we give them to care for their health.

My aim for the future is to make an impact in many settings, so that many people and organisations have health literacy skills.

The importance of memory in severe mental illness

While we all sometimes forget where we put our phone or keys, memory problems can have much more serious consequences. Together with his collaborators, **Professor Jack Mellor** from the **University of Bristol**, UK, is investigating how impairments in a person's ability to form memories can contribute to the symptoms of psychiatric disorders. If they can uncover the biological mechanisms behind conditions such as schizophrenia, they hope to open new opportunities for mental health treatments.

Professor Jack Mellor

Professor of Neuroscience, School of Physiology, Pharmacology and Neuroscience, University of Bristol, UK

PROFILE

Field of research
Neuroscience

Research project
Investigating the biological mechanisms underlying memory and how they relate to psychiatric disorders

Funders
UK Research and Innovation (UKRI), Medical Research Council (MRC)

Talk like a ...

neuroscientist

Cognitive — related to cognition, the mental process of acquiring, evaluating and/or using knowledge

Electrophysiology — the study of the electrical properties of cells

Encode — to create a memory

Neuron — a nerve cell

Neuroscience — the study of the brain and nervous system

Optogenetics — a genetic modification technique that causes an organism to express light-sensitive proteins

Psychiatric disorder — a mental health condition that significantly affects a person's emotions, behaviour or mental state

Schizophrenia — a severe psychiatric disorder that affects the way a person thinks, acts and perceives reality

Synapse — a junction between neurons

Synaptic plasticity — the ability of neurons to modify the strength of their synaptic connections

Every time you have a new experience, you form new memories. Not only do these allow you to remember the past, but they also help you know how to act in the present and future. "Memories are stored in the brain as internal representations of our past experiences," explains Professor Jack Mellor from the University of Bristol. "We predict what will happen in the future based on past experiences, so a good memory is the basis for good decision-making."

An effective memory is, therefore, critical to our behaviour. "If, on a sunny afternoon, you pass an ice cream van on your way home from school, that memory can guide your future actions," says Jack. "Next day, you can take money with you to buy an ice cream and plan your route home to pass the van again."

However, for effective decision-making, we must use memories flexibly. We rarely encounter situations that are identical to past experiences, so our brain generalises memories to make predictions. For example, if the ice cream van has moved the next day, you can relocate it by remembering the sound of its jingle and listening for it. "Flexible memory representations allow us to cope with uncertainty," explains Jack. "If memory becomes inflexible, we are unable to deal with uncertain outcomes." People with certain psychiatric disorders may not be able to use their memory to predict the future consequences of their behaviour, causing them to act in illogical ways, leading to disorientation and frustration. This is why Jack is leading a team of neuroscientists from the University of Bristol, Cardiff University and University College London to investigate the mechanisms underlying memory and how they relate to psychiatric disorders.

The neuroscience behind memory

"Neurons are the building blocks of our brain, connected at junctions known as synapses," says Jack. "If we imagine that each neuron represents a piece of information, to create a memory we must connect


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all the neurons that hold information associated with that memory – a process known as encoding." These synapse connections are formed by the cellular process of synaptic plasticity, which links pieces of information (neurons) into whole experiences (memories). By grouping units of information together, synaptic plasticity enables us to remember events, objects and actions, such as your last birthday, a football and how to form a sentence. "Synaptic plasticity is the fundamental process underlying memory and learning," explains Jack.

Individuals are not only defined by their genetics, but also by their experiences. Synaptic plasticity wires these experiences into your brain, determining how you respond to future situations. This synaptic plasticity begins at a very early age - the psychological theory of attachment states that the relationship between an infant with their primary caregiver is critical to establishing lifelong behaviour patterns adapted to the emotional environment. In theory, synaptic plasticity means we are always making memories. In practice, even our hugely complex brains cannot record everything we experience. Therefore, we have mechanisms that select and filter the most important information for storage, even when we are unaware of it. Understanding how synaptic plasticity works is crucial to understanding how we interact with the world around us and why we make the decisions we do.

How do Jack and the team study synaptic plasticity?

Observing synaptic plasticity in action involves sophisticated laboratory techniques. "Neurons communicate by sending electrical signals," explains Jack. "Electrophysiology methods are the most direct way to measure the electrical properties of neurons. It is difficult to measure large numbers of neurons this way, so we also use tools that convert electrical signals into light signals." This allows the team to image neuronal activity by shining light into the brain to excite fluorescent molecules. "Using advanced microscopy techniques, we can image deep into the brain tissue with very high resolution, enabling us to measure the activity of many neurons that contribute to memories as they are being encoded," says Jack.

> **"If memory becomes inflexible, we are unable to deal with uncertain outcomes."**

The team also uses optogenetics, which involves inserting genes into mice that express light-sensitive proteins on their neurons. "When the protein is exposed to light, it will excite the neuron, allowing us to use light to control the mouse's neuronal activity," explains Jack. Researchers use this technique to discover the functions of individual neurons by activating or inhibiting them and seeing how the mouse responds. In the field of memory research, optogenetics has been used to demonstrate the concept of 'inception' – the implantation of false memories in the brain, popularised by the Christopher Nolan film, *Inception*. Using light, neuroscientists activate neurons that encode an experience in the mouse's memory, such as an encounter with another animal. Even though the mouse has never met that other animal, it will believe it has.

How can synaptic plasticity influence psychiatric disorders?

Jack and the team have discovered that genetic mutations that increase the risk of psychiatric disorders in humans cause impaired synaptic plasticity and memory in mice. "Now, we want to know if these mutations also impair synaptic plasticity in humans," he says. "If so, it would indicate a biological mechanism for the symptoms displayed by people with psychiatric disorders. This would then open new ways to treat them." For example, many genes are associated with an increased risk of schizophrenia. If these genes are related to a core biological function, such as synaptic plasticity, treatments can be targeted to address this underlying mechanism.

"Most psychiatric disorders share symptoms, meaning a person with one disorder is often also diagnosed with another," says Shyline Bajaba, a research technician in the team. "This can be traced back to the molecular mechanisms at work, where a disruption to one particular biological process can have a variety of effects." The team believes that synaptic plasticity is the biological process in question for a range of psychiatric disorders, including schizophrenia.

"We hypothesise that the biological changes observed in people with schizophrenia (such as cognitive impairments) involve synaptic plasticity," explains Jack. "We think synaptic plasticity alters the way that memories are represented in the brain and, crucially, how they can be adapted to changing environments." If this is the case, it may explain why people with schizophrenia often struggle to distinguish reality from fantasy. To test this, Jack and the team will use high-resolution imaging to record neuronal activity in mice with genetic mutations associated with schizophrenia. They will measure synaptic plasticity in brain tissues extracted from mice and humans undergoing brain surgery for treatment of neurological conditions.

Once the biological mechanisms behind schizophrenia have been identified, it will become easier to treat the condition. "With a greater understanding of the biological mechanisms that underlie psychiatric disorders, we hope to develop treatments that not only alleviate the symptoms, but target the underlying biological causes," says Shyline.

About *neuroscience*

Neuroscience is the study of the brain and nervous system, and how their development and structure affect our cognition and behaviour. "Neuroscience is about understanding how fundamental scientific principles give rise to human behaviour," says Jack. "This means it is at the intersection of multiple disciplines, all aiming to describe human existence. For me, this makes it the most interesting field of science."

How interdisciplinary is the field?

Collaboration is vital within any area of science, and neuroscience is no exception. Advances in the field require input from researchers from a wide range of disciplines, including biology, chemistry, physics, maths, philosophy and engineering. "It's important to gather the necessary expertise and to approach the challenge from different perspectives," explains Jack. "Our lab group works with clinical partners, who contribute knowledge about the symptoms and genetics of psychiatric disorders and provide human tissue samples for our experiments. We also have industry partners, who are critical for turning our academic findings into new treatments for patients."

Why does neuroscience rely on animal experiments?

Animal research is essential for understanding how the human brain functions, and what happens when it goes wrong. "We can't access the human brain at the level of detail required to understand the activity of individual neurons, and we can't manipulate human brain circuits to understand the effects of specific neuron activation," explains Jack. Instead, neuroscientists study neurons in mice and apply their findings to help understand the function of neurons in humans. Experimenting on animals is a contentious ethical issue, and it is strictly controlled by legal frameworks to ensure that any animal suffering is minimised. "Before beginning, every experiment is assessed by independent experts to weigh up the potential benefits to science versus the potential harm caused to the animals involved," says Jack. "If the balance is negative, the experiment will not be conducted."

Pathway from school to *neuroscience*

- Jack advises that science and maths are fundamental subjects to study at school and beyond, but he also recommends cultivating other interests to gain a well-rounded education.
- As it is such an interdisciplinary field, many degrees could lead to a career in neuroscience. Members of Jack's team have backgrounds in neuroscience, biochemistry, psychology, physics, computer science and philosophy.

Explore careers in *neuroscience*

- "The most important thing for a career in neuroscience is to be excited about how the brain works!" says Jack. He recommends listening to podcasts such as This Week in Neuroscience (**www.microbe.tv/twin**) and the Huberman Lab Podcast (**www.hubermanlab.com/podcast**), reading about neuroscience from popular science authors such as Oliver Sacks (**www.oliversacks.com**), and watching films that explore aspects of memory such as *Inception* and *Memento*.
- The British Neuroscience Association has a career guide for students (**www.bna.org.uk/careers**) and a wide range of educational resources (**www.bna.org.uk/resources**).
- Members of the team participate in the Bristol Neuroscience Festival, a biannual event that includes a day of demonstrations, interactive activities and talks aimed at secondary school students: **www.bristol.ac.uk/neuroscience/bnf**

Meet *Jack*

When I was younger, I was fascinated by psychology, philosophy and mathematics. I also enjoyed sports and music. As I grew older, I realised my main interest was in human behaviour. The more I thought about it, the more I wanted to find out how to explain it – or, at least, understand it better.

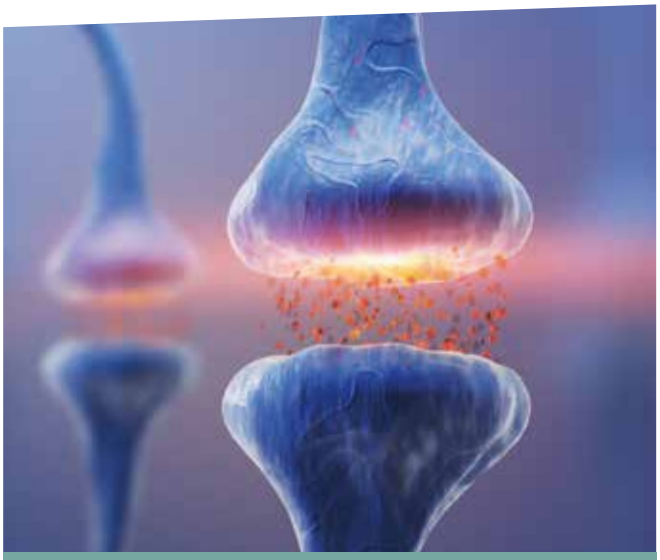
My university education involved the study of chemistry, biochemistry, psychology and physiology. Understanding the brain involves understanding how biology works and having a theoretical appreciation of complex systems – which is why mathematics is important.

There are over 500 trillion synapses in the human brain! This gives us the potential to store lots of information, but computers have now overtaken human brains as the largest storage repository of knowledge. However, human brains can still do many things that computers cannot, even with advanced artificial intelligence.

When I'm not working, I enjoy surfing anywhere with waves and rowing anywhere without waves. I also enjoy being taught by my children, exploring the Scottish Highlands and playing music.

Jack's *top tip*

Find your own path. You don't need to follow in anyone else's footsteps.



Neurons communicate by sending electrical signals across synapses © KateStudio/Shutterstock.com

Meet *Shyline*

I have always been fascinated by criminal behaviour, and in particular how punishment systems, such as prisons, can impact criminals' mental states. I have worked within the Zimbabwean prison system to support the self-improvement of prisoners, where I have met inmates with various mental health issues, including schizophrenia.

In Zimbabwe's conservative society, inmates with psychiatric disorders are still shunned and don't receive the care they need to live functional lives. Working with Jack in this research team allows me to improve my understanding of the biological underpinnings of mental health problems, which will help me support Zimbabwean rehabilitation systems.

> ***It's a common misconception that we only ever use 10% of our brain.***

Before starting my degree in biochemistry and cell biology in Germany, I spent time studying developmental psychopathology. I explored the early warning signs of psychological illness and investigated the development of Alzheimer's disease, which taught me about the intricate synaptic makeup of our brains. I also conducted an internship in Mexico, where I studied how environmental factors influenced anxiety and depression in rats.

