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Destination STEM

Enabling young people to take the lead in exploring careers

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ISSUE 35
Career journeys

WELCOME

"We can't control our starting point – namely the resources we have available to us growing up – but we can control how we respond to it," says Dr Kelsey Fisher-Wellman from the Department of Cancer Biology at Wake Forest University School of Medicine in the US (p 08).

How we proceed from our starting point depends on where we can see our paths leading us. When we know what opportunities are available to us, and when we are empowered to make choices, we can take control of our journey.

Many students enjoy STEM, but they do not always know where it can take them, and personalised careers guidance can be difficult to access in busy, time-pressured schools. To support teachers in enabling young people to take the lead in exploring career journeys for themselves, STEM Learning UK has set up Destination STEM. National Lead Ajay Sharman introduces this innovative online platform (p 04).

Highlighting the wide range of opportunities that come with a background in STEM, Let's Talk Science is committed to preparing young people in Canada for future careers in a rapidly changing world. Founder and President Dr Bonnie Schmidt tells us about the charity's 30-plus years of innovative STEM programmes (p 40).

Empowered with knowledge, skills and choice, young people can direct their own path. "In my view, academic science remains a place where doors can still open for those with talent and determination, regardless of their background," adds Kelsey. "With persistence and hard work, the opportunities are real and within reach."

There are exciting journeys ahead... whatever your destination.

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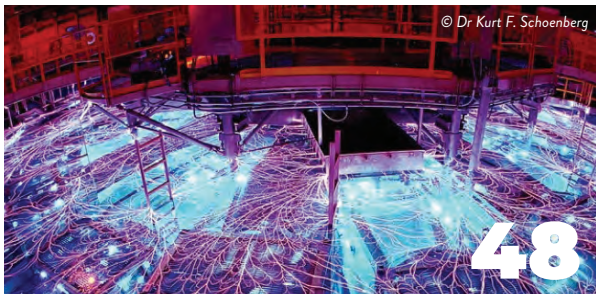
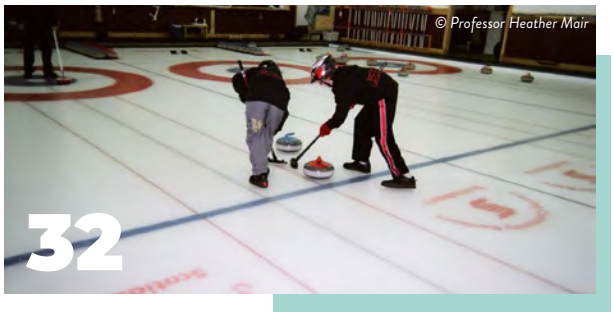
CONTENTS

Research articles

68





Research articles

INTERVIEWS

COVER STORY
Destination STEM
04

Destination STEM: helping to navigate career journeys

While many students enjoy STEM, they do not always know where it can take them. And while teachers would love to be able to provide their students with personalised careers guidance, this can be difficult when time and resources are in short supply. To support teachers in enabling young people to take the lead in exploring careers for themselves, **STEM Learning UK** has set up **Destination STEM**. National Lead **Ajay Sharman** introduces this innovative online platform.

Why is STEM so important?

STEM (science, technology, engineering and mathematics) careers matter because they drive innovation for 'UK Plc', provide high-demand, well-paying jobs, equip individuals with crucial problem-solving skills for a complex world, and are essential for addressing societal challenges and fostering economic growth. From discovering new treatments in medicine to developing cutting-edge technology, STEM professionals contribute directly to progress and a better future.

The opportunities for young people within STEM-based industries and research are endless. STEM Learning is proud to be the largest provider of STEM education and careers support for young people in the UK. We work with teachers, schools, colleges, employers and the government to engage with young people and to inspire them to seize these opportunities.

Why did STEM Learning decide to launch Destination STEM?

It is crucial not to leave STEM careers to chance and to offer STEM resources and opportunities for young people to meet real people in STEM fields. We are passionate about connecting students with role models and offering career and enrichment support, and that's where Destination STEM comes in.

Destination STEM is a UK-based, online platform that provides support, advice and opportunities for young people aged 13-19 to explore careers in STEM. The platform offers resources such as articles, videos and experiences. It provides mentoring and placements, to help students develop skills, connect with employers, and discover potential career paths, and it provides support for teachers and employers looking to engage young people with STEM.

Why is it important to give students the lead when thinking about STEM, careers and next steps?

Destination STEM puts young people at the centre of exploring STEM careers, enabling them to engage with programmes and resources that guide them towards exciting and rewarding futures. Parents and carers also play a key role, supporting young people as they shape their own STEM pathways.

Using our platform, students can easily access opportunities such as online mentoring, research placements and STEM career information, helping them to take control of their journeys and discover roles they may not have known existed.

How should students start exploring Destination STEM?

The platform is free to access and use, so students are free to explore it in their own time and as they wish – there's no time limit or restrictions!

They can start by exploring STEM careers, which lets them discover information on various careers in STEM through articles, videos and events. We want students to build their confidence by finding resources that can boost their STEM skills, connect them with opportunities and guide them through apprenticeship and university applications. For example, students can sign up for a free, online mentoring programme to receive one-on-one career advice from a mentor. By chatting through a safe messaging system with trained and experienced STEM professionals, namely STEM Ambassadors, students can explore options for life after school, including further education and potential careers. Our aim is to put students in charge of the conversation about their future.

What subject support does Destination STEM offer?

Under Destination STEM programmes, students have the opportunity to learn about and become immersed in all areas of STEM, learning about real-world applications, meeting real people in real jobs, and developing skills for the future. Destination STEM supports the curriculum *and* takes students beyond the classroom.

© STEM Learning

How is Destination STEM helping students prepare for life after school?

The career guidance that Destination STEM offers supports personal goal setting, skill development and networking building – all key for students preparing for life after school. The platform offers:

- **Access to opportunities:** STEM fields are expanding, and advice helps individuals understand and pursue these careers.
- **Career alignment:** guidance connects personal interests with impactful STEM roles.
- **Skill development:** advice builds critical technical and transferable skills valued by employers.
- **Networking:** learning how to build professional networks provides essential support and growth.
- **Essential skills:** beyond technical ability, employers seek the 4Cs – Creativity, Critical Thinking, Collaboration and Communication – which help students adapt and thrive.
- **Mentorship and feedback:** learning from mentors and seeking feedback strengthens skills and career progression.

How does Destination STEM enable students to connect with STEM professionals?

STEM Learning has a cohort of over 28,000 STEM Ambassadors, and students can now learn from them through Destination STEM's online mentoring scheme. STEM Ambassadors help students by making STEM subjects relatable and engaging, inspiring them to pursue STEM careers by connecting classroom learning to industry, providing mentorship and serving as positive role models. Ambassadors broaden students' career horizons, raise aspirations and enhance their understanding of STEM's impact on everyday life.

Students will be matched with a mentor based on interests and career paths. They can message their mentor at any time during a 10-week mentoring period. Conversations take place via text-based messaging, so mentors will reply as soon as they can, in between their work commitments. To keep students safe, conversations can only take place via the secure and moderated mentoring platform. All STEM Ambassadors and mentors are enhanced DBS checked, and all have received training to help them maximise their engagement with students.

> ***"It is crucial not to leave STEM careers to opportunities and to offer STEM resources and chances for young people to meet real people in STEM fields."***

© STEM Learning

> ***I've experienced working in a lab environment, which is something I was very keen on learning about. I've also witnessed the collaboration and team effort between scientists when working on a shared goal. Also, I've learnt about a new area of science, biotechnology, which combines both science and data/coding.***
>
> ***– Research Placement participant***

© STEM Learning

What other role models can students meet?

When young people think about life after school, it can be hard for them to picture what employment could look like for them. That's why, with the help of industry experts, we've pulled together insights into careers in different STEM sectors. Students can learn essential life skills, personal values and practical abilities by participating in a 'Day in the Life' session.

The platform provides a series of videos that provide an insight into many roles, from researchers at the UK's Natural History Museum, to aerospace and space scientists building robotic devices to drive on Mars! Many of these videos provide a snapshot of the varied STEM careers available and, for many schools and teachers, there are opportunities to formally invite STEM Ambassadors directly into school! You cannot be what you cannot see and the value of the videos – of the access to such inspirational role models – cannot not be overstated.

What placements does Destination STEM facilitate?

Research Placements and Experiences offer year 12 (or equivalent) students real-world STEM workplace opportunities with universities or industry partners. Funded by strategic partners, these placements let students apply subject knowledge, develop research skills and contribute meaningfully to 'live' projects:

- **Research Placements (2 weeks):** Students get to collaborate with STEM experts on live research questions, producing a scientific or technical report and poster. Students gain hands-on experience, problem-solving skills and an insight into wider career opportunities.

- **Experience Placements (5 days)**: Students work with industry professionals to understand essential STEM skills and workplace challenges, completing a reflective workbook while preparing for future employment.

All successful students are invited to join the STEM Alumni Network, connecting past participants and supporting students beyond school.

These placements are hugely valuable. In an evaluation report we compiled in 2024, 96% of students said they would recommend Research and/or Experience Placements to other students.

Placements enhance university applications, increase career readiness and connect students to professional networks. In the report, the following proportion of teachers agreed that their student improved in the following areas since completing their research placements: communication skills (92%), ability to work independently (92%), problem solving skills (92%), time management skills (85%), and ability to work as part of a team (77%). And all teachers said they would recommend placements to future students.

How is Destination STEM helping teachers?

Destination STEM provides young people with opportunities to develop their skills and knowledge, to aspire to fulfilling careers and to make a positive contribution to their community – all things that we know teachers are striving for. Everything on our site is designed to support the STEM curriculum and is free for all schools and colleges in the UK to use, in whatever way they see fit, to inspire a new generation to think and act differently in their career destination. Teachers can also use Destination STEM to enrich lessons, embed careers into the curriculum and highlight real career pathways linked to STEM subjects. Destination STEM helps teachers to help students to guide themselves!

There is a downloadable teacher handbook on the platform, providing practical suggestions on how Destination STEM can be used to support career provision and the teaching of STEM within their school. It identifies how each activity from the wider campaign can be used to support students' development and aspirations and develop the schools' approach to STEM engagement.

Who supports your work?

STEM Learning is honoured to be supported by a unique collaboration of government, charitable trusts, employers, professional institutions, and scientific societies who share our vision of improving lives through STEM education. Employers and other trusts and foundations can champion, inspire and empower young people to become STEM professionals in the future and support greater social mobility, particularly for students from disadvantaged backgrounds, alongside adding real social value for a better society.

For STEM Learning and Destination STEM, our ethos is about building a better future – for all of us.

We'd love to hear from any businesses and professionals keen to support what we do! Supporting Destination STEM programmes strengthens Corporate Social Responsibility (CSR), Environmental Social and Governance (ESG) and Social Mobility strategies by delivering measurable social value. Employers back STEM initiatives for various reasons, including building future talent pipelines and addressing skills shortages; engaging with diverse new talent drives innovation, fresh thinking and economic growth. Supporting programmes like Destination STEM demonstrates a company's commitment to meaningful causes, improves public image, promotes diversity and inclusion, and connects businesses with local communities – positively impacting students and families.

Many employers offer an opportunity for employees to volunteer through the STEM Ambassador programme and support online mentoring. Many employers have also then gone on to fund Research and Experience Placements, offering tangible opportunities for students. Investment in Destination STEM enrichment activities provides a return on investment of £5.4m social value for every £300,000 invested. This is making life changing opportunities for many young people.

> ***"Learning to use/repair application programming interfaces (APIs) during my Research Placement at the HM Treasury has been incredibly useful – not only in my computer science A level, but also in my workplace when I'm giving technical support for APIs or making new ones."***
>
> ***– Research Placement participant***

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DESTINATION STEM

STEM LEARNING

Could oddly behaving mitochondria hold the key to treating leukemia?

Blood cancers, such as leukemia, are challenging to treat. Usually, chemotherapy does not kill all the cancerous cells, and the surviving cells become resistant to future treatment, resulting in a high fatality rate. At **Wake Forest University School of Medicine** in the US, **Dr. Kelsey Fisher-Wellman** is investigating how mitochondria in cancerous cells differ from those in healthy cells. He has made some intriguing discoveries that could pave the way for new cancer treatments.

Dr. Kelsey Fisher-Wellman

Associate Professor, Department of Cancer Biology, Wake Forest University School of Medicine, USA

Field of research
Cancer biology

Research project
Comparing mitochondria in healthy and cancerous cells to develop treatments for leukemia that target these differences

Funder
US National Cancer Institute (NCI) Grant numbers: P01CA302570, R37CA278826, R01CA299332

Website
fisherwellmanlab.com

doi: 10.33424/FUTURUM631

PROFILE

Talk like a ...

cancer biologist

Acute myeloid leukemia (AML) — a type of blood cancer that occurs when stem cells divide uncontrollably instead of changing into specialized blood cells

ATP — the molecule that provides energy for cellular processes

Chemotherapy — cancer treatments that use small molecules to stop the growth or drive the death of cancerous cells

Electrochemical gradient — a difference in electrical charge and chemical concentration across a membrane, which is the driving force for ions to move across the membrane

Mitochondria — small structures within cells that convert energy from food into ATP

Stem cell — a cell with the potential to develop into many different types of specialized cells

"I run a lab with the ambitious goal of curing cancer," says Dr. Kelsey Fisher-Wellman, a cancer biologist at Wake Forest University School of Medicine. "While this is likely unattainable in one lifetime, it's motivating to have this goal as my guiding star." But Kelsey never set out to cure cancer. As a teenager with a love of baseball and bodybuilding, his dream was to pursue a career as a strength and conditioning coach, and he worked as a personal trainer while studying exercise science at university. However, an internship with the university football team was not as inspiring as he had hoped, so he tried another internship, this time in a scientific research lab. "That decision was a turning point for me," he says. "I discovered a love for lab science, and from that moment on, I was hooked."

Battling blood cancer

After completing his university education and exploring different research opportunities, Kelsey began investigating leukemia, a type of blood cancer. Cancer occurs when abnormal cells divide uncontrollably. Your blood contains different cell types, including red blood cells that carry oxygen around the body, white blood cells that fight disease, and platelets that clot the blood following injury. "All these blood cells begin life as stem cells in bone marrow," says Kelsey. "As these stem cells grow and divide, they change shape and function to become specialized blood cells."

But the specialization process does not always work as it should. "A DNA mutation in a developing cell can prevent it from maturing," explains

Kelsey transfers growth media to acute myeloid leukemia cells.
© Wake Forest University School of Medicine

Kelsey. "The cell gets stuck in an immature stage and begins dividing uncontrollably." This marks the beginning of acute myeloid leukemia (AML), a type of blood cancer. The immature cells fill the bloodstream, outnumbering the specialized healthy blood cells to the point that the body can no longer function properly. AML symptoms include tiredness and shortness of breath, vulnerability to infection, and excessive bleeding when injured.

When it comes to blood cancers, the cancerous cells exist in isolation in the blood or bone marrow, unlike cancers that exist as solid tumors. This makes targeted treatments much more challenging. "Since there's no lump to surgically remove, treatment relies entirely on chemotherapy," says Kelsey. "The challenge with AML is that chemotherapy usually kills most of the cancerous cells, but not all of them. A small number survive at undetectable levels, only to begin multiplying again after treatment stops – a process known as relapse." Additionally, the surviving cells develop resistance to the chemotherapy drugs, so if relapse occurs, chemotherapy is no longer effective. As a result, AML is fatal for over 70% of older adults diagnosed with the disease.

Treatments for AML have remained largely unchanged for decades, so better options are desperately needed. Kelsey is taking a closer look at AML cells to identify key differences in how healthy and cancerous cells function. He hopes this knowledge can inform the development of new treatments that exploit these differences.

Mysterious mitochondria

Mitochondria, often called 'the powerhouse of the cell', are found in every cell in the body, except for red blood cells. "Mitochondria convert the energy stored in food into a form that our cells can use – a molecule called ATP," explains Kelsey. "This energy powers everything our cells do, from moving muscles to thinking thoughts." Mitochondria also have a key role in resource management. They manage supplies of important molecules that cells need to grow and function (such as proteins and fats), and they send signals to the cell's nucleus to coordinate the cell's actions based on available resources and energy levels.

> ***We want to develop a treatment that damages the mitochondria of AML cells, but not healthy cells.***

Kelsey's research has shown that mitochondria play a crucial role in the effectiveness of chemotherapy for treating AML. "Triggering cell death often involves damaging the mitochondria," says Kelsey. "So, we want to develop a treatment that damages the mitochondria of AML cells, but not healthy cells." This requires discovering the differences between mitochondria in these two cell types.

To achieve this, Kelsey and his team developed a tool known as 'mitochondrial diagnostics', a set of lab tests that allows them to create a detailed picture of the mitochondria in cells. This includes which proteins are present in mitochondria, how they are arranged, and how they help the cell survive. "Once we have this information, we look for weak points where AML mitochondria are vulnerable," says Kelsey. "Then we can design treatments that target those vulnerabilities."

Is running in reverse the key to treatment?

Using mitochondrial diagnostics, Kelsey and his team made a surprising discovery. "Normally, mitochondria create ATP, and this process is driven by an electrochemical gradient across the mitochondrial membrane," explains Kelsey. "But AML cells do something unusual – they run this process in reverse." Instead of making ATP, mitochondria in leukemia cells consume it in order to maintain the electrochemical gradient. "We discovered that this gradient is essential for AML cells' survival, especially when under attack from chemotherapy," says Kelsey. "If we disrupt this process, the AML cells become more sensitive to treatment." He hopes this discovery will lead to new treatments for leukemia that target the cell's energy system.

Kelsey and his team will continue to investigate the mitochondrial differences between AML and healthy cells. "The more we learn, the better we can design treatments that take advantage of these differences," he says. "The goal is to develop therapies that destroy the mitochondria inside AML cells while leaving healthy cells unharmed. I believe this precision approach to cancer treatment could hold real promise for improving outcomes for patients with acute myeloid leukemia."

About *cancer biology*

Cancer biology is the study of the biological mechanisms underlying cancer development and how to address them through treatment. These mechanisms are wide-ranging, from the genetic and molecular foundations of cancer (such as the role of DNA mutations), to how cancerous cells grow, spread, and cause illness. According to the National Cancer Institute, two in five people in the US will develop cancer in their lifetime, so developing new and improved ways to detect and treat the disease is essential for a healthy society.

Kelsey enjoys knowing that his work makes a meaningful difference. "Cancer remains one of the most complex and pressing challenges facing society," he says. "Dedicating your life to understanding and treating this disease is a valuable pursuit." He notes that, like any science, cancer biology is iterative and involves building on the discoveries of the previous generation. "It's important to remember that scientific breakthroughs can take years, even decades, to materialize," he says. "Even though the impact of your work may not be immediately visible, that doesn't make it any less worthwhile. There's something deeply fulfilling about contributing to this ongoing legacy and shared endeavor."

Advances in cancer biology mean that cancer treatments are constantly improving. "Cancer is most treatable in its early stages, and there is a lot of progress being made in early cancer detection," says Kelsey. "We are also growing our understanding of the links between cancer and metabolic diseases like obesity and diabetes." Interdisciplinary collaborations between scientists in different fields are helping to build a more comprehensive picture of health and disease, opening new and exciting possibilities for treatments.

Pathway from school to *cancer biology*

Kelsey emphasizes that many innovations in cancer biology come from people who take unconventional educational and career paths. "Instead of sticking to one field during your training, I'd encourage you to explore more broadly," he says. "Don't limit yourself. The more diverse your knowledge base, the more creative and impactful your contributions can be."

Useful subjects to study in high school include biology, chemistry, mathematics, physics, and computer science. At college, a degree in biology, biomedical science, or biochemistry would provide a direct path to a career in cancer biology.

"My background is in physiology and biochemistry," says Kelsey. "But if I could go back in time, I'd seek out training in computer science, epidemiology, and evolutionary ecology. These offer powerful tools and perspectives for biomedical research."

To become an academic researcher, you will need to complete a PhD. "This is typically funded – your tuition is covered, and you receive a stipend," explains Kelsey. "This makes PhDs a rare form of advanced education where you get paid to learn and contribute to science."

Download Kelsey's resources from **futurumcareers.com/cancer-biology-with-dr-kelsey-fisher-wellman**

Let us know what you think of this educational and career resource. To provide input, simply scan the QR code or use this link: **redcap.link/dh5j1nes**

A biosafety cabinet in the Fisher-Wellman Lab.
© Wake Forest University School of Medicine

Explore careers in *cancer biology*

Careers in cancer biology often involve lab-based research. This might be at a university, for a biotechnology or pharmaceutical company, or for a cancer research organization.

Kelsey recommends reaching out to scientists in the field to seek advice and ask about opportunities. "Hands-on experience, especially in a biomedical research lab, is truly invaluable," he says. "Many of the opportunities that shaped my career began with me sending a simple email asking to get involved."

Many labs in the Department of Cancer Biology at Wake Forest University School of Medicine offer summer internship programs for high school and undergraduate students: **school.wakehealth.edu/departments/cancer-biology**

The NIH Summer Internship Program offers paid biomedical research experiences for high school students, including in cancer biology labs: **training.nih.gov/research-training/pb/sip**

Meet *Kelsey*

As a teenager, I was interested in athletics, mainly baseball. Team sports taught me valuable life lessons about how to recover from failure and grow from these experiences. That foundation has helped me navigate the ups and downs of academic life.

I went to college to study exercise science, with the goal of becoming a strength and conditioning coach or athletic trainer. But that changed during my senior year, when an internship in a research lab gave me a glimpse into the life of an academic scientist. The experience was transformative – watching my mentor work had a profound impact on me as I saw someone deeply engaged in solving complex problems that matter to the world. That internship shifted my career goals and set me on a path that I've been passionate about ever since.

I have no formal training in cancer biology. After my undergraduate degree, I completed a master's degree in exercise science followed by a PhD in bioenergetics, where I fell in love with mitochondria. I then spent several years studying metabolic diseases in muscles, before finally pivoting to cancer biology.

Each transition in my career has come with a steep learning curve. Getting into a PhD program wasn't easy because exercise science isn't a typical background for biomedical research. I started behind my peers, having never studied physics or biochemistry, so I taught myself from textbooks to catch up. Moving into cancer biology without training in the field was another challenge, but it suited me as I find a certain sense of satisfaction in embracing struggles. Discomfort, setbacks, and doubt are all part of the process.

I've always been drawn to non-traditional paths and willing to outwork others to succeed. But this hasn't been without challenges – I've had plenty of failures along the way. For example, it took four failed attempts over two years before I finally received my first big grant. There were moments when I seriously questioned whether I was on the right path.

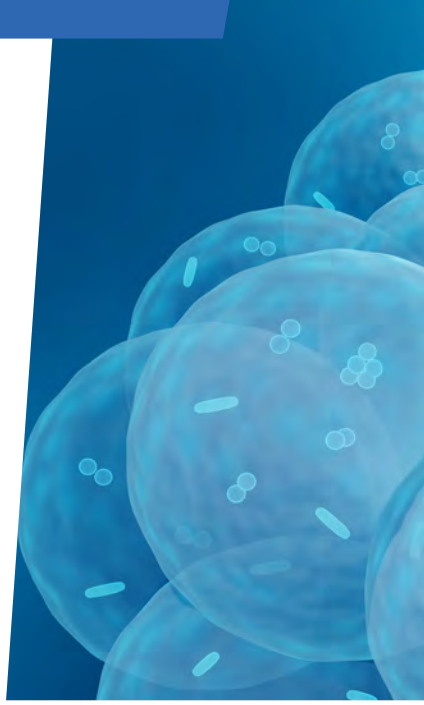
I'm motivated by setting ambitious goals and then working hard to reach them. As an academic cancer biology researcher, the freedom to pursue research that fascinates me is the best part of my job. I also enjoy collaborating with brilliant colleagues to tackle some of society's toughest problems.

When I'm not working, my two young daughters keep me on my toes. I also enjoy exercising, playing golf, and surfing – a hobby I picked up while working in Australia after my PhD. A big perk of an academic career is the opportunity to live and train abroad, which can enrich both your scientific and personal life.

Kelsey's *top tip*

We can't control our starting point – namely the resources we have available to us growing up – but we can control how we respond to it. In my view, academic science remains a place where doors can still open for those with talent and determination, regardless of their background. With persistence and hard work, the opportunities are real and within reach.

Breath by breath: how T cells protect our lungs from infection



Every day, we breathe in around 11,000 litres of air, full of microbes, dust particles and pollutants. Our lungs must work tirelessly to filter the air we breathe - so how do they keep us healthy despite so many potential threats? **Dr Anukul Shenoy** from the **University of Michigan Medical School** in the US, is investigating how immune cells that live inside our lungs – lung-resident T cells – detect danger, remember past infections and protect us from pathogens.

Dr Anukul Shenoy

Assistant Professor, Department of Microbiology and Immunology, Department of Internal Medicine, Division of Pulmonary and Critical Care Medicine, University of Michigan Medical School, USA

Fields of research
Immunology, microbiology

Research project
Investigating lung-resident T cells and developing new therapeutic treatments based on findings

Funders
US National Institutes of Health (NIH); University of Michigan Medical School

Website
shenoy.lab.medicine.umich.edu

doi: 10.33424/FUTURUM655

PROFILE

Talk like an ...
immunologist

Antimicrobial molecules — substances made by the body that kill or stop the growth of harmful microbes

Commensal — a microorganism that lives in the body without causing disease

Barrier epithelial cells — cells that form the outer layer of tissues and organs, creating barriers and regulating exchanges between body compartments

Immunocompromised — having a weakened immune system that makes it harder to fight infections

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

Pneumonia — a lung infection that causes inflammation and fluid buildup in the air sacs

Sepsis — a life-threatening reaction that occurs when the body overresponds to infection, damaging its own tissues

T cell — a type of white blood cell that identifies and destroys infected cells and helps coordinate the immune response

Thymus — the organ where T cells mature and learn to distinguish foreign microbes from our own cells

Every breath we take connects our body to the outside world. With each inhale, air travels deep into our lungs, carrying dust, pollutants and countless microbes. To protect us, the lungs are lined with a thin layer of epithelial cells – a living interface between the external environment and the tissues within. This layer spans an area about the size of a tennis court, yet is less than one millionth of a metre thick, forming a delicate surface where oxygen enters the blood and carbon dioxide leaves.

"Barrier epithelial cells act as the immune system's eye, watching out for problems and triggering our immune response to keep us healthy," explains Dr Anukul Shenoy from the University of Michigan Medical School. Constantly exposed to the outside world, our lung epithelial cells must allow gas exchange while blocking harmful invaders. By producing mucus and antimicrobial molecules, and by working with immune cells, they keep the air reaching our lungs almost sterile. But what happens when something manages to get through this barrier?

Download Anukul's resources from **futurumcareers.com/breath-by-breath-how-t-cells-protect-our-lungs-from-infection**

T cells: the memory makers of the immune system

When something manages to slip past the lungs' epithelial defences, the immune system turns to one of its most specialised lines of defence: T cells. "T cells are a special type of immune cell that initially develop in our bone marrow but finish their development in the thymus, hence their name," explains Anukul. "They are capable of extraordinarily long-lasting memory and can remember pathogens for our entire lifetimes."

Once activated, T cells can become either helper T-cells, which release signals to coordinate the immune response, or killer T-cells, which destroy infected cells before the infection can spread. Another group, regulatory T-cells, helps to calm the immune system once the threat has passed, preventing unnecessary tissue damage.

Some T cells go a step further by taking up permanent residence in our tissues. In the lungs, these resident T cells remain after an infection has cleared, continually patrolling the airways and staying alert for returning pathogens. Acting as vigilant guards, they can recognise familiar threats, alert neighbouring immune and epithelial cells, and eliminate infection before it becomes serious. "Because of these layers of specialisation, T cells are important immune cells that are widely considered to be ideal targets for vaccines that could generate lasting protection from pathogens," says Anukul.

When bacteria take advantage: *Streptococcus pneumoniae*

One of the key focuses of Anukul's research is *Streptococcus pneumoniae* – a bacterium that quietly lives in the back of the nose and throat of many healthy children and adults. Most of the time, it coexists harmlessly with its human host. But, when inhaled into the lungs of people with weakened immunity, it can cause serious disease.

> ***"Our lab is deeply interested in understanding how epithelial cells perform so many key tasks beyond their basic specialised functions."***

"In a healthy person, our epithelial cells and immune cells team up and clear the inhaled bacteria without disease or symptoms," explains Anukul. "However, if the host is immunocompromised, this bacterium is no longer eliminated by the immune system, allowing it to multiply within our lungs." Once established, it can cause pneumonia, spread into the bloodstream to trigger sepsis, or even lead to meningitis (a serious infection that affects the brain and spinal cord). This ability to exploit weak immune systems, combined with its widespread commensal infection rate, makes it a leading cause of infectious deaths among infants, the elderly and immunocompromised individuals.

Part of what makes *S. pneumoniae* so difficult to control is its adaptability. It can quickly acquire new genes from its environment, helping it to resist antibiotics and disguise itself from immune cells and vaccines. For these reasons, the World Health Organization has classified it as a 'priority pathogen', requiring urgent research.

Anukul and his team in the Shenoy Lab take inspiration from the fact that most healthy adults carry *S. pneumoniae* without harm. "This suggests that healthy human lungs have all the adaptations and cell types required to keep this bacterium in its commensal state without causing severe disease," explains Anukul. "Thus, we are interested in understanding how lung-resident T helper cells, epithelial cells and other immune cells communicate to sense, respond to and clear *S. pneumoniae* without symptoms, which could guide the development of improved vaccines and therapies." Ultimately, Anukul's research aims to prevent infections in vulnerable populations and provide a framework for tackling other bacteria that are harmless in healthy people but pathogenic when immunity is compromised.

What does the future hold?

"Our lab is deeply interested in understanding how epithelial cells perform so many key tasks beyond their basic specialised functions," says Anukul. "These include detecting, eliminating and tolerating threats, recruiting immune help, guiding inflammation, building memories, and repairing barrier tissues." By exploring how lung epithelial cells balance these roles during infection and recovery, Anukul's team hopes to reveal new ways to strengthen tissue health. Their findings could help shape next-generation vaccines and therapies that target epithelial cells directly, improving the prevention and treatment of diseases such as pneumonia, asthma, long-COVID and even some cancers.