It's a common misconception that we only ever use 10% of our brain. In fact, even when we're sleeping, we're using a lot more than that!

In my free time, I love crocheting, knitting and jogging. I also enjoy playing netball, reading non-fiction and listening to true crime podcasts.

Shyline's *top tips*

1. It's never too early to begin working towards your dream. If you get it wrong, you can always start over.
2. Seek out good mentors, because supportive supervision is more important for your personal growth than attending a prestigious university.

How wearable tech can combat Parkinson's disease

Every time we move around, our body is performing a complex array of tasks to move us in the direction we intend to go and to keep us balanced as we do so. A number of diseases, such as Parkinson's disease, damage this process. At the **Balance Disorders Laboratory** at **Oregon Health & Science University** in the US, **Professor Fay Horak** is investigating how exercise regimes and wearable technologies can help people with Parkinson's disease to regain mobility and autonomy.

Professor Fay Horak

John Nutt Endowed Professor of Neurology, School of Medicine, Balance Disorders Laboratory, Department of Neurology, Oregon Health & Science University, USA

Fields of research
Neurology, motor control neuroscience, physical therapy

Research project
Investigating the effectiveness of an exercise programme to improve mobility and turning for individuals with Parkinson's disease

Funders
US National Institutes of Health (NIH), Department of Defense (DoD), Department of Veterans Affairs (VA)

PROFILE

Talk like a ...

neuroscientist

Biofeedback — a technique that uses sensors on the body to provide live feedback on body functions, such as coordination of walking movements

Closed head injury — a head injury that does not involve a break in the skull

Dynamic balance — the ability to control the body's centre of mass, retain balance and remain stable when moving

Multiple sclerosis — a disease that involves nerve damage in the brain and spinal cord

Neurological — related to disorders of the nervous system

Neuropathy — a type of nerve damage that often affects sensation in the hands and feet, that can be caused by diabetes or cancer treatment

Parkinson's disease (PD) — a progressive neurological disorder that causes slow, stiff movements and difficulties with walking and balance

Proprioceptors — sensory receptors in muscles that sense changes to the body's position and motion

Vestibular system — a sensor system in the inner ears that senses movement and position of the head

Wearable technology — sensors worn on the body, for example, to measure movement

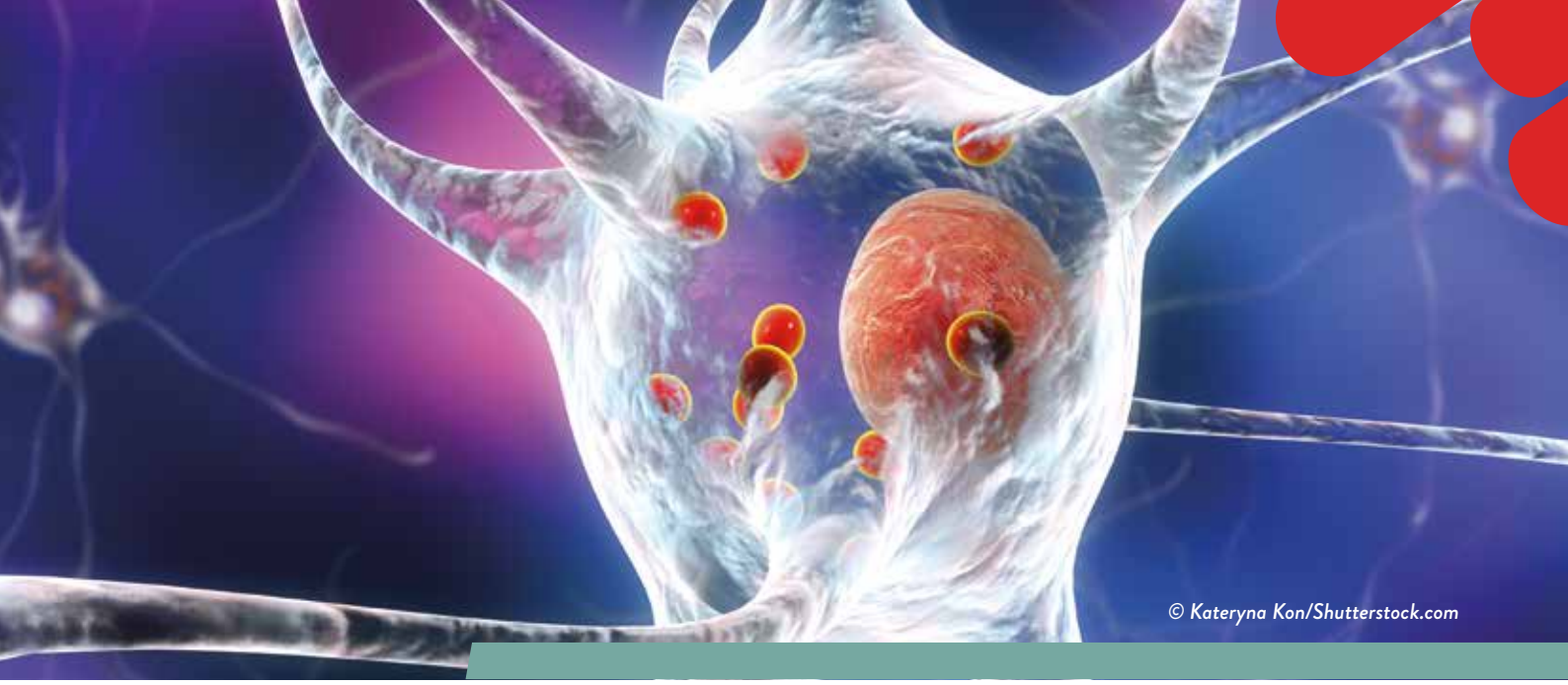
Parkinson's disease (PD) is a disorder of the brain and nervous system that tends to get progressively worse over time. Early symptoms may include hand tremors and slower movements; with time, it can severely affect balance and automatic movements like walking and speech. While there is no cure, it is often possible to improve balance and mobility in people with PD to improve their overall quality of life.

Professor Fay Horak is Scientific Advisor for the Balance Disorders Laboratory at the Oregon Health & Science University. She is investigating the role exercise regimes and wearable technologies can have in helping people with neurological diseases, such as PD, improve their balance and mobility. This research involves investigating how these diseases affect balance and movement, and how the body responds to interventions.

Turning is complicated

We perform turns so frequently that we are rarely aware when we do turn. "Almost all daily tasks, such as dressing, showering and walking around the house, require the brain to control balance while turning," says Fay. "People turn about a hundred times every hour!" Despite us doing it all the time, turning is a complex process. "Effective turning involves top-down coordination: first turning the eyes, followed by the head, the trunk and, finally, the legs," explains Fay. "This involves being aware of our surroundings, knowing where our limbs are and will be, and remaining balanced throughout."

Balance is especially important because turning has the potential to cause instability. "To turn, we need 'dynamic balance' – the ability to control



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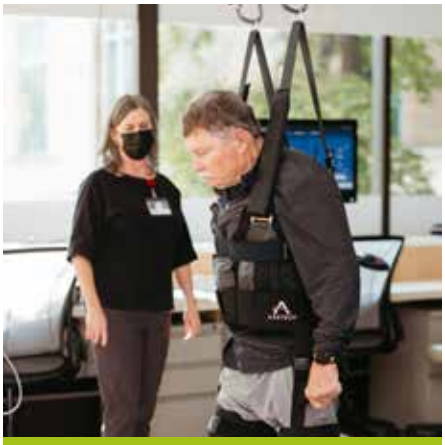
the body's centre of mass over a moving base," says Fay. "Our centre of mass is just in front of the lower spine, and our base's edges consist of the outer edges of our feet." As we turn, there is a higher chance of our centre of mass going outside the limits of the base – which leads to instability. This is a particular risk for older people who have impaired mobility. "A recent video analysis of elderly people in long-term care found that 41% of falls occurred during turning," says Fay. "Additionally, as falls during turning tend to involve falling sideways, they are up to eight times more likely to result in a hip fracture."

The turning test

Because coordinating a turn is a complex, but common, mobility task, the process can be used to assess whether people might have mobility or balance issues. "Turning requires advanced motor planning by the brain, lots of attention, and balance adjustments, all of which are impaired by ageing and by PD," says Fay. "For example, people with balance problems tend to turn more slowly and with smaller steps than those without such issues."

Turning impairment can be an early warning sign of PD, as people in the early stages of the disease may still walk normally but turn more slowly. "PD impairs the ability to coordinate multiple parts of the body,



Patients are supported by a harness while practising dangerous movements like turning.

> **"Turning requires advanced motor planning by the brain, lots of attention, and balance adjustments..."**

as well as our neural control of balance," says Fay. "Unlike most people who turn one part of the body at a time, people with PD turn the whole body at once." There is a good reason why turns typically start with the eyes and head: to give our vision and vestibular system time to adjust. As people with PD do not start turning from the top-down, they are more at risk of becoming unbalanced.

Many people with PD 'freeze' when trying to turn, feeling like 'their feet are glued to the floor'. "Freezing is a common reason for falls," says Fay. "In fact, PD is responsible for more falls than any other chronic disease." Part of Fay's work involves finding ways to measure abnormal balance and mobility so she can identify risk of falls for people with PD. Current pharmaceutical- or surgery-based treatments for PD do not improve balance and may even make it worse. This is why Fay believes in the importance of exercise and rehabilitation for a PD treatment regime.

The Balance Disorder Laboratory

Together with Dr Martina Mancini and Dr Laurie King, current directors of the Balance Disorders Laboratory, Fay focuses on diseases that affect people's balance, including PD. "Participants in our studies include people with a range of neurological conditions, including PD, closed head injuries, multiple sclerosis and neuropathy," she says. "We also have participants of matching ages without these conditions as control groups." The Balance Disorder Laboratory has an array of equipment to measure traits associated with balance and movement. "To measure precisely how participants walk and balance, we use body-worn sensors, reflective markers on joints, and electrodes that record muscle and brain activity," explains Fay. "People also return home wearing sensors to record the quality of their walking and turning during daily life."

A large proportion of the lab's studies focus on finding ways to improve balance in people with neurological disorders. "Martina studies the effects of novel rehabilitation approaches using new technologies, such as vibration and visual biofeedback that give participants information about the quality of their movements," says Fay. Instantaneous feedback can help patients to be aware of and consciously change any undesirable movement patterns. Often, these patients are supported by a harness suspended from the ceiling while practising dangerous movements like turning, so that they are at no risk of falling, which helps build confidence and eliminate fear of injury.

From the lab to the home

Chief among the lab's outputs is the creation of the Agility Boot Camp, where people with PD practise various dynamic balance tasks to help them regain lost abilities, such as being able to talk and walk effectively at the same time. "We have also shown that people with PD benefit from biofeedback about how their legs are moving," says Fay. "Now, we're studying whether a six-week, specific exercise programme with a physical therapist can improve the quality and safety of turning." This study involves measuring every turn made by participants a week before and a week after the exercise programme.

Such programmes could have a profound impact on the quality of life of people with PD. "In the Balance Disorder Laboratory, Laurie is studying whether people with PD can safely and effectively do balance exercises at home, with help from video-based sessions with a physical therapist," explains Fay. "This includes measuring their walking and balance from body-worn sensors." If these studies are successful, this will place rehabilitation efforts within the hands of people with PD themselves – allowing them to work towards their own improvements in their own time.

About *neuroscience*

Neuroscience involves the study of the nervous system: how it is built, how it works and what happens when it goes wrong. It is an especially important discipline given its findings can be applied to the treatment of neurological disorders, which cause more hospitalisations and disabilities than any other class of diseases in the US.

Neurological disorders are arguably the most complex diseases in existence because they affect the most complex organ of all – the brain. Many neurological disorders still have no known cures, which highlights the importance of neuroscience research. The Oregon Health & Science University (OHSU) focuses on collaborative research efforts that move quickly from discovery to clinical trials, helping to make treatments available as rapidly as possible.

Such work involves a high degree of coordination between researchers and practitioners, as well as working closely with trial participants and patients. Collaborations also go further afield. "I have collaborated with experts in engineering, psychology, statistics, physics, medicine, imaging, and many other disciplines," says Fay. "This includes scientists from all over the world."

OHSU spans both academic research and clinical practice. Many faculty members participate in both scientific research and clinical care, as well as mentoring to ensure that knowledge is shared. OHSU's neurology department is connected to the VA Portland Health Care System (a health care centre run by the US Department of Veterans Affairs for ex-military personnel) via a sky bridge, allowing researchers to approach patients for participation in clinical trials.