Confocal microscopy image of a mouse spleen, an organ with an important role in the immune system. © Shenoy Lab

About *immunology*

Immunology is the study of how the body defends itself against infection and maintains internal balance. Our immune system is made up of an extraordinary network of cells and molecules that communicate constantly to recognise and respond to threats such as bacteria, viruses and fungi. "Working in the field of immunology often feels like trying to solve a giant jigsaw puzzle that evolution has been building for millions of years," says Anukul. "Different immune cells and molecules have co-evolved to ensure the smooth functioning of our organs and tissues."

"Immunology is rewarding because our discoveries are broadly applicable to different disease states and organs," continues Anukul. "Given the limited number of genes we possess, it is very often the case that our immune system has repurposed the same cells, pathways and mechanisms to solve similar problems in different body sites."

However, studying such a complex system is not easy. The immune response involves intricate communication between different cell types within and across organs. "Such complex multicellular and multi-organ phenomena cannot be mimicked in a lab using simplistic systems, so we use animal models for experiments," explains Anukul. "To ask if a certain molecule is important in an immune circuit also requires the ability to delete or express that molecule specifically in one cell type or developmental stage, which demands genetically engineered mouse models that are expensive and time-consuming to create." Despite these challenges, each new insight reveals more about how the body protects itself – knowledge that could one day transform how we prevent and treat disease.

Pathway from school to *immunology*

In high school, build a strong foundation in biology, chemistry and mathematics.

At university, molecular biology courses, such as genetics, biochemistry, microbiology, animal physiology, cell biology and developmental biology, will be useful.

Take courses with a lab component, as they can help you become comfortable with scientific equipment and experimental techniques.

"Be proactive, be curious and do not shy away from asking questions," says Anukul. Look for research opportunities early; many universities offer summer internships where students can gain practical experience studying real biological problems. Asking teachers or professors about available placements is a great way to get started.

Explore careers in *immunology*

"For those looking to get more exposure, there are professional societies, such as the American Association of Immunologists (**aai.org**), the Society for Mucosal Immunology (**socmucimm.org**), the American Thoracic Society (**site.thoracic.org**) and the European Federation of Immunological Societies (**efis.org**), that have great resources to get you involved in immunology," says Anukul.

Explore what the leading researchers in the field are working on and discovering by listening to podcasts such as *Immune* (**microbe.tv/immune**), *The Immunology Podcast* (**immunologypodcast.com**) and the *Mucosal Immunology Podcast* (**socmucimm.org/resources/mucosal-immunology-podcast**).

For students seeking practical experience, the University of Michigan Health Sciences Summer Institute runs the Summer Pre-College Exposure Academy (**umhs.smapply.io**) which is designed to give highly-motivated high school students exposure to healthcare professions.

Meet *PhD students in the Shenoy lab*

"Just like a successful immunological response, science thrives on teamwork," says Anukul. "The scientific enterprise flourishes when individuals from all backgrounds, experiences and viewpoints are welcomed and empowered. Each unique perspective – shaped by personal history, culture and identity – adds a valuable piece to the grand puzzle of discovery. By creating an environment where every person is heard and valued, their curiosity is encouraged, and their questions are celebrated, scientific progress becomes more innovative, robust, and ever closer to revealing the profound beauty that underlies the complexity of the natural world and those studying it."

Meet *Olivia Harlow*

I am currently studying how *Streptococcus pneumoniae* makes the lungs more suitable for T cells to live there long-term so that these T cells can then help to protect against future *S. pneumoniae* infections.

I first worked in Dr Shenoy's lab as part of the University of Michigan's rotation scheme for biomedical sciences PhD students. This system allows students to try out a lab to see if they like the research, people and principal investigator. I was Dr Shenoy's first graduate student, so we made sure that we had good communication, aligned our expectations about the project, and planned for potential challenges during my PhD.

I've been interested in immunology since first learning about it in high school. My first science job was as a summer research fellow at my undergraduate institution, where I worked on a type of immune cell that is similar to those I work with now.

The first time I applied for a PhD, I didn't get into any school I applied to. I then worked as a post-baccalaureate research employee at the Mayo Clinic, where I learnt valuable technical skills (like working with research animals) and life skills (like living alone). That experience helped me consider what research I was curious in pursuing in graduate school, what school I wanted to go to and who I was interested in working with. I was then a more competitive applicant the next time I applied to graduate school!

To unwind from work, I like to go walking or running outside to enjoy the weather and clear my head. I also unwind by playing video games, watching TV or painting.

Olivia's *top tip*

Ask a lot of questions! Immunology is a dense subject that is not always straightforward. Even now, I ask a lot of questions in our lab meetings because I'm curious about all the immunological processes that could influence the work in our lab!

Meet *Sophie Maxfield*

My project involves asking questions about how the hygiene hypothesis works on a cellular and immunological level. The hygiene hypothesis is a theory which states that exposure to different microbes early in life can lead to protection against the development of allergic disease later on. To study this, my project is investigating mechanisms of how exposure to bacteria in the lungs can prevent the development of asthma.

Many of the most interesting aspects of immunology can be seen at the exact site where a pathogen actually makes contact with the host. This host-pathogen interface has always fascinated me, so working in a lung epithelial immunology lab felt like the perfect opportunity to start asking questions I'd had since I first started learning about immunology.

My favourite aspect of immunology is that rules can almost always be broken. While the field has established several core tenets of how we understand the immune system to function, we are frequently discovering new cell types, modes of intra- or inter-cellular communication, and their roles in health and disease.

As a low-income, first-generation college student, one of the largest hurdles I've faced is navigating academia to pursue the career I want. I've lacked guidance on how to apply for college, graduate school and jobs in the field, as well as how to build skills or reach benchmarks needed to advance my career at each of these stages. Through this, I've learnt that one of the most valuable skills is taking initiative and asking for help.

I like to relax by listening to and making music, working out, reading, cooking or watching TV with my cat. Creative hobbies help me recharge.

Sophie's *top tip*

Make sure not to neglect humanities subjects, as these will give you insights into how to better communicate your ideas and can help you understand how to address concerns from audiences at all levels of expertise.

How do rare genetic disorders affect vitamin B12 metabolism and embryonic development?

Vitamin B12 plays a crucial role in our growth and development. Without it, our bodies cannot produce healthy blood cells or maintain a functioning nervous system. For most people, a balanced diet provides enough vitamin B12 to stay healthy, but for some, rare genetic disorders mean their bodies cannot use this vital vitamin properly. **Dr Ross Poché** from **Baylor College of Medicine** in Houston, Texas, USA, uses mouse models to study these disorders, understand how they disrupt embryonic brain development and explore new ways of treating them.

Dr Ross Poché

Associate Professor of Integrative Physiology, Baylor College of Medicine, Houston, Texas, USA

PROFILE

Fields of research
Rare disease research, mouse genetics, developmental biology

Research project
Using mouse models to investigate rare genetic diseases that cause vitamin B12 deficiency

Funders
US National Institutes of Health (NIH); National Institute of Child Health and Human Development (NICHD, grant R01 HD116761); National Eye Institute (NEI, grant R21 EY035812)

Website
pochelab.com

doi: 10.33424/FUTURUM637

Talk like a ...

rare disease researcher

Coenzyme — a molecule that helps an enzyme do its job effectively

DNA — the molecule that contains the genetic instructions for building and maintaining living organisms

Enzyme — a protein that speeds up chemical reactions in the body

Gene — a segment of DNA that provides instructions for making proteins

Genetic mutation — a change in the DNA sequence that can affect how proteins are made or function

Neural tube — the early embryonic structure that develops into the brain and spinal cord

Prenatal vitamins — nutritional supplements taken during pregnancy to support the healthy development of the baby

Vitamins are a group of essential nutrients that the body needs in order to function properly. Although our bodies can make some vitamins — for example, vitamin D is produced in the skin when exposed to sunlight — most of them must come from the food we eat.

Vitamin B12 is crucial for our health and is absorbed mainly from animal products, such as meat, eggs and dairy. It is essential for making new red blood cells and maintaining a healthy nervous system, so people following plant-based diets need fortified foods or supplements to stay healthy. Without vitamin B12, nerves can become permanently damaged, and, in extreme cases, death can occur.

During pregnancy, the need for B12 is even greater. "A developing embryo relies on a constant supply of B12 to build the brain, spinal cord and other organs," says Dr Ross Poché at Baylor College of Medicine. "B12 deficiency during this time can result in serious birth defects and lifelong disabilities, which is why prenatal vitamins are so important."

What happens when the body cannot use B12 properly?

"In rare cases, babies can suffer from severe developmental disorders caused by vitamin B12 deficiency, even if their B12 blood levels appear normal," explains Ross. "These are genetic disorders where the body is unable to use B12 properly, despite having enough of it."

Micro-computed tomography of a whole 15-day-old mouse embryo. © Dr Ross Poché

Ross's lab studies two such conditions. The first is called 'combined methylmalonic acidemia and homocystinuria type C', or cblC for short. In this disorder, a baby's cells are unable to convert vitamin B12 into its active form, causing the body to act as if it is severely lacking the vitamin. The second condition, known as cblX, is a related disorder that causes similar effects through a different cellular pathway. Both disorders disrupt brain development and overall health during early life.

How do these disorders affect embryonic development?

Genetic disorders like cblC and cblX, which affect how cells use vitamin B12, cause much more severe developmental problems than dietary B12 deficiency. Unlike a lack of B12 from food – which can often be treated with supplements – these genetic conditions prevent the body from properly using the vitamin, so supplements do not work. Babies with cblC or cblX often suffer from permanent brain and nervous system defects that significantly impact their quality of life.

Our complex brain develops from a simple embryonic structure called the neural tube, which must grow and form many different types of neurons and cells essential for the body's functions. "This is a very complex process, and it is currently unclear precisely how vitamin B12 deficiencies impact it," says Ross. "My lab hopes to shed some light on this question."

What causes cblC and cblX, and how do they affect the body?

Genetic mutations are changes in our DNA sequence – the unique code in our genes that tells cells how to make proteins. Even small changes can affect how these proteins are produced or function. In cblC, a mutation in a gene called MMACHC disrupts the process that converts vitamin B12 into its active forms, which act as coenzymes in important cellular processes. Without these coenzymes, the cellular processes begin to break down.

"Imagine your brain is a city that must build and maintain huge neighbourhoods, and each neuron is a house in one of those neighbourhoods," says Ross. "The workers in charge of building, fixing and cleaning these houses are enzymes. However, some of these enzymes can't do their jobs alone — they need special power tools called coenzymes." In cblC, vitamin B12 is not activated by MMACHC, meaning these coenzyme power tools do not work properly, and the enzymes are left unable to carry out essential tasks. This means the cells cannot build or repair DNA and proteins effectively, or clear away harmful waste. The rapidly growing neighbourhoods of the developing embryonic brain are especially vulnerable to this breakdown in cellular work.

"On the other hand, cblX is caused by mutations in another gene that acts like the city's electrical grid manager," explains Ross. "This gene ensures that enough MMACHC is produced to keep all the B12 power tools charged and ready." If it is not working correctly, the city's power stations fail, MMACHC levels drop, and the power tools sit idle – even if vitamin B12 is present in the body. The result is the same: stalled construction, toxic build-up, and increasing damage in the most delicate parts of the brain and nervous system.

How do mouse models help Ross understand these disorders?

Studying rare genetic diseases like cblC and cblX in humans can be very difficult because patient samples are limited and complex. That is why Ross and his team use mouse models – genetically modified mice that carry the same mutations found in human patients. While cell cultures (human cells grown in a dish) have led to advancements in research, they cannot replicate the complexity of a whole living body, where cells constantly interact with tissues, organs, hormones and the immune system.

"Mice share a high degree of genetic similarity with humans, and they allow us to study the effects of specific mutations on the entire organism," says Ross. "In my lab, we create genetically modified mice that carry the same mutations that cause rare disorders like cblC and cblX."

Their recent studies on cblX mice revealed not only the expected nervous system problems but also new craniofacial defects – changes in the shape of the skull and face. This discovery broadens understanding of how the disorders impact different tissues and could guide the development of treatments that address both metabolic and structural problems.

"Without the proper nutrients or without the ability to use those nutrients properly, embryonic development can go off track in profound ways," says Ross. "We're still discovering all the different ways in which vitamins help our bodies grow and stay healthy. Studying rare diseases like cblC and cblX can teach us broader lessons about nutrition, genetics and early development."

About *rare disease research*

Rare disease research focuses on understanding uncommon genetic conditions that often arise from mutations in a single gene. Because these diseases are complex and affect multiple body systems, scientists rely on advanced tools to study them. Mouse models have become essential in this field because mice share many genetic and biological similarities with humans. By introducing the same mutations found in human patients into mice, researchers can observe how these changes impact the whole organism throughout development and into adulthood. "While alternative methods like cell cultures are valuable tools in research, they don't replace mouse models — they complement them," says Ross. "For now, studying rare diseases in the context of a living system is still the most powerful and reliable way to move from basic science to real therapies that improve lives."

Ethical considerations are central to animal research. Scientists follow strict guidelines to ensure that studies involving mice are carried out responsibly and humanely. Before any research begins, proposals undergo careful review to confirm that animal use is necessary and justified. Researchers also adhere to the principles of replacement (using alternatives when possible), reduction (minimising the number of animals used), and refinement (improving methods to reduce pain and distress). "We never take animal research lightly," says Ross. "Our goal is not only to advance science but to do so responsibly and respectfully, acknowledging that animals have made many of the greatest medical breakthroughs possible."

"Studying rare diseases is essential not only because it brings hope to patients and families who have been historically overlooked, but also because these conditions often serve as powerful models for understanding fundamental biology," says Ross. "Many rare diseases are caused by mutations in a single gene, making them ideal for uncovering how specific genes and pathways function in health and disease." Insights gained from rare disease research often highlight biological pathways relevant to more common illnesses such as cancer, heart disease and neurodegeneration. Additionally, innovative technologies, such as gene editing and precision medicine, frequently originate in this field, benefiting a broad spectrum of medical research.