Pathway from school to *neuroscience*

- At school and post-16 years, Fay recommends taking subjects such as mathematics, biology, chemistry and English to gain a good grounding in relevant science and analysis techniques, and how to communicate them.
- At university, a degree in neuroscience, physiology, anatomy, biology, psychology, movement science or physical therapy can provide a pathway to a career within neuroscience.

Explore careers in *neuroscience*

- The Balance Disorders Laboratory participates in 'Saturday Academy', a Portland-based programme that partners high school students with laboratories and companies for summer internships. Find out more: **www.saturdayacademy.org**
- Pathways to Science provides information on a range of upcoming neuroscience summer camps, internships and other engagement opportunities for high school students: **www.pathwaystoscience.org/discipline.aspx?sort=MED-NeuroSci_Neuroscience**
- Fay recommends the Society of Neuroscience (**www.sfn.org**) for opportunities such as internships and support for high school students to attend their events. Other relevant societies include the International Society of Posture and Gait Research (**www.ispgr.org**), the Society for the Neural Control of Movement (**www.ncm-society.org**) and the Movement Disorders Society (**www.movementdisorders.org**).
- According to PayScale (**www.payscale.com/research/US/Job=Neuroscientist/Salary**), a starting neuroscientist makes on average $82,000 a year in the US.

Meet *Fay*

While I was studying physical therapy, my mother was diagnosed with brain cancer. This motivated me to read about brain science and to better understand what led to specific movement disorders, as well as how rehabilitation could help. I decided to get a master's degree in neuroscience, performing original research about proprioceptors (sensory receptors) in the muscles of cats. I fell in love with neuroscience research and moved to work with primate and human participants for my PhD.

An ex-CEO with Parkinson's disease asked me to develop a new technology that would allow measures of walking and balance to be used in clinical trials. His foundation helped our Balance Disorders Laboratory and start-up company (APDM) develop novel, wearable technology to measure the quality of walking, turning and balance. Our sensors are now used in many clinical trials for PD and other neurological diseases.

> ***I have been honoured to receive an array of national and international awards for my work.***

I am delighted that the Balance Evaluation Systems Test (BESTest) that we developed is now the most popular clinical balance test in the world. I am also proud to have contributed to developing the wearable technology that is now used internationally, and I have been honoured to receive an array of national and international awards for my work.

I enjoy mentoring young neuroscientists to achieve their goals. I also aim to help pharmaceutical companies make the best use of digital measures of balance and walking, to make their clinical trials for neurological disorders more successful.

Fay's *top tips*

1. Find a great mentor. This might be a teacher at school or a laboratory or hospital researcher where you volunteer as an intern.

2. Try to find a range of experience in different areas of neuroscience. Careers in neuroscience can vary hugely, and day-to-day tasks are only obvious when you see them for yourself. While some neuroscientists, like me, work with lots of people, others work mostly with animals or cells.

The links between sleep and Alzheimer's disease

The causes of Alzheimer's disease, a brain disorder, are still far from fully understood. At the **University of North Carolina at Chapel Hill** in the US, **Dr Graham Diering** and **Dr Shenée Martin** believe that the quality of our sleep could be a big contributor. Their experiments are taking a close look at the biomolecular and neurological changes that happen when our sleep is disrupted, and whether this could be a trigger for the development of Alzheimer's.

Dr Graham Diering

Dr Shenée Martin

Department of Cell Biology and Physiology, School of Medicine, The University of North Carolina at Chapel Hill, USA

PROFILES

Fields of research
Biochemistry, neuroscience

Research project
Studying the biochemical and neurological links between sleep disruption and Alzheimer's disease

Funders
US National Institutes of Health (NIH): National Institute on Aging (NIA), Simons Foundation Autism Research Initiative (SFARI)

Talk like a ...

biochemist

Alzheimer's disease — a progressive disease beginning with mild memory loss and possibly leading to near-complete loss of cognitive function

Amyloid plaque — abnormally formed proteins in the brain

Axon — the long part of a neuron which conducts electrical impulses from one end of the cell to the other

Cerebrospinal fluid — the protective fluid that flows around the brain and spinal cord

Dendrite — a branched extension of a neuron that can receive signals across synapses

Locus coeruleus — a small area of the brain stem important for wakefulness, arousal and learning

Mislocalised — found at the wrong location

Neuron — the cells found throughout the brain and nervous system that carry nerve impulses, allowing us to process our environment and perform cognitive functions

Pathology — the study of disease and the changes caused by disease

Piezoelectric — a material that creates an electrical charge when mechanically stressed

Synapse — the gap across which nerve impulses pass from one neuron to another

Tau protein — a protein that can help neurons keep their shape, but can also cause negative effects when mislocalised and when they form a mass

Much of how the human brain functions and develops remains a mystery to science. Even answers to fundamental questions, such as why we sleep, remain relatively hypothetical. "Incredibly, even in 2024, the reasons why we sleep are the biological mechanisms behind beneficial sleep function remain mysterious," says biochemist Dr Graham Diering. With neuroscientist Dr Shenée Martin (who gained her doctorate conducting this research), Graham is aiming to learn more about the benefits of sleep and, specifically, how a good night's sleep might protect us from the development of Alzheimer's disease.

The restorative benefits of sleep

We all know that sleep is good for us – but why? It is likely that much of the answer lies in allowing our brain to process the day's information and discard anything not needed, allowing it to continue gathering information the next day. "Synapses are the connections between the neurons in our brain," explains Graham. "Modification of these connections is essential for learning and forming memories." Our experiences while we are awake shape our synapses, making them larger and stronger – but this also makes them difficult to maintain and can fill up the capacity to make new connections. "After a long day, synapses can become saturated, meaning we cannot store further information," says Graham. "Therefore, there is a need for a restorative balancing process. This is where sleep comes in."

While we sleep, many of the synaptic connections made during the day will selectively weaken, freeing up synaptic strength for the next day. The processing of memories is especially important in terms of prioritising which information to keep

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and which to discard. "Not all our experiences are important enough to consolidate into long-term memory," says Graham. "You don't need to remember what you had for breakfast last week, for instance." In fact, forgetting is an important process for allowing the storage of new information – and humans are good at it. "The synapses responsible for storing important information are protected, while others are weakened during sleep, which helps consolidate important memories while discarding unimportant ones," explains Graham. "Speculation suggests that dreaming is an important part of this sorting and selection process."

Sleeping also brings other benefits for the brain. "Neurons become less excitable when we sleep, meaning they are activated less frequently," says Graham. "This is important to maintain neuron health over a lifetime." Sleep also gives the brain a chance to 'do the laundry'. "Cerebrospinal fluid, which surrounds brain cells, accumulates toxic waste products from cellular activity during the day," explains Graham. "During sleep, cerebrospinal fluid flow physically washes the brain clean, clearing away these toxic byproducts."

Sleep disruption

As they get older, many people find it progressively more difficult to fall asleep and to sleep soundly, leading to an overall negative effect on their sleep quality. "There is evidence that sleep fragmentation, where people have difficulty staying asleep, may be the most detrimental," says Graham. Poorer sleep makes it harder to access the benefits of sleep. "Sleep disruption impairs our ability to process memories and can promote inflammation in the brain – a key aspect of Alzheimer's susceptibility," says Graham. "It also means that brain cells are overactivated, causing damage to cells."

When it comes to Alzheimer's specifically, researchers have identified some key indicators that are linked to both Alzheimer's and poor sleep quality. "For instance, impaired cerebrospinal fluid flow can lead to the accumulation of toxins that aggregate to form amyloid plaques, one of the hallmarks of Alzheimer's," says Graham. "Toxic Tau proteins also accumulate inside neurons, forming neurofibrillary tangles (abnormal formations of Tau) which ultimately kill brain cells." Toxic Tau proteins spread in a pathogen-like way, released from neurons when they are excited during waking hours. "Sleep decreases the release of Tau, while increased time awake accelerates its spread through the brain," says Graham. "Thus, sleep loss accelerates Alzheimer's pathology both by driving neuronal excitability and by decreasing the flow of cerebrospinal fluid."

Does poor sleep lead to Alzheimer's?

"The Tau protein is normally found in the axons of neurons, but, recently, it's also been found in the postsynaptic dendrites, where neurons receive information," says Shenée. "We hypothesise that the Tau protein's presence here may make synapses more vulnerable to the effects of sleep loss." Principally, this mislocalised Tau is found in neurons in the cortex and hippocampus, areas of the brain that focus on memory and higher cognition. "The presence of Tau at synapses may hamper synapses' ability to change in strength, which impairs the formation of new memories," says Graham. "Tau may also damage the synapses themselves, contributing to synapse loss and, therefore, memory loss – a symptom of Alzheimer's."

The team theorised that sleep disruption might cause or accelerate this mislocalisation of Tau. They tested this theory using mouse models. To acutely disrupt mice's sleep, the team tap lightly on their cages, change their bedding or move the cage. To test chronic sleep disruption – where sleep is routinely disturbed in the long-term – the team places the cage on a device that periodically and lightly shakes the cage. "Interestingly, we found no measured effect on levels of mislocalised Tau in the cortex or hippocampus," says Graham. "But when we looked in the locus coeruleus, a key structure in the brain stem that promotes waking, we found that sleep disruption does drive an increase in Tau pathology there." The locus coeruleus is typically one of the first locations where Tau pathology is found in the early stages of Alzheimer's disease. "The locus coeruleus neurons are also important for learning, so loss of these neurons can contribute to cognitive decline," says Graham. "Interestingly, only male mice showed an acceleration of cognitive decline. We have a theory that females have a type of 'cognitive reserve' in the hippocampus, which we will investigate further."

Does Alzheimer's lead to poor sleep?

The team has a strain of mice that have been bred to produce high levels of Tau mislocalisation. "We can monitor mouse sleep behaviour non-invasively in our lab," says Shenée. "A piezoelectric mat is placed underneath their cage to detect any physical activity, including small movements and breathing rate." The team tested the sleep patterns of these mice throughout their lifetimes compared to those of normal mice. "We found that Tau Alzheimer's mice develop changes in sleep behaviour early on, well in advance of robust Tau pathology or cognitive decline," says Graham. "This suggests that sleep disruption is an early symptom that could be a major contributor to disease progression."

The team may have uncovered a positive feedback loop. Poorer sleep leads to Tau mislocalisation, which in turn leads to even poorer sleep, which accelerates Tau mislocalisation – and so on. "With this view, there is less an issue of cause and effect, and more of breaking the vicious cycle," says Graham. "Protecting or improving sleep could help in slowing or halting the progression of Alzheimer's."

To the real world

The team knows that more research is needed to fully understand the links between sleep disruption and Alzheimer's susceptibility, but the benefits of sufficient and undisrupted sleep in preventing cognitive decline are already clear. "Widely-used sleep-aid medicines, namely sleeping pills, are simple sedatives that are unlikely to improve restorative sleep functions," says Graham. "Future research can support the development of next-generation sleep medicines that actually enhance the benefits of sleep."

Shenée is especially interested in the differences observed between male and female mice. "While we could clearly distinguish the differences, the mechanisms behind those differences and what they mean remain unknown," she says. "We are also intending to run a project on how to rescue sleep disruption and halt cognitive decline. This is exciting work and could strengthen the case for prioritising sleep to stave off disease."

About *biochemistry*

Biochemistry applies chemistry to biological processes at the molecular and cellular level. It studies the chemical reactions within living things and how these reactions affect function. Its applications are broad, including healthcare, drug development, biotechnology, manufacturing and forensics. Graham explains more about his field.

"One of the most exciting things about being a scientist is that when we have a successful experiment, we are often observing something that has never been seen before. We are pushing the boundaries of human knowledge. This is a very rewarding feeling.

"My favourite part of my job is working with other scientists. The best science is driven by interaction and collaboration. New advances in science are also greatly facilitated by bringing in new generations of scientists that approach old problems with new ideas. I love to mentor young scientists in my lab, see their successes and watch them advance their careers.

"Biomedical research is a fast-moving and quickly-growing sector of the economy. People trained in science literacy and research are highly desired in many sectors. There is considerable growth in the pharmaceutical and biotechnology sectors, which creates opportunities for people skilled in both science and business. This growth especially benefits from trained scientists in the areas of public policy and education. It is important to make individual and societal decisions based on scientific evidence.

"If you're considering a career in biochemistry, talk to people in the sector. Reach out to as many people as you can, be it professors at universities, research scientists or relevant people in your local community. Learn about the experiences of others, how they navigated their education and career paths. And try to get involved in research itself, if you can. Building a personal network can help hugely in finding these opportunities."

Pathway from school to *biochemistry*

- Graham says that biology, chemistry and, increasingly, statistics are important core subjects. He also recommends building skills in computer coding and using artificial intelligence. To build science communication skills, he suggests nurturing skills in the arts and graphic design.
- Depending on your specific areas of interest, relevant degrees at university include biochemistry, biology, biomedicine, molecular biology, microbiology, natural sciences and neuroscience.

Explore careers in *biochemistry*

- The University of North Carolina hosts an annual science expo which showcases scientific experiments and features talks and demonstrations from researchers: **our.unc.edu/event/unc-science-expo-at-morehead-planetarium/**
- Pathways to Science has a directory of summer camps, internships and more for those interested in a biochemistry career: **www.pathwaystoscience.org/discipline.aspx?sort=MED-Biochem_Biochemistry**
- According to Talent.com, the average biochemist salary in the US is $61,800 per year.

Meet *Shenée*

Dr Graham Diering and Dr Shenée Martin at Shenée's PhD graduation ceremony, 2023

I started out as a psychology major because I enjoyed learning why people do the things they do. In my junior year, I was introduced to a scholars' programme that gave students the opportunity to conduct research at different universities during the summer. I took a leap of faith and landed an opportunity to conduct research in Puerto Rico.

My experience in Puerto Rico inspired me to be a neuroscientist. The lab studied Alzheimer's disease and my mentor, Dr Irving Vega, taught me everything from basic biology to the signs of brain disease. All my mentors in the lab taught me new techniques, and their love of science really radiated through. I became fascinated by the research environment and, specifically, about the breakdown of the human brain and why it happens.

I come from a small island, where not many people I knew pursued a PhD in STEM. I was fortunate enough to be presented with opportunities that challenged my educational aspirations and unlocked my love of research. This new path led me to multiple research experiences at different universities and a network of amazing people from different backgrounds, which greatly broadened my horizons.

> ***It can be difficult to stay motivated, but the successes make it worthwhile... I have received awards for my work and met some amazing minds along the way.***

Pursuing a PhD is challenging because you are the driver of your own success. There are many failures along the way. I had to deal with negative data, failed experiments and repeated grant rejections. It can be difficult to stay motivated, but the successes make it worthwhile. Although my results did not come out exactly as planned, we reported male and female differences that had not been shown before. My grant applications became stronger, and my research was eventually funded. My writing and science communication skills improved drastically. I have received awards for my work and met some amazing minds along the way.

My proudest career achievement, so far, is being awarded a competitive fellowship grant from the National Institute of Aging. I applied three times and was rejected twice. I worked very hard on putting the story together, so it was very rewarding when it finally came through. I now hope to secure a research position in industry.

Shenée's *top tips*

1. Resilience and grit are fundamental for succeeding in graduate school; do not lose sight of your goal.
2. Surround yourself with likeminded people, be open to new opportunities and make great connections with your peers.
3. Stay curious and get involved. Try to volunteer in a lab or science museum, and find research opportunities if you can.

Remembering resistance: non-genetic memory in bacteria

Typically, the skills and properties developed through adaptation during a lifetime may not be directly passed onto the next generation as encoded in genes – they are learnt. However, **Dr Hanna Salman** and **Dr Andrew Mugler**, from the **University of Pittsburgh** in the US, are finding evidence that bacteria can pass on 'memories' to their offspring, over several generations. Understanding more about this process is crucial for the fight against the rise of antibiotic resistance in bacteria.

Dr Hanna Salman

Dr Andrew Mugler

Department of Physics and Astronomy, University of Pittsburgh, USA

PROFILES

Field of research
Biological physics

Research project
Using experimental and theoretical methods to investigate non-genetic memory of antibiotic resistance in bacteria

Funders
US National Science Foundation (NSF) award numbers DMS-2245816, PHY-2014116 and PHY-2118561, US-Israel Binational Science Foundation (BSF)

Talk like a ...

biological physicist

Antibiotic — a substance that inhibits the growth of, or destroys, bacteria

Bacteria — a large group of single-celled organisms, some of which can cause disease

Daughter cells — genetically identical cells formed when a cell undergoes mitosis

Mitosis — a type of cell division resulting in two daughter cells with the same number of chromosomes as the parent cell

Messenger RNA (mRNA) — a genetic 'messenger' molecule involved in protein synthesis

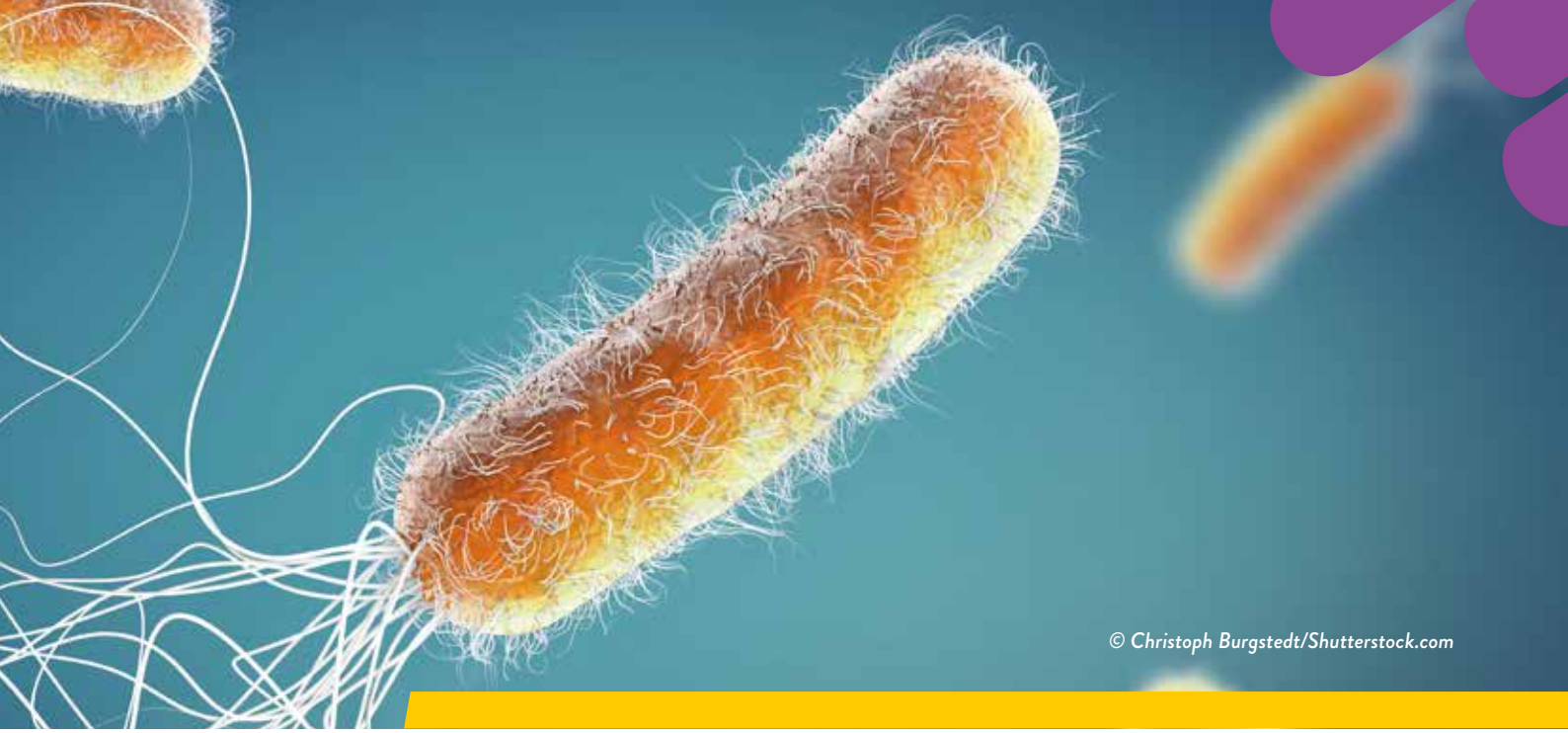
Non-genetic memory — in bacteria, information or characteristics that are passed on by mechanisms other than through genetic inheritance

Antibiotic resistance is a growing problem that seriously threatens humanity's collective ability to fight bacterial disease. Scientists from many different fields are working on addressing this issue. One such field is the relatively new discipline of biological physics, which involves taking lessons from physics and applying them to biological questions. Dr Hanna Salman and Dr Andrew Mugler both work in the same department at the University of Pittsburgh but take different – yet complementary – approaches to understanding antibiotic resistance. While Hanna's lab undertakes experiments with bacteria, Andrew's lab develops mathematical equations and computer programmes that model the outcomes of such experiments. Combined, they are studying a previously inaccessible pathway by which bacteria can potentially develop antibiotic resistance.

Non-genetic memory

A cell's DNA is where instructions of how to make all cellular components are stored. It was, therefore, believed that all cellular properties are determined by the DNA, and that DNA was the only carrier of memory between consecutive generations. However, cellular components are produced by complex interactions between cellular machinery and the DNA. This suggests that cellular machinery passed between consecutive generations can also influence the cell's memory. Bacteria divide to form two new, identical 'daughter' cells via a process called mitosis. This means that, as well as the genetic material, both daughter cells retain other cellular content from the parent cell. "When a cell divides, all of its content is divided between the two daughter cells," says Hanna. "If a cell happens to have a certain property – more molecules of a specific type, for instance – then this property may be retained in its daughters."

This process is different from genetic inheritance, because while information encoded in genes is very stable, the cell's molecular content exhibits large fluctuations, which can lead to deviations in the cell's attributes from their steady state. "Cellular properties may persist for several cell divisions before the natural



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processes that keep these attributes steady kick in," says Andrew. "As a result, cellular 'memory' can last for multiple generations – longer than the lifetime of the cell itself."

It is only in recent years that scientists have paid significant attention to this process of non-genetic memory in bacteria. "Previously, it was thought that when cells divide, the 'memory' of the previous generation is essentially wiped," says Hanna. "Now, it has been established that cell properties are subject to complex control mechanisms, but it is still generally assumed that non-genetic memory only lasts a generation or so." However, Hanna and Andrew's labs are uncovering evidence that suggests that this memory can persist for multiple generations – which has huge significance for the real world.

Antibiotic resistance

"Bacterial resistance to antibiotics is a major health concern," says Andrew. "Often, bacteria are able to develop antibiotic resistance without mutating their genome, by changing their cellular properties." If this resistance can be passed on through multiple generations, it has the potential to be a big problem. Previously, it was assumed that antibiotic resistance was always inherited genetically, through mutations in the bacteria genome, but non-genetic memory presents a possible second pathway for such resistance to emerge. "We need to understand non-genetic cellular memory in a quantitative way, how it is affected by antibiotics, and the underlying molecular mechanisms behind it," says Hanna. "With this knowledge, we can potentially reduce or even prevent bacteria's ability to develop resistance."

Hanna and Andrew's teams are investigating how different antibiotics appear to affect this intergenerational memory. "This study will allow us to better understand how cells develop antibiotic resistance," says Hanna. "In addition, we're planning to study how the abundance of messenger RNA (mRNA) can affect the cell's memory." mRNA is the 'messenger' molecule that carries the genetic information stored on DNA to the cellular machinery that uses this information to build specific proteins. "mRNA is also passed on from mother to daughter, so its abundance is likely an important factor affecting cellular memory," says Andrew.

> **"This study will allow us to better understand how cells develop antibiotic resistance."**

Experiment and theory

The teams have been making some interesting findings: specifically, that non-genetic cellular memory can endure for multiple generations. "These findings are at odds with current understanding of how cells control their properties and division cycles," explains Hanna. "This indicates a gap in our collective scientific knowledge." The teams are aiming to fill this gap with a two-pronged approach: Hanna's lab focusing on further experiments, and Andrew's lab focusing on mathematical modelling. "We aim to develop a fundamental experimental and theoretical understanding of the observed multi-generational memory," says Andrew.