Pathway from school to *rare disease research*

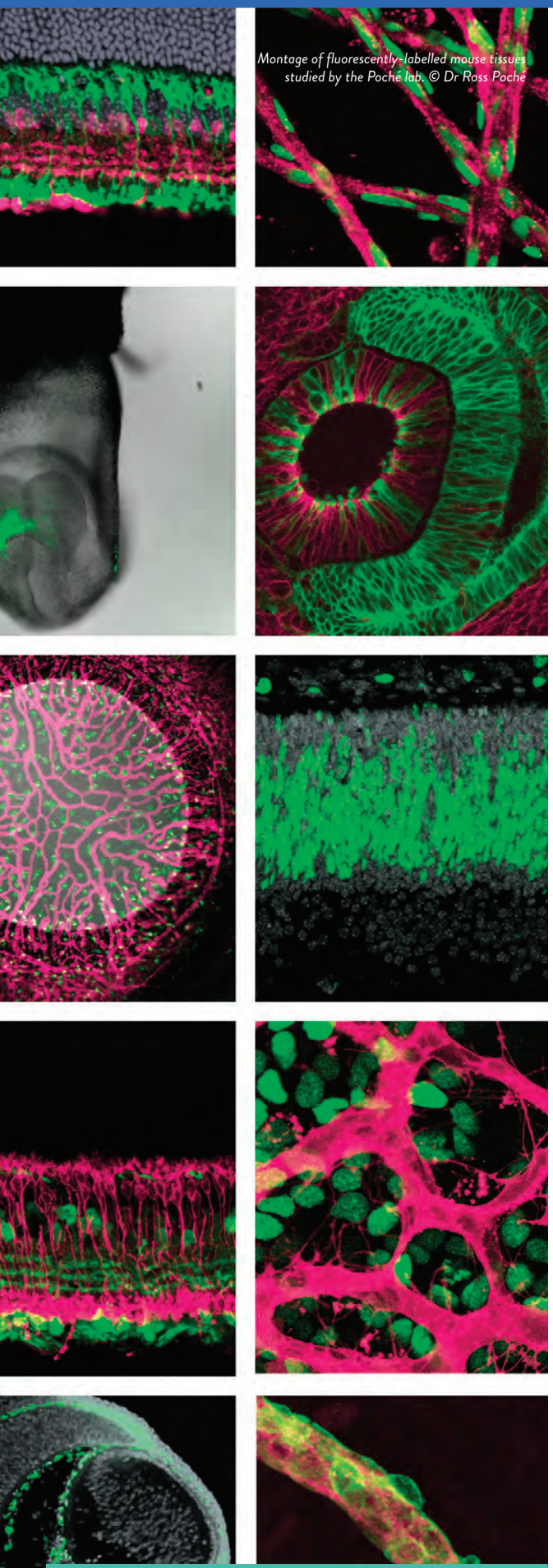
"Fundamental courses in biology, chemistry, physics and statistics are important, but don't overlook the humanities — areas like literature, history, philosophy, visual art and the performing arts," says Ross. "The best scientists aren't just skilled at doing science — they're also excellent communicators, creative thinkers and problem-solvers."

"As soon as possible, reach out to professors doing research in the field for intern positions in their labs," says Ross. "Many of us are happy to mentor excited and engaged budding biomedical researchers."

Explore careers in *rare disease research*

Professions in rare disease research include academic scientists, physicians and genetic counsellors, who help families understand inherited diseases, explain testing options, and provide emotional support during important medical decisions.

If you are interested in rare diseases, some useful organisations to explore include the National Institutes of Health Office of Rare Diseases Research (**rarediseases.info.nih.gov**), the National Organization for Rare Disorders (**rarediseases.org**), the Undiagnosed Diseases Network (**undiagnosed.hms.harvard.edu**) and the European Organization for Rare Diseases (**eurordis.org**).



Montage of fluorescently-labelled mouse tissues studied by the Poché lab. © Dr Ross Poché

Meet *Ross*

Growing up as an identical triplet, I spent a lot of time being grouped together with my brothers — people often saw us as one unit instead of three individuals. But, by high school, our personalities started to shine through more clearly, and we worked hard to show we were different. Around that same time, I read about Dolly the sheep, the first mammal cloned from an adult cell. She was described as a genetic copy of the sheep she came from. That got me thinking: if Dolly was a clone, and I'm an 'identical' triplet, does that mean I'm a clone of my brothers? That moment was eye-opening. I realised that even with nearly identical DNA, my brothers and I were clearly not the same — and that fascinated me.

As a teenager, I had many interests, including biology — but I was especially drawn to visual art and the idea of visually capturing aspects of nature and the human experience in ways no one had seen before. That same creative impulse carries over into science. Just as artists use paintbrushes to reveal the unseen, scientists use technology and experimentation to uncover the hidden patterns of the natural world. This blend of curiosity and visual thinking ultimately led me to become a developmental biologist.

One of the best parts of this work is the intellectual freedom — the ability to ask big questions and pursue research that genuinely interests me. I also really enjoy the culture of the lab. It doesn't feel like a traditional job; it feels like I'm just living my life, being myself, while also contributing something meaningful to the world.

In college, I worked in a lab focused on mapping mutations that cause Usher Syndrome Type 1 (USH1) — a rare congenital disorder that disproportionately affects infants in the Cajun population of Louisiana, causing profound hearing and vision loss. I often interacted with the parents of children affected by USH1, and I vividly remember how desperate many of them were for answers — and for hope that one day their babies might regain their hearing and sight. Without knowing which genes were involved, there was little possibility of developing a treatment. But now, gene therapy trials are underway and, within a few years, they may offer cures for children born with this devastating condition. Results like this are deeply motivating, and they remind us that there is still much work to be done.

To succeed in rare disease research, there are a few essential qualities that rise above the rest: intense curiosity, creativity and relentless determination. Scientific research is filled with setbacks, and the best scientists are those who know how to 'fail well'.

Being a scientist doesn't really feel like 'work' to me — it's something I genuinely love doing. That said, I do have a life outside the lab with other passions that keep me balanced and energised. One of my biggest interests is cooking. I find a lot of joy in preparing meals and hosting dinner parties, especially when I get to feed people I care about.

Ross' *top tips*

Pursue a topic that truly excites you, and embrace the process of 'failing well'. Setbacks are where the deepest learning and most meaningful breakthroughs begin.

Download Ross' resources from **futurumcareers.com/how-do-rare-genetic-disorders-affect-vitamin-b12-metabolism-and-embryonic-development**

What increases someone's risk of developing addiction?

Why are some people more likely to develop alcohol or drug problems than others? **Professor Ashley Acheson**, a behavioural neuroscientist at the **University of Arkansas for Medical Sciences** in the US, is exploring how risk factors, such as having a family history of alcohol or other substance use disorders, can affect the brain, immune system and behaviour of children and young adults. By studying the biological factors that may increase addiction risk, he aims to identify a 'pre-addiction' stage so that serious alcohol and drug problems could be prevented.

Professor Ashley Acheson

Department of Psychiatry, University of Arkansas for Medical Sciences, USA

PROFILE

Field of research
Behavioural neuroscience

Research project
Investigating biological and behavioural factors associated with risk for alcohol and other substance use disorders

Funder
US National Institutes of Health (NIH)

doi: 10.33424/FUTURUM648

Talk like a ...

behavioural neuroscientist

Alcohol or other substance use disorders — medical conditions in which someone struggles to control their alcohol or drug use, despite negative consequences

Bacterial endotoxin — the outer membrane of a bacterial cell that causes an immune response

Cognitive performance — how well the brain carries out mental tasks such as memory, attention and decision-making

Cortisol — a hormone released in response to stress

Cytokines — proteins released by immune cells that coordinate the body's immune response

Early life adversity — negative experiences during childhood

Magnetic resonance imaging (MRI) — a technique that can take images of a living brain

Stress response — how the body reacts to challenges or threats

White matter — bundles of nerve fibres that allow different brain regions to communicate

"Addictive disorders have tremendous costs for afflicted individuals, their families and their communities," says Professor Ashley Acheson, a behavioural neuroscientist at the University of Arkansas for Medical Sciences. "If we better understood what makes people vulnerable to addiction, we could do better at preventing it." Ashley's research focuses on identifying behavioural and biological traits associated with addiction risk factors, such as having a family history of alcohol or other substance use disorders and exposure to early life adversity. "Just having these risk factors doesn't mean someone will develop alcohol or drug problems," he emphasises. "However, they are more likely to have behavioural characteristics that put them at increased risk."

Research by Ashley and others has found these characteristics include things like increased impulsivity and, to a lesser extent, increased tendencies for depression and anxiety. The underlying biology driving these behavioural characteristics is much less clear, and Ashley believes that understanding this may be critical for improving prevention and treatment of addictive disorders. Much of this work has been done as part of the Family Health Patterns Project, a long-running study aimed at identifying behavioural and biological factors underlying risk for addictions, started by Professor William Lovallo in 2001.

What biological systems does Ashley study?

Ashley and his team have focused on

Ashley and his collaborator Professor Xiawei Ou in the MRI control room where they scan Arkansas children for the HEALthy Brain and Child Development Study.

studying brain differences associated with having a family history of alcohol or other substance use disorders. They have found evidence for reduced or altered white matter in frontal regions of the brain which are critical for decision-making and impulse control. They have also found evidence for altered brain activity while performing tasks involving these same processes.

Ashley and his team have found that a family history of alcohol or other substance use disorders is also associated with decreased stress responses. They observed this by asking young adults to take part in a mock job interview or give a short speech – situations in which most people feel nervous. Typically, stress causes the heart to beat faster and leads to a spike in the hormone cortisol. However, those with a family history of alcohol or other substance use disorders generally had smaller increases in heart rate and cortisol.

While decreased stress responses may seem beneficial, this could be problematic as stress hormones play important roles in regulating the immune system. This led Ashley to hypothesise that immune regulation could be altered or impaired in people with a family history of alcohol or other substance use disorders. Indeed, blood tests showed that having a family history of alcohol or other substance use disorders was associated with having more white blood cells, and when Ashley and the team exposed these immune cells to bacterial endotoxin in the lab, more cytokines were released. They are now studying why this immune overreaction occurs, and how it may affect the brain. "We think that altered immune regulation and increased immunoreactivity could result in neural changes that are responsible for risk-related behavioural characteristics," says Ashley.

How does Ashley study brains and behaviours?

Ashley uses advanced magnetic resonance imaging (MRI) techniques to capture high resolution anatomical images of young adults' brains. For example, diffusion MRI tracks water movement and can be used to study white matter characteristics, while functional MRI can be used to study blood flow through the brain. "Brain differences in people with alcohol or drug problems are often assumed to be a consequence of excessive use," explains Ashley. "But we have seen similar differences in at-risk people before alcohol or drug problems start."

To assess behavioural traits, Ashley and the team use self-reported measures. Participants complete questionnaires about their mood, social behaviours and alcohol and drug use, and they take computer-based tests of attention, memory and reactions to stimuli. Decision-making tasks are also important. For example, participants are asked whether they would rather receive a smaller reward now or wait for a larger one later. By varying the size and timing of rewards, Ashley and the team can observe how participants value immediate versus delayed outcomes, giving insight into self-control and future planning. They have discovered that participants with a family history of alcohol or other substance use disorders are more likely to choose smaller, immediate rewards than larger delayed ones. They have also observed that people who were exposed to more early life adversity (whether or not this was associated with a family history of alcohol or other substance use disorders) are less likely to value delayed rewards.

Why are some people at increased risk of addiction?

"We don't know for sure why some people have an increased risk of addiction," says Ashley. "However, we have found that having a family history of alcohol or other substance use disorders and exposure to early life adversity can set a chain of events in motion that can increase the risk for addiction." The team believes that altered immune system regulation contributes to neurological changes, including disruption to white matter development and white matter damage. These brain changes are linked to cognitive differences, such as not valuing delayed rewards. This reduced cognitive control can influence behaviour, contributing to traits such as impulsivity and, ultimately, making people more vulnerable to addictions.

** Do you need support? **

The National Association for Children of Addiction provides help and support for people with a family history of alcohol or other substance use disorders:
US: **nacoa.org**
UK: **nacoa.org.uk**

In the US, the Substance Abuse and Mental Health Services Administration provides support for substance use disorders: **samhsa.gov**

In the UK, FRANK provides information about drugs (including alcohol) and a confidential helpline: **talktofrank.com**

The HEALthy Brain and Child Development Study

"At the moment, we don't know how much of addiction risk is inherited or a result of stress and other exposures during pregnancy and early life," says Ashley. To help better understand this, Ashley is one of the principal investigators of the nationwide HEALthy Brain and Child Development (HBCD) Study. "This is the largest study of childhood brain development ever conducted in the US," he says. "We are following over 7000 mother-child pairs from before birth to at least age 10, to investigate how external factors influence brain development throughout childhood." The study uses MRI, other brain scanning techniques, cognitive tests and observations of family interactions to track how children's brains develop over time. Researchers also examine how external factors, including parental alcohol and drug use, early life adversity, and the social and physical environments children grow up in, affect development.

Could we prevent addiction?

Ashley hopes his research will be used to identify the early signs that someone may be at higher risk of developing an alcohol or other substance use disorder, much like doctors can detect pre-diabetes before the full condition develops. "We want to do the same for addiction," says Ashley. "We want to identify a pre-addiction state where we can intervene before major problems start. Understanding the underlying biology of addiction risk is crucial for this. I think there is tendency to think people should just make better choices about alcohol and drugs, but the reality is there are likely underlying biological differences that makes that a lot harder for some people."

About *behavioural neuroscience*

"Behavioural neuroscience is the study of how the brain controls and influences behaviour," explains Ashley. It combines psychology and neuroscience, integrating an understanding of brain structure and function with the study of behaviour and associated processes. Researchers in this field investigate how biological processes in the brain regulate behaviour, emotions, decision-making, learning, memory and social interactions. By linking behaviour to brain activity, behavioural neuroscientists explore why people think and act the way they do, including studying biological mechanisms underlying addiction and other mental health conditions.

Download Ashley's resources from **futuurmcareers.com/what-increases-someones-risk-of-developing-addiction**

Ashley's team collects blood samples from participants to investigate immune regulation in people with a family history of alcohol or other substance use disorders.

Pathway from school to *behavioural neuroscience*

At high school, study biology and psychology to learn about the brain and human behaviour.

At university, study an undergraduate degree in neuroscience or psychology, followed by a graduate degree in behavioural neuroscience.

"Get research experience," advises Ashley. "Look for opportunities to work or volunteer in a behavioural neuroscience research lab and help with experiments or analysing data. This will give you useful practical experience, which is important for graduate school admissions."

Explore careers in *behavioural neuroscience*

Many behavioural neuroscientists work as academic researchers in universities, conducting studies to investigate how the brain influences behaviour. There are also opportunities for careers in the pharmaceutical and other industries.

Ashley highlights the importance of getting exposure to research. "This is important to get a sense of what research careers involve," he says. "Talk to researchers to get a good understanding of what their jobs are really like and whether this is a career path that seems right for you."

International organisations such as the American Psychological Association (**apa.org/education-career/k12**), the Society for Neuroscience (**sfn.org/outreach**) and the British Neuroscience Association (**bna.org.uk**) provide educational resources and careers guidance.

Meet *Ashley*

My brother and I were the first in our family to graduate from college. I wasn't very motivated in high school, and I wasn't excited about going to college, but my parents encouraged us to at least give it a try. However, once I started, I discovered how much more interesting studying at college was. High school was a lot of homework and memorisation, but in college everything became much more conceptual and interesting.

At college, I became interested in psychology. Ever since I was a little kid, I've loved watching nature shows and learning about animal behaviour – and I still do! I've always thought behaviour was fascinating, and that drew me to psychology.

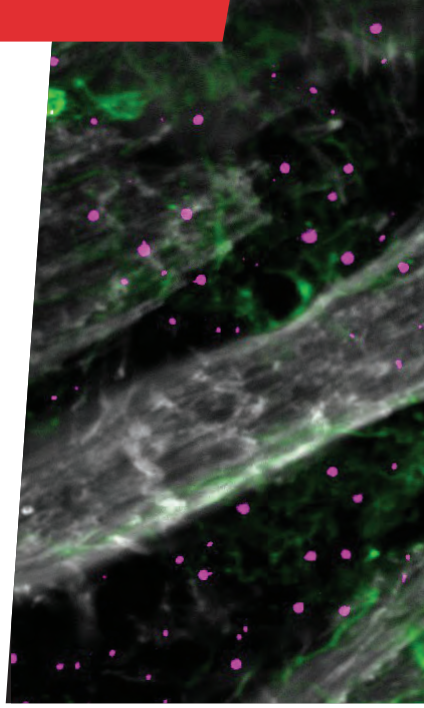
I wasn't sure what I would do with psychology after college. I considered working in human resources (HR), so I took some business classes, but I didn't enjoy them. Eventually, I took a class called physiological psychology (essentially behavioural neuroscience), and I loved it. I volunteered in my professor's lab and completed my honours thesis with her. She was a great mentor, and it's hard to imagine getting from where I started to where I am now without my college experience and her guidance.