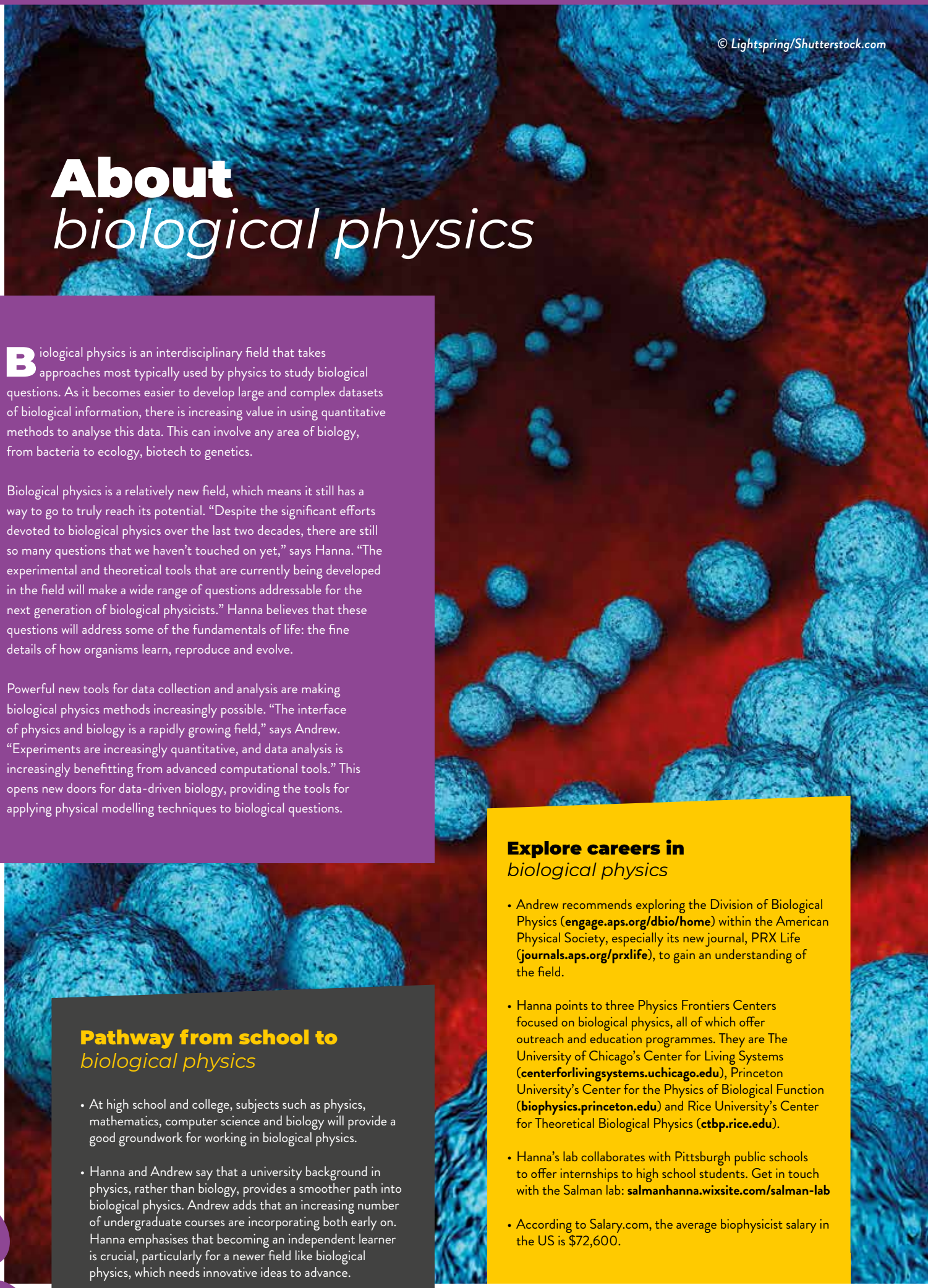
Both experiment and theory are necessary to build a strong scientific case for these findings. "Experimental results suggest a model of a possible underlying mechanism, but mathematical theory is required to make this model plausible, precise and predictive," says Hanna. "Conversely, the predictions made by theoretical models need to be tested with real-life experiments." This collaboration between experimentalists and theorists has been underway in the realm of physics for decades but is a relatively new approach for biological systems.

Non-genetic memory in bacteria is not simply a matter of generations having more or less of certain molecules. There are complex interactions to account for, which is why sophisticated modelling approaches are needed. "Statistical physics provides the framework for describing fluctuations in cellular properties," explains Andrew. "These tools allow us to describe how molecular abundances fluctuate in time, and how they depend on one another, ultimately helping us predict the outcome of experiments." These experiments need to be tightly controlled to be compatible with the model. "We continuously strive to develop new experimental systems to accurately control the environment and perform molecular manipulations," says Hanna.

Looking ahead

By understanding the molecular control behind non-genetic memory, researchers can then unlock mechanisms to influence or disrupt this control. "If we understand how this memory is affected by antibiotics, we can influence it to prevent cell adaptation to new antibiotics," says Andrew. "Additionally, control mechanisms in biology are often common across many different types of cells, so what we learn here may also be relevant to other contexts." For instance, the uncontrolled proliferation of cancer cells appears to involve a non-genetic change similar to bacterial adaptation, so it is possible that the teams' findings may be useful for slowing or stopping the spread of cancer.

Hanna and Andrew are aiming to develop ever-more sophisticated approaches to study this multigenerational memory in more detail. "Experimentally, we are working on building new devices and new genetic tools to measure the properties of multiple molecule types in many pairs of daughter cells at the same time," says Hanna. "Theoretically, we are developing a mechanistic theory of cell division to describe how molecular fluctuations and memory work from the molecular to the cellular scale," adds Andrew.



About *biological physics*

Biological physics is an interdisciplinary field that takes approaches most typically used by physics to study biological questions. As it becomes easier to develop large and complex datasets of biological information, there is increasing value in using quantitative methods to analyse this data. This can involve any area of biology, from bacteria to ecology, biotech to genetics.

Biological physics is a relatively new field, which means it still has a way to go to truly reach its potential. "Despite the significant efforts devoted to biological physics over the last two decades, there are still so many questions that we haven't touched on yet," says Hanna. "The experimental and theoretical tools that are currently being developed in the field will make a wide range of questions addressable for the next generation of biological physicists." Hanna believes that these questions will address some of the fundamentals of life: the fine details of how organisms learn, reproduce and evolve.

Powerful new tools for data collection and analysis are making biological physics methods increasingly possible. "The interface of physics and biology is a rapidly growing field," says Andrew. "Experiments are increasingly quantitative, and data analysis is increasingly benefitting from advanced computational tools." This opens new doors for data-driven biology, providing the tools for applying physical modelling techniques to biological questions.

Pathway from school to *biological physics*

- At high school and college, subjects such as physics, mathematics, computer science and biology will provide a good groundwork for working in biological physics.
- Hanna and Andrew say that a university background in physics, rather than biology, provides a smoother path into biological physics. Andrew adds that an increasing number of undergraduate courses are incorporating both early on. Hanna emphasises that becoming an independent learner is crucial, particularly for a newer field like biological physics, which needs innovative ideas to advance.

Explore careers in *biological physics*

- Andrew recommends exploring the Division of Biological Physics (**engage.aps.org/dbio/home**) within the American Physical Society, especially its new journal, PRX Life (**journals.aps.org/prxlife**), to gain an understanding of the field.
- Hanna points to three Physics Frontiers Centers focused on biological physics, all of which offer outreach and education programmes. They are The University of Chicago's Center for Living Systems (**centerforlivingsystems.uchicago.edu**), Princeton University's Center for the Physics of Biological Function (**biophysics.princeton.edu**) and Rice University's Center for Theoretical Biological Physics (**ctbp.rice.edu**).
- Hanna's lab collaborates with Pittsburgh public schools to offer internships to high school students. Get in touch with the Salman lab: **salmanhanna.wixsite.com/salman-lab**
- According to Salary.com, the average biophysicist salary in the US is $72,600.

Meet *Hanna*

I have always wanted to understand why and how natural phenomena occur. I find it exciting whenever I finally understand why things around us behave the way they do. This passion was in part inspired by my dad, who was a high school physics teacher. He saw my aptitude for science and encouraged me to pursue it.

The road to an independent academic position in science is very long and often difficult. To go through it requires hard work and a lot of support and encouragement along the way. Every experiment that succeeded after much work, and every word of support and encouragement I received from my advisers, were the eureka moments that gave me confidence that I could make it as a scientist.

In addition to making new discoveries in research and understanding how the world around us works, the most rewarding thing of leading my own lab is to see my students grow as scientists, become independent and accomplished researchers, and achieve their own career goals.

When carrying out new and innovative research, many attempts will fail. This might discourage new students from continuing the work and trying new ways to achieve their goals. The most challenging thing as a group leader is to maintain students' motivation in the face of these failures.

There are several scientific discoveries that I am proud of, but what I am most proud of so far is that all my students were able to reach the next milestone they wanted to achieve upon completing their work with me, and which advances them toward the career goals they set for themselves.

What initially attracted me to biology is that unlike inanimate systems, biological systems can vary in their behaviour under the same environmental conditions. I am currently working toward understanding how this variability develops over time and how information passed on from one generation to the next allows for this diversification. We have recently developed a new experimental tool that can help us shed some light on this question, and I hope that we can use it to answer this question, in the near future.

Meet *Andrew*

I always loved mathematics and art. I found that science, especially physics, combines aspects of both, because it requires creative problem solving. I also had a dedicated and dynamic high school physics teacher who pushed me to pursue science.

I considered leaving graduate school to teach, but I realised that research-focused careers often include the freedom to teach, whereas teaching-focused careers rarely allow for extensive research. I'm glad I chose this path because I love doing both.

It is deeply rewarding to see a graduate student go from knowing nothing about a field to becoming an expert and, essentially, begin teaching me! I also love solving puzzles, so it is personally rewarding to have that be a part of my livelihood and get to share that with others.

It is challenging to sustain a steady stream of new ideas. It requires staying very engaged with the field and foreseeing where my group can contribute meaningfully.

Although I have won several early career awards, I am proudest of an award I won with others: the American Physical Society's Oppenheim Award. It honours the best paper in Physical Review E, a specialised biological physics journal. It is not the most prestigious award, but I am proud because my student was the paper's first author, and it means that people really engaged with and enjoyed the paper.

I am also proud that undergraduate students I have advised on research projects have won some of the highest awards available, including a Fulbright Scholarship and the American Physical Society's highest undergraduate award.

The past few decades have seen a huge advance in our understanding of the molecular interactions that drive cell behaviour, but new technologies are generating more data than ever before at the cellular and population levels. A primary goal of mine is to take the mathematical tools from physics that I have applied to molecular interactions in the past and apply them to cell- and population-level interactions in the future.

Hanna's *top tips*

1. Make sure that you really love your chosen research area and have genuine interest in it.

2. Don't just follow trends; they will fade and change with time, and only by being interested in what you do will you overcome challenges and keep the motivation to achieve your goals.

Andrew's *top tip*

Aim to gravitate towards the subjects and people who interest you most. You don't have to know what you will be doing in five or ten years from now, but if you explore and trust your instincts, you will find yourself doing what you love and are good at.

How can we develop more effective vaccines?

When the COVID-19 pandemic struck the world in 2020, our everyday lives were put on hold until immunologists and vaccinologists discovered how to protect us. Incredibly, multiple vaccines for the disease were developed and approved for use within record-breaking time. At the **University of Colorado Anschutz School of Medicine** in the US, **Professor Ross Kedl** and his team are studying the immune system in the hope of exploiting it to develop more effective vaccines.