My favourite part of being a scientist is coming up with new ideas. The most rewarding parts of my job are developing hypotheses, interpreting data, and figuring out how my findings integrate with work others are doing. My colleagues make my work enjoyable, especially ones from different training backgrounds who have different perspectives.

A lot of my free time goes to family activities with my wife and kids. I also exercise a lot. Most people in my neighbourhood probably know me as the guy who lifts weights in his garage and walks his dogs every day. I used to scuba dive regularly and am looking forward to getting back into that when the kids are older.

Ashley's *top tip*

Look down the road. My summer job after my freshman year in college was unloading semi-trucks for a wholesale food and restaurant supply distributor. I would ride along with the drivers, and we'd make deliveries to restaurants, cafeterias, grocery stores and prisons throughout Wisconsin, Minnesota and Illinois. Not long I after I started, I asked one of the drivers how he managed to drive through busy metro areas. He told me he was always looking several blocks down the road, because if he only looked at a few car lengths ahead he never would have enough time to deal with anything. Something about that stuck with me. Life is a lot easier when you're not just focused on the challenge right in front of you and can see a bigger picture instead.



The molecular mechanisms behind a devastating disease

Huntington's disease is a serious genetic disorder that causes problems with movement, thinking and mood, and eventually leads to death. It is known to be caused by an error in a single gene, but the molecular mechanisms that are affected by this error are not fully understood. At the **University of Minnesota** in the US, **Dr Rocio Gomez-Pastor** is studying these mechanisms, with the hope that her findings will inform new, innovative ways to treat the disease.

Dr Rocio Gomez-Pastor

Associate Professor, Gomez-Pastor Lab, Department of Neuroscience, University of Minnesota, USA

Field of research
Neuroscience

Research project
Studying the molecular mechanisms of neurodegeneration and cell death in Huntington's disease

Funder
US National Institutes of Health (NIH)

Website
sites.google.com/umn.edu/gomez-pastor-lab

doi: 10.33424/FUTURUM649

PROFILE

Talk like a ...

neuroscientist

Huntingtin — the gene, and the protein it encodes, that causes Huntington's disease when mutated

Huntington's disease (HD) — a progressive, genetic brain disorder that causes neurons to degenerate over time, affecting thinking ability, mood and movement

Neuron — a nerve cell that transmits electrical signals to send messages between the brain and the body

Preclinical — the stage of medical research that happens before human testing (e.g., on cells or animal models)

Protein folding — the process where a linear chain of amino acids folds into the specific three-dimensional structure that allows a protein to fulfil its function

Protein homeostasis — the dynamic regulation of protein concentrations within a cell

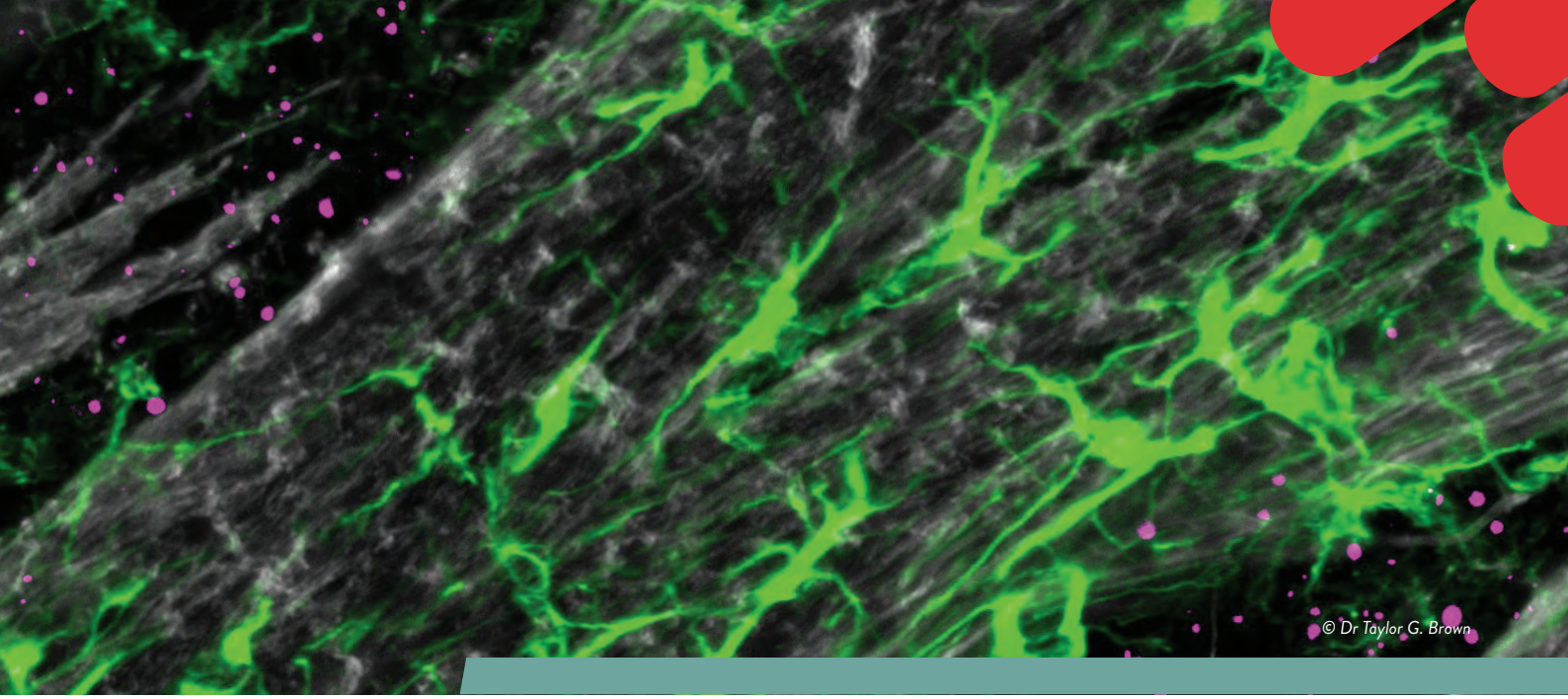
Synapse — a junction where two nerve cells meet and a chemical signal is transmitted

Huntington's disease (HD) is a devastating and ultimately fatal neurological condition that affects around 1 in every 10,000 people. Symptoms tend to begin appearing in middle age. "HD is an inherited brain disorder that is caused by a change in a single gene called huntingtin," says Dr Rocio Gomez-Pastor of the University of Minnesota. "The mutated version of this gene contains a certain DNA sequence that repeats too many times." This gene codes the huntingtin protein, so the mutation leads to an abnormal protein that accumulates in brain cells, disrupts their functioning, and eventually kills them. "Typically, the more repeats of this gene that a person has, the earlier and more severe the disease," says Rocio.

Rocio is a neuroscientist who is focusing on molecular pathways associated with huntingtin. She is looking at how a certain molecular signal leads to further signals, and is aiming to understand the eventual purpose of these signals in modifying and regulating activities within the cell. Her lab is studying the huntingtin protein, and how the way it interacts with molecular pathways differs when it is normal or mutated, to understand how exactly it can cause such damage. "Exploring how cells are disrupted may provide a promising avenue for developing effective therapies," says Rocio. "HD is a terrible disease that urgently needs a cure."

Balance in the brain

Proteins are encoded by our genes, and complex molecular mechanisms



regulate their production and management, to ensure that levels of different proteins remain in the correct balance – a process known as protein homeostasis. "We're studying how brain cells keep their proteins healthy and balanced, and what happens when this process fails," explains Rocio. "By identifying the molecular pathways that restore protein balance and resilience, we aim to discover new strategies to slow or prevent HD progression."

The sequence of amino acids within a gene defines the shape of the protein that it encodes via a process called protein folding. The shape of the protein determines its function, so mistakes in the gene can lead to malfunctioning proteins. Normal huntingtin is an essential protein, especially for neurons, thought to play a role in transporting molecules within cells, chemical signalling and even protein homeostasis itself. But when huntingtin is mutated, it disrupts these processes and interferes with other proteins. "We examine these molecular changes, such as how mutant huntingtin affects protein folding, and downstream effects, such as neuron survival, synaptic signalling and connectivity," says Rocio.

Mixed signals

The Gomez-Pastor Lab is focusing on medium spiny neurons (MSNs), which are the brain cells most affected by HD. "MSNs control movement, coordination and some forms of cognition," says Rocio. "We are particularly interested in how the mutant huntingtin protein disrupts communication between neurons." Neurons communicate via synapses – the small 'gaps' between the cells that form the junctions in neural pathways. An electrical signal travels from one end of a neuron to the other. When it reaches the synapse, the cell transforms the electrical signal into a chemical signal, which travels across the synapse and activates the next neuron. "Synaptic signalling is essential for memory and other cognitive functions," says Rocio. "Mutant huntingtin protein disrupts this process, which may explain the cognitive deficits that develop early in HD."

> ***"Exploring how cells are disrupted may provide a promising avenue for developing effective therapies."***

To understand exactly what these disruptions mean at the whole-organism level, Rocio's team studies mouse models: a normal control group and groups with different levels of huntingtin mutations. "We use animal models to connect these cellular changes to behavioural changes," she says. A multidisciplinary approach, covering every aspect from the molecular level to the behavioural level, is essential to truly understand the disease. "HD affects the brain at every scale," explains Rocio. "By combining molecular biology, cell biology and behavioural studies, we can gain a more complete understanding."

From the lab to the clinic

The development of such a comprehensive understanding of HD could pave the way for new ways to treat and manage the disease. "There remains a critical need for a deeper understanding of the mechanisms that drive HD," says Rocio. "By uncovering how mutant huntingtin disrupts protein homeostasis, neuron function and synaptic signalling, we hope to identify key pathways that can be targeted to protect vulnerable neurons."

So far, Rocio's lab has identified key molecular pathways that are disrupted by mutant huntingtin – which reveals useful targets for therapies that could restore these pathways. "We have begun to develop and test small molecules to improve protein homeostasis and restore the cell's natural protective mechanisms," says Rocio. "These approaches have shown promise in preclinical models." Her findings may also have applications beyond HD. "Insights from our work may also apply to other neurodegenerative disorders where protein misfolding and synaptic dysfunction play a role," says Rocio. "This could lead to advances in treatments more broadly."

With these findings in hand, the Gomez-Pastor Lab now aims to build on its research to identify ways to treat both motor and cognitive malfunctions associated with Huntington's disease. "Our focus is on translating our findings into strategies to protect neurons in HD patients," explains Rocio. "Ultimately, our goal is to develop therapies that are both effective and accessible for people living with this disease."

About *neuroscience*

Neuroscience is a broad field that involves the study of the structure and function of the brain and broader nervous system. "Neuroscience can be highly collaborative and multidisciplinary," says Rocio. "It combines insights from molecular biology, neurochemistry and therapeutics, to name a few fields."

Rocio's particular speciality focuses on the molecular pathways behind neurological diseases, which has direct applications for improving well-being. "We have the opportunity to uncover the fundamental mechanisms that drive neurodegenerative diseases," says Rocio. "It is incredibly fulfilling to see how discoveries at the molecular and cellular levels can translate into strategies that improve patients' lives."

A growing base of knowledge and a dazzling array of new and emerging technologies are helping neuroscientists make discoveries that once seemed unreachable. "Advances in genetics, imaging and computational tools are making new discoveries possible," says Rocio. "This will open doors for new therapies to be developed." The next generation of neuroscientists will be at the forefront of this wave of discovery.

And the real-world impact of such discoveries is self-evident. Recently, for example, studies have identified potential cures for Huntington's disease – a possible lifeline for tens of thousands of people. "Ultimately, knowing that our research could contribute to treatments that enhance quality of life makes the challenges and long hours in the lab deeply worthwhile."

Pathway from school to *neuroscience*

Rocio recommends building a strong foundation in science, mathematics and critical thinking at school.

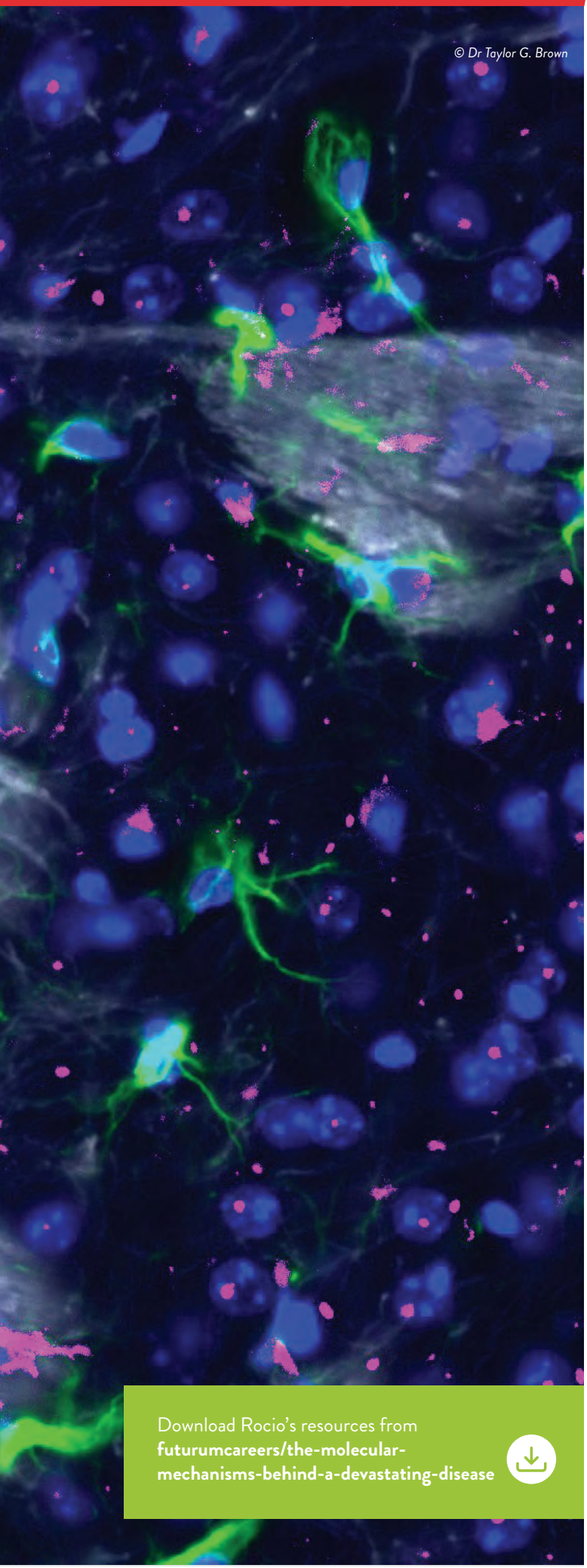
At university, a wide range of choices can lead to a career in neuroscience, depending on your interests. "While biology, chemistry and psychology are helpful, it's important to remember that neuroscientists come from a wide range of backgrounds including engineering, computer science and the social sciences," says Rocio.

Explore careers in *neuroscience*

Rocio recommends getting involved in research early, such as through college labs or summer programmes. Rocio and her colleague in the Department of Neuroscience, Dr Marija Cvetanovic, founded the Go4Brains Program at the University of Minnesota, a week-long summer neuroscience programme for students who have historically faced challenges in accessing science and medicine opportunities. Go4Brains offers hands-on experiences, mentorship and exposure to cutting-edge research: **sites.google.com/umn.edu/go4brains/home**

Rocio also suggests joining professional societies such as the Society for Neuroscience (**sfn.org**) and the International Brain Research Organization (**ibro.org**) to access networking opportunities, seminars and career resources.

Indeed outlines key information about careers in neuroscience: **indeed.com/career-advice/finding-a-job/how-to-become-a-neuroscientist**



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Download Rocio's resources from **futurumcareers/the-molecular-mechanisms-behind-a-devastating-disease**

Meet *Rocio*

My family owned a restaurant in Spain, but my upbringing was humble. Overcoming the distance, cultural differences, and challenges of being a first-generation scientist and, then, professor in the US has been deeply rewarding.

I became a neuroscientist almost by accident. I originally studied molecular biology and genetics, but I had always been fascinated by the brain and how it works. I became a Neuroscience Scholar at Duke University to connect this curiosity with real-world problems. There, I met inspiring scientists who worked directly with patients affected by Huntington's disease and other movement disorders, which showed me that my research could improve lives.

A pivotal moment for me came when I began working with both research scientists and clinicians. Being able to obtain human samples and validate my observations of cell and mouse models of HD was truly a Eureka moment. It made me feel that my research was directly contributing to progress in understanding and addressing the disease.

Running a lab and conducting research can be demanding. I try to stay organised and prioritise tasks while remaining flexible for when unexpected challenges arise. I rely on my team, colleagues and students to collaborate, share ideas and tackle problems together. I also remind myself that setbacks are a natural part of research, and that each challenge is an opportunity to learn and improve. Finally, I make time for family, hobbies and physical activity, which help me maintain perspective and energy.

I am proud to know that my work and mentorship is inspiring younger generations. As a first-generation scientist, I understand how challenging it can be for many people to access opportunities in science. It's highly rewarding to see students go on to pursue careers in science and know that I can have a lasting impact on the next wave of neuroscientists.

My ultimate goal is to continue until patients with HD have ways to live healthier and more fulfilling lives. I also hope to expand our knowledge into the broader field of neuroscience, particularly by exploring how synaptic regulation influences cognitive processes. And I aim to continue mentoring the next generation of scientists, helping them grow and make their own impact.

Rocio's *top tips*

1. Stay curious, ask 'why?' and dive into hands-on research wherever you can.
2. Don't be shy about reaching out to mentors – they love to share their experience.
3. Embrace challenges and learn from mistakes. They're part of the discovery process.
4. Neuroscience is a huge, exciting playground. Bring your own unique perspective and creativity – it might just lead to the next big breakthrough.

Health is wealth

Racism in healthcare is a serious barrier that prevents Indigenous peoples from receiving the care they need. At the **University of Saskatchewan** in Canada, **Dr Holly Graham** is supporting Indigenous nurses and nursing students, and she has developed a guide to empower healthcare professionals to address racism when they witness it.

Dr Holly Graham
R. D. Psychologist

Professor in Psychiatry, College of Medicine, University of Saskatchewan, Canada

Registered Nurse and Registered Doctoral Psychologist

PROFILE

Fields of research
Nursing education, Indigenous health

Research projects
Addressing mentorship and reconciliation with a focus on creating safety for Indigenous peoples to access healthcare

Funders
Canadian Institutes of Health Research (CIHR); Saskatchewan Health Research Foundation (SHRF); Canadian Nurses Foundation (CNF); Canadian Foundation of Innovation (CFI); Department of Psychiatry, College of Medicine, University of Saskatchewan

doi: 10.33424/FUTURUM619

Talk like a ... nurse

Cardiopulmonary resuscitation (CPR) — the lifesaving first aid technique of giving chest compressions and rescue breaths to circulate blood and oxygen when someone's heart has stopped

Colonialism — the takeover and control of Indigenous lands and cultures by settlers

Culturally safe care — healthcare that is respectful, aware of the power imbalances and potential biases within the system, and ensures that patients feel safe and valued

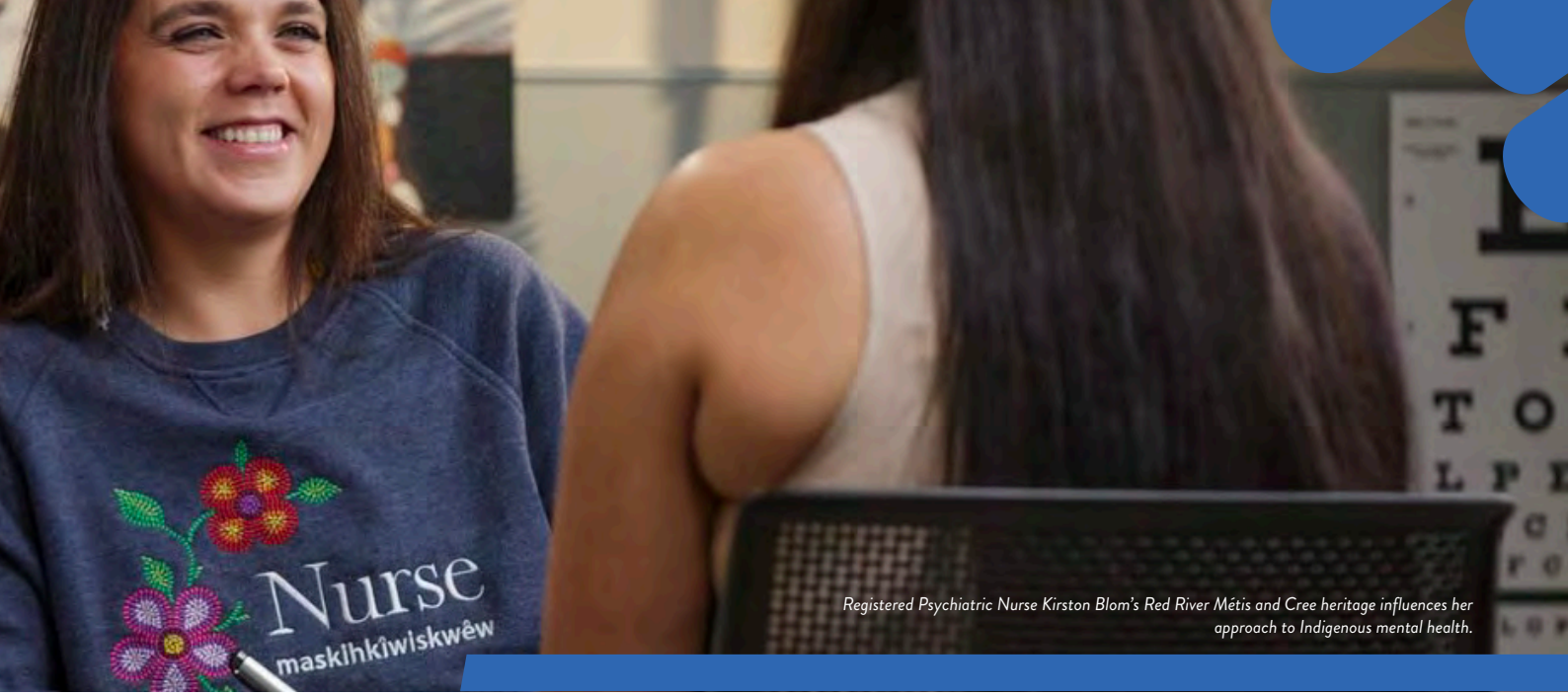
Evidence-based care — medical decisions based on the best available scientific research, not personal opinions or stereotypes

Racism in healthcare can be a matter of life or death. In 2020, Joyce Echaquan, a 37-year-old Atikamekw woman, went to a Canadian hospital with stomach pain. Due to racial stereotyping, staff assumed she was a drug user despite there being no evidence for this. Joyce died two days later, while being abused by hospital staff. Racism and prejudice played a significant role in her death.

For Indigenous peoples in Canada (First Nations, Inuit and Métis), centuries of colonialism have led to earned deep mistrust in medical systems — and this mistrust still affects health outcomes today. When people do not feel safe or respected by healthcare providers, they are far less likely to seek medical help. As a result, health issues often go untreated until they become much more serious. And even when Indigenous patients do seek care, their concerns may be overlooked, their symptoms dismissed and their voices unheard.

"I have a second-degree black belt in karate," says Dr Holly Graham, a Registered Nurse and member of the Thunderchild First Nation. "I was competitive and teaching in my own Dojo. Then in 2005, I started to have pain in my left knee, but my doctor just told me that I had arthritis and said there was no need to x-ray it." After years of living with this pain and being dismissed by her doctor, Holly eventually managed to seek a second opinion in 2015, and she finally had an x-ray which revealed she had a rare condition that caused extra bones to grow in her knee joint.

"My example shows how First Nation peoples not only struggle to access emergency care due to the lack of trust in the healthcare system, but even when they see their doctor, their concerns are not taken as seriously," says Holly. "If my doctor had x-rayed my knee when I first told him I had pain, I could have had surgery immediately



Registered Psychiatric Nurse Kirston Blom's Red River Métis and Cree heritage influences her approach to Indigenous mental health.

instead of living in pain for years and losing the ability to run and practice karate." Holly's story is not unique. It highlights how racism in healthcare is not always about life-or-death emergencies — it is also about being ignored or mistreated in ways that quietly damage people's health over time.

Saving lives with CPR

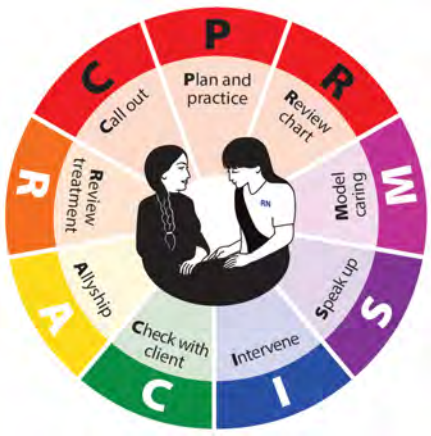
The tragic death of Joyce Echaquan deeply affected Holly. "I asked myself, 'As a nurse, what can I do to make sure this never happens again?' " Around the same time, Holly had been watching the TV show *Grey's Anatomy*. "Everyone who comes into hospital in *Grey's Anatomy* seems to be given CPR (cardiopulmonary resuscitation)," says Holly. "CPR can save lives, and I wanted to create a plan to save lives lost related to racism. So, I decided I'd use the same acronym – CPR – to highlight the urgency of addressing racism in healthcare."

Holly created the CPR RACISM guide to help healthcare professionals address racism:

- **C**all out, how can I help?
- **P**lan and practice your intervention strategy
- **R**eview the chart, speak to and assess the client
- **R**eview the client's treatment plan and politely ask for the reason(s) for the current approach
- **A**dvocate for and educate yourself about anti-racism and practice allyship
- **C**heck with the client and listen to their concerns, be the safe person
- **I**ntervene, always be an active bystander
- **S**peak up about your concerns and get support for yourself
- **M**odel safe, competent and compassionate care

> ***CPR can save lives, and I wanted to create a plan to save lives lost related to racism.***

The guide draws on interventions Holly has been using since the beginning of her nursing career in the 1980s, when she worked in the USA and witnessed racism directed at Black patients and colleagues. Her mentor, Dr Verna St. Denis, helped shape her thinking about race and education. As Holly progressed through her nursing career, she realised many of her colleagues did not know how to intervene when they witnessed racism or how to teach nursing students to combat racism.



The CPR RACISM guide offers a clear approach: "If a nurse thinks a client is not receiving appropriate care, they should review the client's chart themselves and listen to the client, then consider what evidence-based care they need based on their symptoms," says Holly. "When speaking out against racist behaviour, it's important to target the behaviour not the person – labelling someone as a racist in the moment is never helpful."

Promoting the Seven Sacred Teachings

The Seven Sacred Teachings (Spiritual Laws) are guiding values that help people live in balance with themselves, others and the world around them. These teachings – love, respect, courage/bravery, honesty, wisdom, humility and truth – are rooted in Indigenous knowledge systems and can be applied in everyday life to build better relationships. "Loving yourself allows you to love others," says Holly. "Respect is about honouring all living things. Courage helps us speak up when something is wrong and do the right thing, even when it's hard. Honesty is speaking from the heart, holding and keeping your promises. Truth is your key to freedom. Humility is related to being humble and reminds us to get up after we tumble. And wisdom comes from listening and the lessons we learn through our experiences. When people live according to these values, we will have healthier relationships and can build healthier communities."

These Indigenous values are at the heart of CPR RACISM. "To me, the Seven Sacred Teachings are embedded in the

CPR RACISM guide because it is about promoting these values for all of creation and humanity," says Holly. Just as the teachings encourage us to act with honesty, courage and humility in our relationships, the guide calls on healthcare professionals to reflect on their actions, listen to patients and intervene when they witness injustice.

Supporting Indigenous nurses

Indigenous nurses often face unique challenges during their education, training and careers – and many of these come from a clash of worldviews. "The Western model traditionally views health very much on the physical level, but the Indigenous view of health encompasses physical, mental, emotional and spiritual wellness," explains Holly. "If, as a nurse or nursing student, you are told that how you see the world is wrong or doesn't apply to medicine, then it is hard to stay in a profession that doesn't respect your beliefs."

To help address this, Holly created the kā-wīci-pimohtēmāt Professional Nursing Practice Group – a network where Indigenous nurses can connect, share their experiences and feel supported. The group also works directly with the provincial regulatory body to shape healthcare policies related to Indigenous peoples in Saskatchewan. Anti-racism education and training is now a required part of Canadian nursing education. "This means that nursing graduates will be better prepared to provide culturally safe care and have the skills to address racism in healthcare settings," says Holly.

Holly is also the project manager for the miyo mashihkêwiyiniwak (Good Medicine People) space at the University of Saskatchewan. "This new research space was created to address health disparities for Indigenous peoples and to centre Indigenous worldviews," she says. "The Seven Sacred Animals that represent the Teachings are etched on a glass wall as you enter this space."

Through her work addressing racism and supporting Indigenous nurses, Holly is building a brighter future for healthcare in Canada. "Patients feel more comfortable if they can identify with their healthcare professionals," she explains. "Indigenous nurses are uniquely positioned to understand the needs of Indigenous patients because we have shared understandings of history, culture and belief systems. We need more Indigenous nurses if we want to address health disparities and ensure everyone can feel safe in healthcare."

Pathway from school to *nursing*

At high school, study biology, chemistry and mathematics to build essential knowledge about the human body and medical science, and to develop problem-solving skills that are vital in nursing practice.

At university, a degree in nursing will prepare you for a clinical career as a Registered Nurse.

"Engage with nurses and other healthcare professionals and try to shadow them in their work," advises Holly. "Attend career days and volunteer in healthcare settings like long-term care facilities."

Take opportunities to work with people, such as helping with youth groups or community-based activities. "Nursing is all about developing relationships with people," says Holly. "You will have to deal with people who are unwell and unhappy, so you need to enjoy working with others."

Registered Nurse Jennifer McGillivary dances in traditional regalia.