Professor Ross Kedl

Department of Immunology and Microbiology, University of Colorado Anschutz School of Medicine, USA

PROFILE

Fields of research
Immunology, vaccinology

Research project
Understanding the innate and adaptive immune systems to develop adjuvants for vaccines

Funder
US National Institutes of Health (NIH)

Talk like an ...

immunologist and vaccinologist

Adaptive immune system — the part of the immune system that provides a targeted response to specific pathogens

Antigen — a foreign substance (e.g., a pathogen) that triggers an immune response

Adjuvant — a substance added to a vaccine to improve its effectiveness

Antibody — a protein produced by B cells of the adaptive immune system to neutralise pathogens

B cell — an immune cell that produces antibodies

Extracellular — taking place outside a cell

Innate immune system — the part of the immune system that provides a general response to any pathogens

Intracellular — taking place within a cell

Pathogen — a microorganism that can cause disease, such as a virus, bacterium or fungus

Pathogen recognition receptor (PRR) — a protein expressed by an immune cell that identifies pathogens

T cell — an immune cell that destroys infected cells

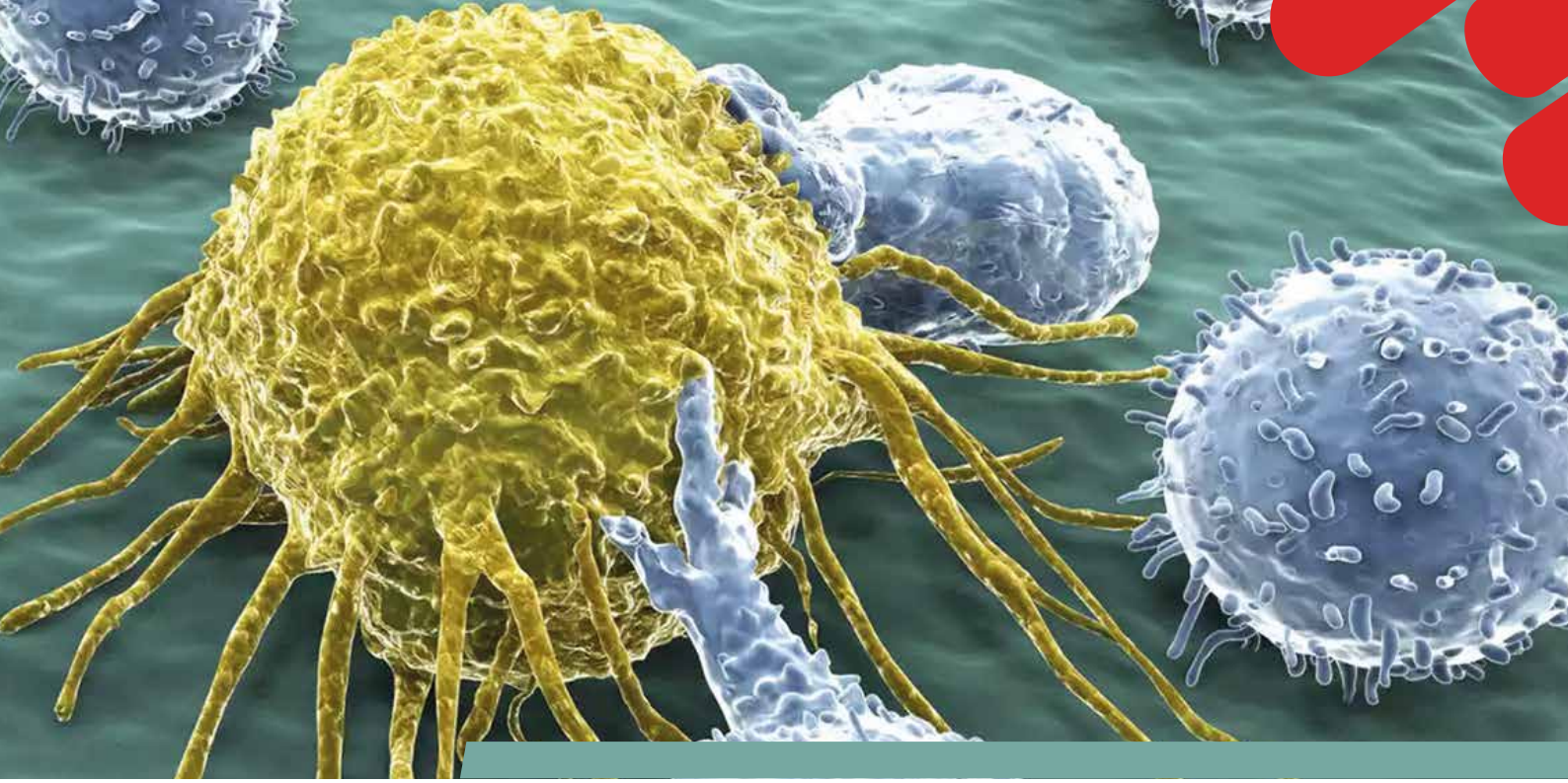
Your immune system is a complex network of cells and biological systems that protects you from diseases. It is made up of two parts, the innate and adaptive immune systems, which work together to combat infections. "As an analogy, you can think of these two parts of the immune system as a combination of the transportation security administration (TSA) at the airport and more advanced security units," says Professor Ross Kedl, an immunologist and vaccinologist at the University of Colorado Anschutz School of Medicine. "The TSA officers are very good at detecting possible threats from people or baggage. If a threat is detected, the TSA officers initiate containment efforts, such as closing the airport or grounding planes, then they pass along the information to the police or military, who can devise a specific plan of attack for the threat at hand." Like the TSA officers, our innate immune system alerts the body to threats from pathogens, before passing control over to the adaptive immune system, which provides a more specialised and targeted response.

How does the immune system respond to pathogens?

Firstly, the innate immune system uses pathogen recognition receptors (PRRs) to identify whether the pathogen is a virus, bacterium or fungus. "At a certain level, any one virus can 'look' much like any other virus, and the same is true of bacteria and fungi," says Ross. "However, an extracellular fungus infection is very different from an intracellular virus infection, so the immune system needs to mobilise different immune cells for different types of pathogens."

Once the PRRs have identified the type of infection, the innate immune system passes this information to the adaptive immune system. "Armed with this knowledge, the adaptive immune system will set about making a large number of cells and molecules that recognise that type of infection and eliminate it from the body," Ross explains.

The adaptive immune system is composed of B cells and T cells, which have different methods for protecting our bodies. When triggered by an antigen, B cells produce



antibodies, which are soluble protein molecules that travel through the bloodstream and bodily tissues, before binding to the pathogen to help neutralise it. In contrast, T cells destroy infected cells in the body. "There are two main types of T cells – those that coordinate responses to both intracellular and extracellular infections (CD4 T cells) and those that are focused on 'hand-to-hand combat' with infected cells (CD8+ T cells)," says Ross. CD8+ T cells can directly kill virus-infected cells and cancerous cells, while CD4 T cells are 'helper' cells that activate other immune cells to fight the infection. This is an important distinction, as our bodies need to make sure they produce the right type of T cells to get rid of infections.

For example, if a person is infected with a virus, which replicates inside cells, their immune system needs to produce CD8+ T cells that combat infected cells. However, fungal infections replicate outside of cells in bodily tissues. "In this case, generating CD8+ T cells doesn't make much sense and would be a waste of energy," explains Ross. This is because CD8+ T cells only fight infected cells, not infected tissues. Instead, the body would need CD4 T cells to fight a fungal infection.

How do vaccines take advantage of the immune system?

Armed with this knowledge about the immune system, vaccinologists take advantage of the characteristics of our innate and adaptive immune systems to develop vaccines that protect us from pathogens. "T and B cells can live for decades in the body," says Ross. This means that if you are reinfected by a pathogen you have previously been exposed to, your adaptive immune system will remember how to attack that specific pathogen, allowing your body to produce a targeted and rapid response. It is this feature of adaptive response that allows vaccines to protect us, as they deliver a dead or weakened pathogen, or even just specific molecules derived from the pathogen, into the body so the immune system learns how to fight the infection.

How do adjuvants improve vaccines?

In the 1920s, French veterinarian Gaston Ramon and English immunologist Alexander Glenny were each experimenting and trying to develop a vaccine against diphtheria, a bacterial infection. By injecting hamsters with inactivated diphtheria toxin, the scientists observed that the animals did not produce a strong antibody response to the infection. However, if they first mixed the toxin with another substance before injecting it, the hamsters had a significantly better antibody response.

Any substance added to a vaccine to increase its effectiveness is known as an adjuvant, derived from the Latin word *juvare* that means 'to help'. "Adjuvants encourage the immune system to deliver a more powerful response to an infection," explains Ross. "They stimulate the innate immune system which then causes the T and B cells of the adaptive immune system 'wake up and pay attention'."

In Ramon's case, he discovered that the hamsters' immune systems responded more to the diphtheria toxin if it was mixed with a range of substances, including tapioca (a starch from the cassava plant), agar (a gel-like substance from algae) and even breadcrumbs! Glenny used alum (aluminium salts) as the adjuvant in his diphtheria vaccine, a substance still used as the adjuvant in many vaccines today.

Why is Ross studying adjuvants?

"Currently, we have vaccines that are very good at making antibodies, which protect us from infectious diseases like COVID-19 and measles," says Ross. "But if you want your immune system to fight off something you already have, like a chronic disease or cancer, you need to make a lot of T cells for that to work. I'm interested in how to get vaccines to make very large CD8+ T cell responses, to kill virus-infected or cancerous cells."

Some recent cancer therapies use this technique to encourage the patient's T cells to kill the cancerous cells. "When this works, it's remarkable, but it doesn't work as well or as often as we wish, and one of the reasons is that not everyone makes as many T cells as they need to." Interestingly, Ross and his team discovered that part of the reason why vaccines do not produce a strong CD8+ T cell response is that the adjuvant is often not effective enough. In response, they are now exploring the effects of combination adjuvants that target multiple molecules of the innate immune system. Having tested their vaccines on mice, these combination adjuvants seem to create a powerful connection between the innate and adaptive immune responses, leading to a much stronger T cell response. After further testing, Ross hopes that the team's combination adjuvants will be approved for clinical use in humans, paving the way for new vaccines to treat cancer.

Members of Ross' lab are on a mission to develop more effective vaccines, and to have fun while they do so!

About *immunology and vaccinology*

Immunology and vaccinology are closely related fields, but there are key differences between them. While both are branches of medicine and biology, immunology is the study of immune systems, while vaccinology applies this knowledge to develop vaccines that protect against infectious diseases and cancer. There is, therefore, a lot of overlap between immunology and vaccinology, as vaccines work by leveraging the natural ability of our immune systems to form a very specific response against an antigen and then remembering that response for years afterward.

The importance of vaccines

The crucial work of immunologists and vaccinologists was highlighted during the COVID-19 pandemic. As the disease spread rapidly around the world, forcing friends and family members to remain isolated from each other and leaving a trail of devastation in its wake, immunologists and vaccinologists worked overtime for months on end to develop a vaccine against the virus.

Usually, it takes 10-15 years to develop a new vaccine, but, thanks to the urgent need from the global community and the dedication of immunologists and vaccinologists, COVID-19 vaccines were developed in record time. "It's worth noting that mRNA vaccines were in development for more than 10 years before COVID-19 began and had already been clinically tested for viral diseases such as Ebola and Zika," says Ross, highlighting how COVID-19 vaccines were developed by building upon previous vaccinology advances. The first COVID-19 vaccines were approved for use less than a year after the disease was first identified, and this huge achievement saved hundreds of thousands of lives, allowed lockdowns to lift and dramatically changed the course of the pandemic.

If a COVID-19 vaccine could be developed so quickly, why have vaccinologists still not developed vaccines for other viruses?

The human immunodeficiency virus (HIV), which causes acquired immunodeficiency syndrome (AIDS), was first identified in the 1980s and has since caused over 40 million deaths around the world, but no successful HIV vaccine has yet been developed. "The virus that causes COVID-19, a beta coronavirus called SARS-CoV2, is a very basic virus that does not have many mechanisms to hide from, or counteract, the immune response against it," explains Ross. "In contrast, HIV is a much more complex infection. HIV mutates quickly and keeps changing what its surface looks like. This makes it very hard for antibodies to bind to and neutralise the virus. On top of that, HIV infects CD4 T cells, which are needed to not only fight the virus but to maintain a healthy immune system to fight off any other diseases, so developing a vaccine against HIV is much more complicated."

Pathway from school to *immunology and vaccinology*

- At school and post-16 years, study biology and chemistry to learn about the human body, cells and biochemical processes. It would also be useful to study English, as communicating research results and writing grant applications are an important part of scientific jobs.
- At university, a degree in biology, immunology, biochemistry or biomedical science could lead to a career in immunology or vaccinology. "Take classes in genetics, microbiology and immunology if they are offered," says Ross.
- Try to get some hands-on experience in a research lab while you are studying. Look for summer internships and ask faculty members in local immunology or vaccinology departments if they have any research or job shadowing opportunities. "You'd be surprised at how open professors are to taking in interested students, no matter their age," says Ross.
- The University of Colorado Anschutz School of Medicine offers a number of outreach opportunities for schools in the local area, as well as summer lab research experiences for high school and undergraduate students: **www.cuanschutz.edu/offices/inclusion-and-outreach/programs**

Explore careers in *immunology and vaccinology*

- There is a wide variety of career paths in immunology and vaccinology, including working in academia, medical settings or in the pharmaceutical industry. "The immune system is involved in all organs and biological processes, so studying immunology opens up the entire world of research in medical biology," says Ross.
- The University of Colorado Anschutz School of Medicine has many online resources for students, including informative videos, that explore ideas in immunology and vaccinology: **medschool.cuanschutz.edu/immunology-and-microbiology/teaching-resources/curriculum-resources/curriculum-resources-videos**
- The American Association of Immunologists (**www.aai.org/Education**) and the British Society for Immunology (**www.immunology.org/careers**) both have a wealth of resources about studying and working in immunology.