Download Holly's resources from **futurumcareers.com/health-is-wealth**

Explore careers in *nursing*

Nursing is a very flexible career. You can work with people of all ages, from babies to elderly patients, and in a huge range of places, from hospitals to mental health clinics to community health centres. And you can specialise in whichever area most interests you, such as emergency care, oncology (cancer) or mental health.

"It is a huge privilege to care for others when they are in need and to share in a small part of their journey through life," says Holly.

"Health is wealth," says Holly. "When you don't have health, it's hard to appreciate the rest of life. And one of the benefits of being a nurse is that you learn how to improve your own health."

These videos share personal stories of Indigenous nurses who graduated from the University of Saskatchewan, inviting you to consider a career in nursing: **youtube.com/playlist?list=PLUaewQzUIZwpw1afWztcnq3X44tAa8YDU**

Meet *Holly*

When I graduated from high school, I wanted to be a police officer then go into law. But I was only 17, so I wasn't old enough to start police training. My mother was a Certified Nursing Assistant, and it was her dream that one of her children would become a Registered Nurse. She suggested I take a two-year nursing programme so I could stay in school until I was old enough to get into Police College.

I never wanted to be a nurse because I was terrified of needles – I used to faint whenever I had injections! But I decided to enter the nursing programme to keep my mom happy and I thought I'd just drop out when we started to give needles. But when it came to it, I discovered that I didn't mind giving needles to other people. So, I stayed in the programme and, when I graduated, I realised that nursing was a good fit for me because I enjoyed caring for people. I've now been a nurse for 40 years!

I enjoy the fact that nursing is both a science and an art. There's the science of anatomy, physiology and pharmacology. But there is also an art to how you deliver care, communicate with your patients and make them feel safe.

My family has felt the impact of colonialism and racism. My mother was sent to a residential school, but she never spoke about it, so I didn't know anything about her experiences. She refused to teach us the Cree language because she said we would have a better chance to succeed in life if English was our first language. As a child, I never understood why Indigenous peoples were poorer than the white people around us – I thought that Santa must like white children better because he gave them better gifts.

From an early age I participated in Cree cultural traditions, such as Sundances, Pow Wows and Sweats. Participating in Sundances has been central to the development of my spirituality. I was given my Cree name, *okimāwahtik-iskwēw*, at a Sundance when I was eight by a blind Elder who had dreamt of me. He said it was an important name with a lot of responsibility, and that I would bring peace and happiness to those around me.

How ethnography highlighted the value of curling for communities

The sport of curling provides more than just exercise for its players. Growing up in rural Canada, **Professor Heather Mair** witnessed the importance of curling in the social life of her community. Now a recreation and leisure researcher at the **University of Waterloo**, she has conducted ethnographic studies to investigate the social role of curling clubs and explore the impact of curling on well-being. Heather is also leading a partnership dedicated to making the sport more accessible to everyone.

Professor Heather Mair

Department of Recreation and Leisure Studies, University of Waterloo, Canada

PROFILE

Fields of research
Recreation and leisure, community sport

Research project
Investigating the social role of curling in rural Canada and increasing the accessibility of the sport

Funders
Social Sciences and Humanities Research Council of Canada (SSHRC); Curling Canada

doi: 10.33424/FUTURUM643

Talk like a ... recreation and leisure researcher

Ethnography — a qualitative research method of prolonged observation, often involving the researcher immersing themselves in a community to understand cultures, habits and experiences

Photovoice — a participatory research method in which people take photos relating to their own lives and then use them to share their perspectives and experiences with others

Social capital — social value created by the relationships, networks and shared understandings within a group of people that provides benefits to individuals and the group as a whole

Third place — a social place that is not home (the 'first place') or work/school (the 'second place')

Professor Heather Mair, a recreation and leisure researcher at the University of Waterloo, had only curled a few times before she decided to dedicate her career to studying the sport. "My mum curled a little when I was young, so curling was in my life, but I hadn't had many chances to try the sport myself," she says.

Curling originated on frozen ponds in Scotland during the 16th century, when members of the community would come together during the harsh winters. It has since evolved into a highly technical sport, typically played by teams of four who slide granite stones across a sheet of ice, using brooms to guide them. The aim is to get your team's stones as close as possible to a target area, while knocking the other team's stones out of the way.

Heather is not studying the sport itself, but the social role it plays in communities. "Growing up in a rural village, I had a sense that the curling club was a really social place for the community," she explains. "Curling is a team sport, so it's social in that way. But it also has all these wonderful social traditions off the ice. After a match, most teams sit in the club and have a drink with their opponents. During competitions, many clubs host big community meals."

Immersion through ethnography

Heather takes an ethnographic approach to her research. "Ethnography is about understanding a culture, and to do this, you need to be immersed in it," she explains. For one study, Heather spent five years travelling around Canada visiting rural curling clubs. "I wanted to illustrate just how valuable curling clubs are as social spaces," she says. "As an ethnographer, I had to go into curling clubs and take part in those social activities, then observe and record what was happening." She

An image from Heather's photovoice project, showing what curling means to this group of rural women curlers. © Heather Mair

also interviewed club members about the role that the curling club played in their lives and communities.

For another project, Heather and her research team gave cameras to women curlers in rural areas and asked them to take photos showing the role that curling played in their health and well-being. In addition to photos of people curling, many women took pictures of the social aspect of the sport, showing people sitting in the club and laughing. "This photovoice project allowed women to convey what curling meant to them in unique ways," says Heather. "It also allowed us to use those photos to convey the value of curling to the outside world. Photovoice is a powerful way to share the impact of the sport."

Heather's studies have shown how curling clubs are far more than just sport environments – they are gathering places and community hubs. For instance, many rural curling clubs can function as the local bar, where people meet to socialise and drink, and the off-ice areas are often hired out for community events such as weddings. "Curling clubs are what we call 'third places' – places that are neither home nor work/school," explains Heather. "They help us build social capital by forming relationships with people outside our circle of family and colleagues, which is so valuable to individual and community health and well-being."

Curling for everyone

In recent years, the issues of diversity, equity and inclusion have been brought into sharp focus and many organisations, including Curling Canada (the national governing body for curling in Canada), are assessing how they can ensure they are welcoming to everyone. Together with her colleagues Laura Leitch, Dr Simon Barrick and Dr Kristi Allain, Heather is helping to lead this initiative through Partners Transforming Curling. This partnership with Curling Canada, regional curling associations and local curling clubs is an opportunity for stakeholders at all levels of the sport to have conversations about how to make curling more diverse, equitable and inclusive.

> ***"Curling clubs are what we call 'third places'. They help us build social capital... which is so valuable to individual and community health and well-being."***

"One magical thing about curling is that it's always adapted to address its members' needs," says Heather. For example, if people struggle to crouch down on the ice to slide the stones, they have the option of using a stick to push the stones while standing or sitting. "I wanted to learn from these adaptations that make curling accessible to people with physical disabilities," says Heather. "How can we adapt curling clubs to make them accessible for everyone?"

Curling clubs across Canada have been introducing initiatives to make curling more welcoming to all. "For example, there's a wonderful programme called 'Out on Ice' where curling can be a safe space for LGBTQ2+ people, whether or not they were originally curlers," says Heather. She and her team are evaluating initiatives like these using interviews, observations and focus groups to see how effective they are at making people feel welcome. From the results, Partners Transforming Curling will distribute information about 'What makes a welcoming curling club?' to clubs and curlers across Canada.

"We want to get everyone having conversations about diversity, equity and inclusion in curling," says Heather. "We want all curlers to think about what messages their clubs are sending to potential new members. If a new person walked into the club, would they immediately feel that they belong in curling?"

Heather has shown the vital role that curling plays in communities and she is now ensuring that everyone can benefit from its social value. But has this research turned Heather into a curler herself? "I've learnt to curl over the years as part of my research," she says. "I do love to curl, but I have no balance – I'm terrible!"

© Heather Mair

About *recreation and leisure studies*

Recreation and leisure studies is an interdisciplinary field that combines aspects of social sciences, health studies and business studies to explore the links between activities, physical and mental well-being, society and the economy. Recreation and leisure researchers are interested in how people spend their time. They investigate what these activities mean to individuals and communities, how they benefit from them and what barriers people might face to participation. Researchers are increasingly interested in how leisure activities prevent illness and improve mental well-being, especially in terms of addressing social isolation.

Researchers use a range of methods for their work, including interviews, surveys, focus groups and observations. Some, like Heather, use ethnography and photovoice approaches. Others might use data recorded by wearable devices to study patterns of activity and physiological responses, or social media to understand trends.

The importance of leisure

"Sport and leisure activities fulfil all three aspects of health and well-being: physical, mental and social," says Heather. "They help you stay active, build relationships, relieve stress and feel connected in your community. Being physically active with other people is probably the best thing you can do for all levels of your health!" This means it is important that everyone has the opportunity to participate in sports. And it is important to know that sport is for everyone, regardless of ability.

Heather is passionate that we all make leisure activities (whether sport-related or not) a priority in our life. "Leisure shouldn't be an afterthought, something that we only do if we can fit it in," she says. "It is very important to make time for leisure activities as they are so important for mental health and well-being."

Pathway from school to *recreation and leisure studies*

Heather believes it is important to study what you enjoy, and any subject can lead into recreation and leisure studies. "A lot of students haven't heard of recreation and leisure studies when they stumble across our classes," she says. "They come from all backgrounds – arts, engineering, healthcare, sciences – and discover that they can have an exciting career in recreation and leisure."

Studying social science subjects will help you develop research skills, including ethnographic methods, survey design, data collection and analysis, and how to write research reports.

"Look for leadership courses," advises Heather. This could be through coaching a youth sports team or volunteering with a local sports club. Volunteering in community organisations or working part-time in your local leisure centre will build valuable leadership and people skills.

Look for opportunities to take part in research studies. Participate in surveys and focus groups about sports you are interested in or contact university researchers and ask to help them with their research projects.

Explore careers in *recreation and leisure studies*

"If you have a passion for sport, you could carve out an exciting career related to it," promises Heather. "As well as academic research studying leisure activities, you could work in a local sports club, for a national sports association, or as a swimming teacher at the local recreation centre. There's a whole range of careers that are rich and rewarding."

"The great thing about recreation and leisure studies is that you can build a career around making people healthier and incorporate your own interests into this," says Heather. "I enjoy seeing people realise that sports and activities they love can become a powerful force in their life."

Learn more about the research being carried out by Heather and her colleagues in the Department of Recreation and Leisure Studies at the University of Waterloo: **uwaterloo.ca/recreation-and-leisure-studies/research/centres-groups**

Download Heather's resources from **futurumcareers.com/how-ethnography-highlighted-the-value-of-curling-for-communities**

Meet *Heather*

I grew up in a small village where we all played sports all the time. As a teenager, I was part of everything I could be part of – sports, community events, student activities, music groups. I think I just loved being involved – I was a joiner!

I have degrees in political science, political economy and rural development. I never knew about recreation and leisure as a field of study when I was younger – it took me a long time to get here! I started out studying rural tourism because I was curious about how it creates rural development. I've always been critical of a community basing its entire economic development on tourism, which is often the case in rural Canada when resource-based economies become difficult for financial or environmental reasons.

I was always interested in the theoretical side of community well-being and development. But then my PhD advisor got me involved in projects where I was out working in the community – facilitating, collaborating, doing active research. Once I saw the complexity of communities and the passion of community members, I couldn't go back to just theoretical studies! And so I started to consider what it was that I was really interested in, and I realised I was fascinated by the social aspect of curling clubs.

I'm obsessed with watching curling competitions on TV. Sadly, my husband and daughter couldn't care less about the sport! They tease me about always wanting to watch curling. Fortunately, I can say it's for my work, so they have to let me watch it!

When I'm not watching curling, I enjoy being outside – taking the dog on long walks and birdwatching. Dog walking is another fascinating area of research – I'd love to study the networks formed between dog walkers in the park!

Heather's *top tip*

Do what you love. Think about what really fires you up and imagine how it could be a bigger part of your life. Contemplate how your passion could become a path forward for you.

The relational determinants of health: an Indigenous journey to wellness

The belief that we are all intimately interconnected with the world around us and the beings that live in it is the foundational belief of many Indigenous nations around the world. For thousands of years, Indigenous Peoples of the lands and waters now known as Canada thrived and stewarded relationships with the land and its beings. However, European colonisers ruptured many of these relationships and inflicted, and continue to inflict, immense harms on Indigenous Peoples. For many years, **Shelley Cardinal** from the **Canadian Red Cross** and **Debra Pepler** from **York University** have worked alongside Indigenous communities, learning with them and co-creating resources to support them in understanding historical and ongoing violence and moving toward wellness.

Shelley Cardinal

Senior Director, Office of Indigenous Relations, Canadian Red Cross

Debra Pepler

Distinguished Research Professor of Psychology, York University, Canada

Fields of research
Cultural safety, Indigenous wellness, healthy development, psychology, violence prevention

Research project
Supporting Indigenous communities' journeys to wellness through the relational determinants of health model

Funders
Social Sciences and Humanities Research Council of Canada (SSHRC); British Columbia's Crime Reduction Research Program (CRRP)

doi: 10.33424/FUTURUM654

PROFILES

Glossary

All My Relations — A foundational Indigenous belief that refers to the interconnectedness of all things, and the obligations that flow from those relationships

Circle of wellness — the physical, mental, emotional and spiritual dimensions that, when fulfilled, restore 'All My Relations' and return Indigenous communities to a place of health and well-being

Cycle of violence — the combined impacts of the many historical and ongoing harms inflicted on Indigenous communities by colonisers, disrupting 'All My Relations'

Indigenous People — the people that inhabited a land from the earliest times, before the arrival of colonists

Relational determinants of health — the physical, mental, emotional and spiritual processes that help to restore traditional flows and 'All My Relations', supporting Indigenous communities to move from the cycle of violence to the circle of wellness

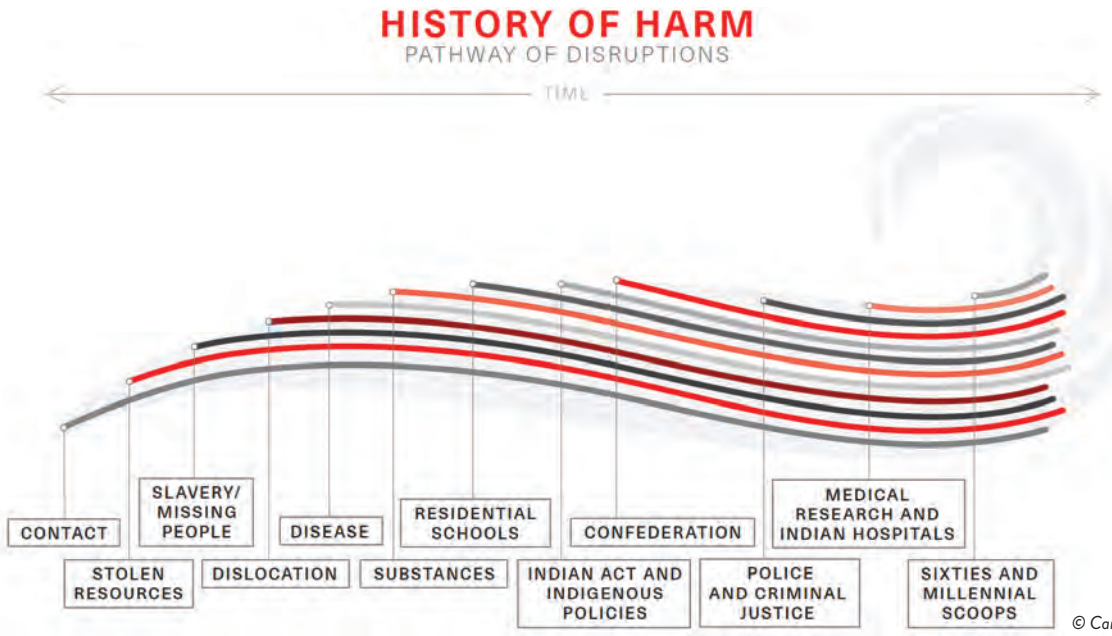
Traditional flows — Indigenous ways of being, knowing and doing

In Canada, Indigenous communities continue to overcome the past and present injustices that have disrupted their relationships with each other, the land they steward, and the plants, animals and resources they live in relationship with. By reconnecting these relationships, Indigenous communities are restoring their cultural strengths to continue thriving, in spite of the role that colonialism still plays in Indigenous communities and nations.