Ross' *top tips*

1. Get to know people. Science is best done in a community, and the people you meet today are going to be your employers, grant readers and manuscript editors tomorrow.
2. Be humble. If you aren't, there's a good chance you will eventually be humiliated.
3. Passivity is not an asset. Actively engage in your future!
4. Stay curious.

Meet *Ross*

I was captured by biology thanks to my high school biology teacher, Mr Strand. He was an all-round great teacher, but when he talked about how the DNA in my cells carried all the information necessary to make another 'me', I was hooked.

My plan was to teach high school biology. After graduating with an undergraduate degree in biology from the University of Minnesota, I enrolled in their post baccalaureate secondary education programme. I was accepted, but I deferred my place for a year while my wife finished her degree. During that time, I worked in a research lab on campus. About six months in, I was performing an experiment called a 'Western blot'. I didn't have time to complete the experiment because it was late in the day and we had company coming over for dinner, so I put the incomplete blot in the lab fridge for the night. I don't remember anything about dinner that night because I was so distracted by how my experiment might have gone. I eventually got up at 4am and went to the lab to find the answer. As it turns out, the experiment was a total flop! But I was already troubleshooting and problem solving what might have gone wrong, what I could do next and how I could make the experiment successful. It suddenly occurred to me that if this sort of thing was keeping me up at night, I should probably rethink my career path and consider doing research.

My first job as an independent researcher was at 3M Pharmaceuticals. The company had developed many novel compounds which I thought could be interesting as vaccine adjuvants. It was my time at 3M that sparked my initial and ongoing interest in using adjuvants to make better T cell responses. We made some interesting discoveries while I was there, including discoveries about combination adjuvants, however 3M had no interest in pursuing these ideas commercially. So, I formed a small start-up company called ImmuRx with some colleagues to explore combination adjuvants further. While we never got to see our work in clinical use, my experience at 3M and ImmuRx gave me the expertise to consult with companies attempting to commercialise products targeting anything from immune regulation to gene therapy.

Most people don't know this, but being a tenured faculty member only means that the university agrees to pay half my salary. They provide nothing for my actual research, or to pay for my lab members to do the research, so I have to write grants to get funding to cover the expenses of lab supplies and salaries. Though the grant writing is heavy work at times, it's worth it for the fun of the research I get to do.

Trying to unravel the mysteries of the immune system has always held my fascination like nothing else in science. I also enjoy training students and early career researchers and seeing their passion and excitement for the work come alive and flare into a lifelong pursuit.

Creating a clear image of myopia: discovering the causes and developing treatments

Myopia, also known as near-sightedness, causes blurry distance vision and is estimated to affect over 30% of the world's population. At **Emory University School of Medicine** in the US, **Professor Machelle Pardue** and her research team are working to better understand the underlying causes of myopia. They hope their discoveries will identify novel therapeutic interventions for treating myopia in children.

Professor Machelle Pardue

Vice Chair and Director of Research, Department of Ophthalmology, Emory University School of Medicine, USA

PROFILE

Field of research
Ophthalmology

Research project
Investigating the retinal mechanisms of eye growth and myopia development

Funder
US National Institutes of Health (NIH)

Talk like an ...

ophthalmologist

Axial length — the length of the eye, usually measured from the front of the eye to the back of the retina

Emmetropisation — a process that occurs after birth whereby the refractive components of the eye and the axial length come into balance to achieve clear vision

Myopia (near-sightedness) — a type of refractive error that typically occurs when the eye is too long and light focuses in front of the retina, causing distant objects to appear blurry

Ophthalmology — the branch of medicine focused on the eye and vision

Optical power — the degree to which a lens or other optical system bends or focuses light

Photoreceptors — the cells in the retina that are responsible for detecting light

Refractive error — a common type of vision problem that occurs when light does not focus correctly on the retina, resulting in blurry vision

Retina — the light-sensitive layer of tissue in the back of the eye

Sclera — the white, outermost layer of the eye that provides structural support

Myopia is characterised by blurry distance vision. It is a very common eye condition that currently affects over 30% of the world's population, and its prevalence is rapidly increasing. It is predicted that by the year 2050, 50% of the world's population (equivalent to almost 5 billion people) will have myopia. Glasses and contact lenses can correct the visual symptoms of myopia by helping people to see clearly, but they do not stop the progression of the condition or prevent the associated vision-threatening complications that can lead to visual impairment.

How does myopia occur?

After birth, the optical power (i.e., focusing strength) and size of our eyes come into balance to achieve clear vision, a developmental process known as emmetropisation. However, if the eye's optical power and axial length fail to come into balance, then light does not focus correctly on the retina, the light-sensitive tissue in the back of the eye. This leads to refractive errors, which result in blurry vision. The two main types of refractive error are myopia (near-sightedness), which typically occurs when the eye is too long, and hyperopia (far-sightedness), which typically occurs when the eye is too short.

At Emory University School of Medicine, vision scientist Professor Machelle Pardue is working with her research team: Dr Reece Mazade, Dr Melissa Bentley-Ford, Dr Linjiang Lou and Dr Teele Palumaa. They are improving our understanding of the mechanisms that cause myopia to help reveal novel therapeutic interventions for the treatment of this condition in children.

What influences eye growth and myopia development?

It is well established that both genetic and environmental factors are involved in eye growth and myopia development, although the exact mechanisms remain unknown. Scientists have found many genes associated with myopia, and it is known that children with parents who are myopic (near-sighted) are more likely to develop myopia. The major

Melissa uses a microscope to examine the eye © Pardue Lab

environmental factors associated with myopia are years spent in education and time spent outdoors. More education is associated with more myopia, whereas spending more time outdoors protects against myopia development.

Light exposure plays a critical role in eye growth and myopia development. The lighting environment we are exposed to indoors is very different from the natural light we typically experience outdoors. "The intensity of light is important," explains Machelle. "We have found that bright light and dim light are both important for protecting against myopia development, and that myopic children spend less time in both of these lighting conditions."

Light is also important for regulating circadian rhythms, which are internally driven changes within our body that oscillate with an approximate 24-hour cycle. "Keeping a regular light/dark schedule is highly important for maintaining healthy circadian rhythms," explains Teele. "In fact, several lines of evidence suggest that circadian rhythms are associated with myopia development, and I am studying the mechanisms behind this association."

What is the team investigating?

Visual signals from the environment are processed within the eye to control eye growth and guide emmetropisation. These visual signals are detected and processed by the retina, initiating a chain of events that are then detected by the sclera, the white outermost layer of the eye, to drive changes in eye size. Machelle's lab is studying the retinal pathways and the roles of two signalling molecules, retinal dopamine and retinoic acid, in the regulation of eye growth and myopia development.

Retinal dopamine is critical for many aspects of light-dependent functions in the retina, and it has also been shown to be involved in myopia development. "Retinal dopamine levels are reduced in most animal models of myopia, and we have shown that increasing retinal dopamine levels can prevent experimental myopia in animals," Machelle explains.

> **"We have found that bright light and dim light are both important for protecting against myopia development..."**

Retinoic acid is highly important for regulating many developmental and functional processes within the eye and other organs. In contrast to retinal dopamine, retinoic acid is increased after experimental myopia, and increasing retinoic acid levels can cause myopia in animal models.

How does the team study the mechanisms behind myopia development?

Machelle has established a mouse model of myopia to study the retinal and scleral mechanisms involved in myopia development. "An advantage of the mouse model is that we can manipulate both the genetics and environment," Teele explains. "We can study the impact of a specific gene on myopia development by inactivating or removing it from the genome of the mouse."

Experimental myopia can be induced in animal models by placing a negative powered lens or a translucent light diffuser in front of the eye, both of which cause the eye to grow longer. "We use custom instruments to measure the refractive error and axial length of the mice, which allow us to examine how normal eye growth or the response to experimental myopia is affected with different genetic or environmental manipulations," explains Linjiang. "We also measure whether retinal dopamine levels are altered by these experimental conditions."

"Previous work in the lab has shown that rod photoreceptors, which are responsible for vision in dim conditions (such as at night), play a critical role in refractive development, whereas cone photoreceptors, which function under brighter daytime conditions and are responsible for sharp vision, are less critical," Reece says. "I perform electrical recordings to measure the response of individual cells in the retina to further examine which retinal pathways are affected in experimental myopia."

More recent work from Machelle's lab has demonstrated that the stiffness of the sclera is decreased in experimental myopia and with retinoic acid treatment. "Ultimately, changes in eye size are due to remodelling of the sclera," explains Melissa. "I use high-resolution microscopes to visualise cells in the sclera and examine how they are affected during experimental myopia. This will allow us to better understand the role of these cells in myopia."

How can Machelle's research be applied to therapeutic interventions for children?

Current treatments for myopia can slow its progression, but we do not know how these treatments work. "Identifying the underlying mechanisms responsible for eye growth and myopia development helps us to identify potential targets to develop better treatment interventions for this condition," says Machelle. "For example, light therapies that stimulate retinal pathways could be a practical and non-invasive intervention to target myopia progression in children." This is already an emerging topic of interest in the field, and research findings from Machelle's lab will help inform the development of these therapeutic interventions for treating myopia in children.

About *ophthalmology*

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Ophthalmology is the study of eyes and vision. It includes the study of the structure and function of the eye, how visual function is affected by eye diseases and disorders, and how to prevent and treat eye conditions. "Ophthalmology is a multidisciplinary field, and interdisciplinary collaboration is essential for solving complicated problems. It allows us to look at problems from various knowledge bases and perspectives," says Machelle. "For instance, I am an expert in retinal function and anatomy, and I collaborate with experts in cell biology and development, ocular biomechanics, retinal circuitry and other fields to advance our research in innovative ways."

Opportunities and challenges in ophthalmology research

One of the most rewarding aspects of research is the opportunity to work with a team of intelligent and talented individuals. Each person in a research group provides their unique set of talents and expertise. "It is important to pursue ideas and concepts that interest you. You never know how your expertise can be applied to a new problem or idea," says Melissa. "There are opportunities for basic science research to study the mechanisms underlying eye diseases and to develop treatments for these diseases. Clinical research then applies the knowledge we learn to improve patient care."

"The eye is a wonderous organ!" says Machelle. "Its neurons, muscle, lens and collagen components are all easily accessible through the front of the eye. I find it fascinating to study the perfect coordination of these different components that allow us to see our world. However, it can be challenging to study such a complex organ. There are multiple aspects of the eye and eye health that we are still learning about."

Pathway from school to *ophthalmology*

- At high school and beyond, study biology, physics, chemistry and mathematics.
- Completing a bachelor's degree in a biomedical science field, such as neuroscience, physiology, biology or anatomy, provides a good foundation to help understand basic concepts that can be applied to ophthalmology and vision research.
- "The best way to gauge your interest in ophthalmology and vision research is to do a research project in a laboratory that conducts vision research," says Linjiang. "You will have the opportunity to get hands-on experience in a laboratory setting and learn about vision science." Many colleges and universities have courses that allow you to conduct research in a laboratory for course credit.
- Machelle recommends exploring Webvision (**www.webvision.med.utah.edu**) to learn some basics about the eye. "The National Eye Institute (NEI, **www.nei.nih.gov**) and Association for Research in Vision and Ophthalmology (ARVO, **www.arvo.org**) websites are also useful. ARVO has events for members-in-training, including for students, postgraduate fellows and residents," Machelle advises.

Explore careers in *ophthalmology*

- To become a vision scientist, you should complete a graduate degree, then undertake post-graduate training in a vision research laboratory. You will work in a laboratory to conduct research focused on improving our understanding of vision and eye conditions. This could be at an academic institution or in industry at a private research company.
- To become a clinician specialising in eyes and vision, you will need to complete a medical degree and residency to become an ophthalmologist, or an optometry degree to become an optometrist. Then, you can also do additional training or fellowships to specialise in different areas of the field.

Meet *Machelle's research team:*

Dr Reece Mazade

Research Scientist

I've always been curious about nature, especially animal biology. In high school, an amazing biology teacher encouraged me to submit a scientific research project on bird ecology to the state university, and this experience jump-started my scientific career.

After learning about physiological systems during my biological sciences degree, I became interested in sensory neuroscience. I pursued a PhD in physiological science, investigating how retinal neurons signal in different lighting conditions. As I started applying my findings to vision and eye disorders, my studies led me to the field of ophthalmology.

I love discovering how our eyes translate visual input from the natural world into something we can perceive. The eye's remarkably organised structure and complexity make it an exciting organ to study!

Dr Melissa Bentley-Ford

Postdoctoral Fellow

At an early age, I decided that I not only wanted to learn about the world around me but also to discover how it worked. As a scientist, I can do just that.

After obtaining my bachelor's in biochemistry and PhD in cell and developmental biology, I jumped into the world of ophthalmic research. My background gives me expertise in cell signalling, genetics and molecular biology. By combining this with my colleagues' expertise in neuroscience, physiology, engineering, optics and clinical research, we can tackle questions from different angles.

I became interested in ophthalmology research because I was allured by the fascinating biological questions and complexities that exist in the eye. Every day, I get to wake up and work to discover mechanisms that allow us to see.

Dr Linjiang Lou

Postdoctoral Fellow

My interest in research started during my undergraduate studies in neuroscience. I had a great professor whose passion and excitement for the topic and for research inspired me to pursue a career as a scientist.

I was introduced to vision science and ophthalmology during my PhD in physiological optics. I find vision research fascinating because the eye is so complex and so interconnected with the brain. My research training has focused on eye growth and myopia, a constantly growing field with many questions yet to be answered.

Ophthalmology is a multidisciplinary field. We interact with scientists with diverse backgrounds and expertise, which allows us to approach questions from different perspectives. Having good mentors along the way has helped formulate my perspectives and experience in the field.

Dr Teele Palumaa

Postdoctoral Fellow

My curiosity about how biological processes function in health and disease, particularly in diseases that are a significant burden to societies, inspired me to become a scientist.

While studying medicine, I realised that I was equally interested in science, especially in how our bodies have circadian rhythms. After graduating from medical school, I earned a PhD in clinical neurosciences, conducting research on the circadian rhythms of the retina. Since then, I have been combining clinical life with scientific research. I started an ophthalmology residency programme and with one final year to go, I took a break from clinical work to do science on a post-doctoral level.

I enjoy ophthalmology research because I can make an impact by studying problems that matter on a global scale.

How do our kidneys influence our cardiovascular health?

The human body is a complex and interconnected system. In the **Human Translational Nephrology Lab** at the **University of Iowa**, USA, **Dr Diana Jalal** is investigating the links between the kidneys and the cardiovascular system. Patients with chronic kidney disease are at higher risk of developing cardiovascular disease, so Diana hopes to discover new therapies that will improve their health outcomes.

Dr Diana Jalal

Human Translational Nephrology Lab, Division of Nephrology, Department of Internal Medicine, University of Iowa, and Iowa City VA HCS, Iowa, USA

PROFILE

Field of research
Nephrology

Research project
Uncovering the links between chronic kidney disease (CKD) and cardiovascular disease (CVD)

Funders
US National Institutes of Health (NIH), Veterans Health Administration (VHA), American Heart Association (AHA)

Talk like a ...

nephrologist

Cardiovascular — relating to the heart and blood vessels

Cardiovascular disease (CVD) — a general term for any condition that affects the heart and/or blood vessels

Chronic kidney disease (CKD) — a condition in which the kidneys do not function properly

Diabetes — a disease characterised by unstable blood sugar levels, which can damage the kidneys and cardiovascular system

Dialysis — a medical treatment in which the blood is artificially filtered by a machine

Endothelial — relating to the cells that line the walls of blood vessels

Kidney — the organ that filters the blood

Nephrology — the branch of medicine that studies the kidneys

Placebo — a treatment that has no active properties, given to a control group during clinical trials

Translational research — research that applies lab-based findings to applications in humans

Vascular — relating to blood vessels

37 million people in the US live with some form of kidney disease, and over 800,000 of them suffer from kidney failure, also known as end-stage kidney disease. Chronic kidney disease (CKD) occurs when the kidneys become damaged and their function is reduced. It can lead to kidney failure which, if a patient does not receive dialysis or a kidney transplant, can be life-threatening. "The prevalence of CKD is increasing around the world. This has been linked to the rise in obesity, diabetes, high blood pressure and other cardiovascular risk factors," says Dr Diana Jalal, who leads the Human Translational Nephrology Lab at the University of Iowa. "Diabetes and high blood pressure are the most common causes of end-stage kidney disease."

Diana is interested in the links between the kidneys and the cardiovascular system. She believes that understanding these links could have a positive impact on health outcomes, as individuals with CKD have an increased risk of cardiovascular disease (CVD).

What do our kidneys do?

Kidneys are the body's filtration system. "They filter about 200 litres of fluid every day," says Diana. This is equivalent to more than a bathtub full of fluid being cycled through your kidneys! Our kidneys help us maintain healthy levels of water, minerals and salts in our blood, and they remove waste products from the body, which are excreted in urine. As the kidneys influence blood composition, impairment in kidney function can affect the cardiovascular system, which is responsible for transporting blood around the body.

What cardiovascular problems might people with CKD have?

The chemical nitric oxide plays an important role in the cardiovascular system, as it causes blood vessels to dilate (widen). "If nitric oxide availability is reduced, it leads to impaired dilation of the blood vessels, known as endothelial dysfunction,"

explains Diana. "Endothelial dysfunction is also caused by oxidative stress, which is when there is an imbalance between pro-oxidant and antioxidant substances (chemicals that promote or inhibit oxidation) in the body." Vascular stiffness occurs when blood vessels lose their elastic fibres and accumulate stiff fibres instead, causing the blood vessel walls to harden and forcing the heart to work harder to pump blood around the body.

People with CKD tend to have higher levels of endothelial dysfunction, oxidative stress and vascular stiffness. "While the exact mechanisms that lead to these conditions in people with CKD are not completely understood, it is believed that they contribute to the higher rates of CVD seen in these patients," says Diana.

The importance of translational research

"Translational research allows us to extend findings from lab-based research in cells and animals to clinical outcomes in humans," explains Diana. The Human Translational Nephrology Lab uses translational research to investigate the links between CKD and CVD and to translate these findings into therapies that will benefit patients. This may involve studying cultured cells to explore specific molecular pathways related to the diseases. The outcomes of these studies are then tested on animals, to investigate how the molecular pathways and diseases function in living organisms. Then, the team works with patients to explore CKD and CVD in humans. Sometimes, novel pathways are first identified in humans, then animal and cell models can be used to understand the mechanisms by which these may influence disease in humans.

"Cultured cells do not capture the complexities of human diseases," says Diana. "Animal models are more complex and have led to important discoveries regarding CKD; however, studying CKD in animals in the lab does not reflect all the factors at play in humans with CKD. Evaluating vascular measurements in patients with CKD allows us to better understand the factors that contribute to endothelial dysfunction." In this way, the team can explore the influence of CKD on CVD and test therapies that may reduce the risk of patients with CKD developing CVD.

> **"As the kidneys influence blood composition, impairment in kidney function can affect the cardiovascular system."**

How does Diana measure cardiovascular function?

Diana and her team use a range of methods to evaluate cardiovascular function in patients with CKD. To measure endothelial dysfunction, they place an inflatable cuff on the patient's forearm to cut off blood flow for a few minutes, then release the cuff, causing blood to rush into their arm. This should stimulate the release of nitric oxide, causing blood vessels to dilate. Using ultrasound technology, the researchers measure patients' blood vessel diameters. They have observed that blood vessels in patients with endothelial dysfunction dilate less than in patients without the condition.

"We measure vascular stiffness using the technique of arterial tonometry, which measures the speed at which blood vessel pulses travel from one point to another in the circulatory system," says Diana. In patients with stiffer blood vessels, the speed of travel increases.

The team also collects endothelial cell samples from patients to analyse their protein compositions. "We place a catheter into a vein in the arm, and then insert a thin wire to scrape off some cells from the blood vessel wall," says Diana. The cells are analysed to determine which proteins they contain, as protein expression is an important measure of whether cells are performing their specific function correctly.

Diana and her team use these methods to test the effectiveness of potential new therapies that might improve endothelial function and vascular stiffness in patients with CKD, hopefully preventing them from developing CVD.

What might improve cardiovascular health in patients with CKD?

Diana's team has recently finished two clinical trials investigating whether curcumin (a chemical found in turmeric) and resveratrol (a chemical found in red grapes) improve vascular function in patients with CKD. Patient's participating in the trials visited the Human Translational Nephrology Lab, where their blood pressure, endothelial function and vascular stiffness were measured before the study began. In each trial, participants were randomly assigned to receive either the therapy (curcumin or resveratrol) or a placebo. Participants then took their assigned drug for several months before returning to the lab for end-of-study measurements to assess whether their vascular function was influenced by consuming curcumin or resveratrol. The team is now in the process of evaluating the results of these trials to determine whether curcumin or resveratrol provide health benefits to patients with CKD, and whether they could be used as therapies.

Diana hopes that uncovering how kidney dysfunction leads to cardiovascular problems will result in new therapies, allowing patients with CKD to reduce their risk of developing CVD and live healthier lives.

About *nephrology*

Nephrology involves the study, diagnosis and management of kidney disease. Like many who work in medical research, Diana splits her time between treating patients and conducting research in the lab to learn more about the diseases she is treating.

What does Diana's dual role involve?

As a clinical nephrologist, Diana spends time with patients suffering from kidney conditions, both in hospital and in an outpatient clinic. In the hospital, she takes care of patients who have developed end-stage kidney disease and are dependent on dialysis, and she consults with other medical professionals to address patients' kidney-related problems. "In the clinic, I help CKD patients manage their blood pressure or diabetes, or counsel them about therapies to reduce their risk of developing CVD," she says. "Sometimes, I have to have difficult conversations with them about the need to start dialysis or to investigate kidney transplant options."

As a nephrology researcher, Diana coordinates her team in the Human Translational Nephrology Lab. "Most of the day-to-day research activities are carried out by members of my team, including Katharine Geasland (coordinator), Dr Mingyao Sun (post-doctoral fellow) and Colin Gimblet (doctoral student)," says Diana. "I meet with participants for our trials and answer their questions, but most of my time is spent analysing our data, writing manuscripts to summarise our results and submitting grant applications to get funding for new studies."

What are the rewards and challenges of nephrology?

"I have always enjoyed the fact that my career allows me to form long-lasting bonds with patients and their families," says Diana. "It is extremely rewarding to see patients in whom we are able to maintain stable kidney function, as it shows that what we are doing makes a difference to their health." However, end-stage kidney disease can be fatal, and Diana's hardest days are when one of her dialysis patients dies. But, as she explains, even the challenging aspects of the job are worthwhile and important. "It is difficult when a patient reaches the stage when they need dialysis or a kidney transplant, but I find it a privilege to hold their hand through the tough times."

Pathway from school to *nephrology*

- At school, Diana recommends securing a strong foundation in STEM subjects, particularly biology and chemistry.
- At university, degrees in medicine, biomedical science, biology or nursing could all lead to a clinical or research career in nephrology.

Explore careers in *nephrology*

- This article explains the many roles that nephrologists fulfil for patients: www.healthline.com/health/what-is-a-nephrologist
- The National Kidney Foundation (www.kidney.org) has a wealth of resources about nephrology and kidney disease, including a podcast about life as a nephrologist: www.kidney.org/podcasts/life-as-a-nephrologist
- The International Society of Nephrology (www.theisn.org) hosts an online 'academy', which provides a wide range of nephrology resources, including webinars, courses and podcasts: academy.theisn.org
- Diana's department, the Division of Nephrology at the University of Iowa (www.medicine.uiowa.edu/internalmedicine/nephrology) offers opportunities for students to shadow clinicians and volunteer in research labs: www.uihealthcare.org/job-shadows

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Meet *Diana*

At school, I really enjoyed math and chemistry. Ironically, biology was my least favourite STEM subject in high school, and it wasn't until college that I developed an appreciation for biology.

Growing up, my dad had a significant influence on my dreams to become a scientist. He worked for a large pharmaceutical company in the Middle East, and I used to enjoy visiting him at work and being in the lab across from his office. My dad was always happy when discussing science, and he derived great pleasure from contributing to the betterment of people's lives. He influenced me to want to do the same.

> ***When I discovered the opportunity to work as both a clinical and research nephrologist, it seemed natural for me to follow this path.***

As I grew older, I realised I wanted to pursue a career in medicine. While studying at the University of Jordan, I was inspired to focus on nephrology by the kidney patients I worked with. Most memorably, I met a young woman who had developed kidney failure and whose husband had donated a kidney to her. She later named her two children after the nephrologist who treated her. Several years later, this nephrologist became my father-in-law!

My early love of the lab returned when I moved to the US for further nephrology training. When I discovered the opportunity to work as both a clinical and research nephrologist, it seemed natural for me to follow this path.

When I'm not working, I enjoy spending time with my family and friends. I like cycling with my husband, hanging out with my kids and running with my friends.

Diana's *top tips*

1. Work hard.

2. Don't be afraid to venture outside your comfort zone.

3. Be bold, but stay true to your values.

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