Shelley Cardinal from the Canadian Red Cross and Debra Pepler from York University have developed a model that aims to support Indigenous communities through their journey from the 'cycle of violence' to the 'circle of wellness'. Their 'relational determinants of health' model clarifies the physical, mental, emotional and spiritual processes that Indigenous communities can use to restore their relationships and return to a place of health and well-being.

All My Relations

North America, known as Turtle Island by many Indigenous Peoples, is home to over a thousand Indigenous nations. While each of them has its own unique



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customs and traditions, many beliefs and values are shared across cultures. "All nations share the idea of stewardship," says Shelley. "It is our responsibility to steward the land, caring for it and its beings, who help us thrive in return." This philosophy is captured by the term 'All My Relations'. "We live in relation to all beings, from the animals and water creatures to the birds that fly and the plants that grow on the land," continues Shelley. "And when they thrive, we also thrive."

'All My Relations' is at the heart of many traditional flows, a term used to describe traditional ways of being, knowing and doing. For millennia, these traditional flows defined the ways of being for Indigenous Peoples, guiding every aspect of their communities and supporting the wellness of their members. Traditional flows across Turtle Island were disrupted when Europeans began to colonise Indigenous lands, language and culture. While traditional flows emphasise connection, colonisation is a process of disconnection that ruptured the relationships that were so central to Indigenous communities' well-being.

Layers of harm

"For over 10 years, Shelley and I have been working to document the cumulative and ongoing harms of colonialism that have been inflicted on Indigenous communities over the past 500 years," says Debra. "We have identified 15 layers of harm such as theft of resources, dislocation from ancestral lands, and residential schools, where Indigenous children were forcibly taken and stripped of their culture, language and identity after being removed from their families and communities." The trauma inflicted by these harms is passed from generation to generation. "If a member of these communities has turned to addiction, it is probably because they have first-hand experience of trauma or traces of trauma in their bodies from previous generations," says Debra. "Indigenous communities have been destabilised, so to address individual challenges, we need to start by stabilising the communities - something that the Canadian Red Cross programmes support."

For decades, the Canadian Red Cross has walked with Indigenous communities through 'violence prevention' programmes to support them in creating safe environments for children and youth and addressing their trauma. "However, communities started to tell us that, 'There is a lot of information around the history of harm. We want to understand both the harms and the ways to build community wellness,' " says Shelley.

Flipping the narrative

"The communities were very clear with us that their journey to wellness must include the reintegration of 'All My Relations'," says Debra. "So, this formed the heart of our relational determinants of health model."

Our health is affected by many factors including physical determinants, such as disease and nutrition, and social determinants, such as poverty and isolation. Indigenous Peoples are also affected by Indigenous determinants of health, such as the harms inflicted by colonialism and the resultant inter-generational trauma. "While all of these factors are important, they are really Indigenous determinants of illness," says Debra. "As I understand it, Indigenous world-views tend to be strength-based, so our model flips the narrative from social and Indigenous determinants of health, which focus on harms and violence linked to illness, to the relational determinants of health, which focus on the culturally-grounded processes that sustain communities and help them thrive."

The relational determinants of health

"When developing our model, we started to look at the pathways that could support communities in moving from disruption to reconnection," says Shelley. "We thought about the relational determinants of health in relation to four dimensions of Indigenous well-being: the physical, emotional, mental and spiritual."

Within the physical aspect, reconnecting with the land is key. "When you have been moved or pushed away from your home territory, is there a way of reconnecting to it?" asks Shelley. "If not, connecting to the space that now grounds you is vitally important. Part of this process is learning about whose territory we are currently living on and how we can be a participant in stewarding that territory. We can also think about planting traditional medicine and food plants in our own gardens to form a stronger connection with the land."

The emotional aspect includes nurturing familial relationships, building confidence and self-esteem, and learning about emotional safety. "It's really all about connection," says Shelley. "If we cannot reconnect to our home territory or Nation, we need to think about how we can volunteer and provide service in our local area and support the nations that live there." These activities can help to build and maintain emotional connections with others.

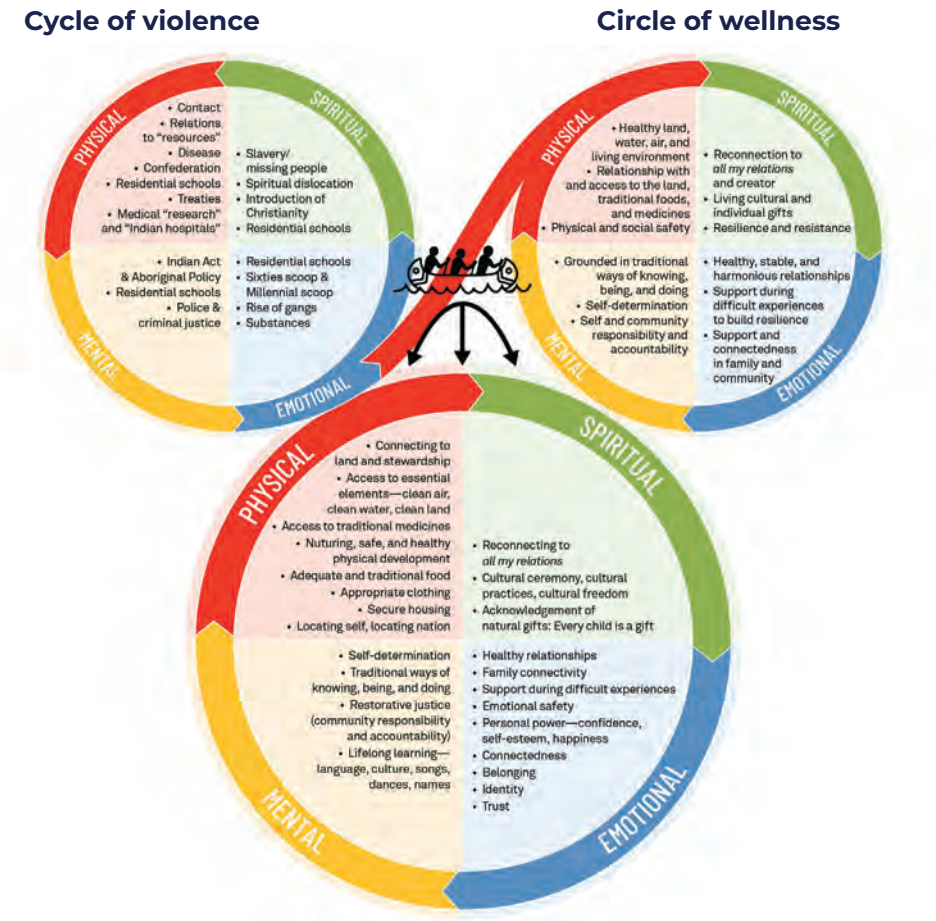
"When we think about the mental aspect, we think about things like self-determination and personal agency," continues Shelley. Self-determination plays a huge part in a community's journey to wellness. "Indigenous communities are continuously restoring their own governance structures and cultural ways of being," says Debra. "They may need support from other Indigenous nations, but nobody knows better than the community what they need to move toward wellness." The mental aspect also highlights lifelong learning of Indigenous language, culture and stories as a key step towards wellness.

The spiritual aspect focuses on restoring traditional flows and 'All My Relations', with ceremony playing a key role. "For me, connecting with other Indigenous People and participating in ceremonies, such as sweats, is very important," says Shelley. Sweats are spiritual ceremonies that take place in sweat lodges and often involve prayer and singing.

Looking to the future

Although Indigenous communities still experience violence and disconnection, the relational determinants of health can support them to reclaim their health and well-being. "Communities are really starting to focus more on the cultural aspects of their wellness," says Shelley. "It's heartening to hear communities actively talking about aspects of language, culture, land and ceremony."

"This research-practice partnership between Indigenous communities, York University and the Canadian Red Cross is strong because we've taken the time to walk alongside the communities and take direction from them," says Debra. "We've expanded our understanding and we know where we need to go in terms of promoting community wellness, and I think that is what's so exciting."



Relational determinants of health

Community Journey to Wellness.
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About *participatory research*

Participatory research involves working alongside individuals and communities and researching topics that impact them. This means that individuals and communities actively participate in the research process, collaborating with researchers and others to co-create knowledge and use this knowledge to bring about social change.

This is radically different to how research involving Indigenous Peoples has been undertaken in the past. Historically, research on Indigenous Peoples in Canada has been unethical, with researchers extracting knowledge from communities without providing any reciprocal benefit. Members of Indigenous communities were also treated as subjects rather than partners, often being harmed in the process. "University teaches you to be independent, to be the expert in the room, to be the leader, to have unique ideas," says Debra. "Participatory research teaches you to be interdependent – if you are not Indigenous, you don't lead, you walk alongside and listen." On the other hand, if you are a member of an Indigenous community, it is of great value when you assert and share your knowledge. "As Indigenous community members, you are the knowledge holders of your Nation," says Shelley.

Debra has been involved in participatory research with Indigenous communities for twenty years, in close partnership with Shelley and others. "You have to go in with humility," she says. "You have no idea what Indigenous People need or want, or what their worldview is." Shelley and Debra's work has involved being guided by members of First Nations communities, Inuit hamlets, and urban Indigenous organisations to understand how to bring about positive change. "Walking alongside and learning from Indigenous colleagues and communities has been an immense privilege," says Debra.

Critical *learnings*

Download Shelley and Debra's resources from **futurumcareers.com/the-relational-determinants-of-health-an-indigenous-journey-to-wellness**

Truth and Reconciliation

"Regardless of the work that you want to do or the career direction that you take, it's good to have an understanding of Truth and Reconciliation," says Shelley. Truth and Reconciliation refers to the process of restoring respectful relationships between Indigenous and non-Indigenous Peoples, acknowledging the harm caused by colonialism, and working towards a future where Indigenous rights are recognised and respected.

Allyship

It is important to remember that calling yourself an ally is not the same as being one. Allyship is an active process of speaking out against oppression, educating others and supporting Indigenous communities. For non-Indigenous people, it starts with listening to and learning from Indigenous communities to understand how you can best walk alongside them.

Cultural safety

Cultural safety involves creating environments in which everyone feels safe, respected and valued, no matter their cultural identity. As you move through your education and career, think about how you can help to create culturally safe spaces by addressing power imbalances, reflecting on your words and actions, and respecting other people's values and beliefs.

Ethical spaces of engagement

When Indigenous and non-Indigenous communities work together, it is important to create 'ethical space'. This involves creating a space where people with different worldviews can come together respectfully to work towards shared goals without the constraints of ingrained power imbalances and cultural assumptions.

Meet *Shelley*

When I was around 5 years old, my Kokum (grandmother in Cree) took me for a walk into the bush to collect porcupine quills. We gathered many quills that day and I learned to love the bush and what it provides us. I've also been a lifelong history buff, and I'm interested in the gifts that culture holds and the harms that have deeply impacted my family and community.

My friends often hear me say, "I love my job." I've worked for the Red Cross for over 25 years and have had the privilege of spending time in hundreds of Indigenous communities who also want to better understand the cycles of violence affecting them. As I've worked alongside communities, I've come to understand how to integrate the stories of our harms and give them space but not power. From this place, we turn and walk towards our wellness.

I'm a curious person and a good listener. As someone who grew up weaving beads, I've used the art of weaving to weave information and transform it in ways that are understandable and generate solutions that I share back to community.

Meet *Debra*

As a youth, I found every opportunity to volunteer or work in youth-serving settings. I wanted to become a physical education teacher, but then I fell in love with research. The questions that I have asked throughout my research career have always focused on the importance of children and youths' relationships at home, at school and in the community.

As a professor, I love working with students and supporting them along their own learning and career pathways. It is a joy to watch students become excited about child and youth development and acquire knowledge and sensitivities to begin a career working with children, youth and families.

I have learned so much about being relational from my Indigenous colleagues, friends, communities and students. It has really changed the way I walk in the world. In our partnership research with Indigenous communities, I have learned to talk little, listen deeply, be patient and know that the expertise lies within the communities. Shelley has been so important in my learning journey, and for that I am forever grateful. Hiy Hiy! ('Thank you' in Cree)

The future is bright

With a vision to empower young people to reach their full potential, **Let's Talk Science** is committed to preparing young people in Canada for future careers in a rapidly changing world. Founder and President **Dr Bonnie Schmidt** tells us about the charity's 30-plus years of innovative STEM programmes.

Let's Talk Science

What did Let's Talk Science set out to achieve when it was established in 1993?

We hoped to inspire and motivate students to pursue science and learn more about research. Starting as a small outreach project to connect university STEM graduate student volunteers with local high schools, we quickly learnt that many early years and elementary school teachers lacked the training and confidence to do hands-on, inquiry-based activities. We soon evolved to support early years to grade 12 educators and students, bringing more hands-on programming to the classroom.

Let's Talk Science's vision has stood the test of time and remains the same – to empower young people to reach their full potential and prepare for future work demands by offering exciting and meaningful STEM programmes. We connect schools with the world of science, technology and innovation to spark curiosity and help develop essential skills. Our programmes are designed for both students and teachers. They highlight how relevant STEM is in everyday life and serve as a starting point for exploring careers. We want to highlight the wide range of opportunities that come with a background in STEM.

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Why do you think there is a risk that Canadian youth are 'switching off' from STEM?

A lot of students lose interest in STEM classes, and there are several reasons for this. Firstly, many don't see how these subjects matter in real life. Secondly, they often don't have role models to look up to in these fields. Thirdly, students might not know about the interesting careers and paths they can take after high school if they stick with STEM. Plus, depending on how STEM classes are taught, they can seem 'dry'. The pressure to get high grades for college or university admission can also make students shy away from what they think are tougher subjects. Unfortunately, not enough students realise that finishing high school with STEM credits offers a wealth of opportunities in college, university and later life. It's important for us to highlight how essential STEM is in our daily lives, in jobs, and for tackling big issues like climate change, biodiversity loss, food security, infrastructure challenges and so much more.

Why is investing in STEM education so important for Canada's future?

STEM is critical for solving some of the most significant issues we face today, like climate change, shifting to alternative energy, and ensuring everyone has access

to clean water, food and healthcare. Plus, STEM-based learning helps develop key skills like critical thinking, problem-solving and communication, crucial for understanding and sorting through all the misleading information we see online. We need people who are curious and ready to ask questions about the world around them. STEM education helps build those skills, making people more resilient and prepared to tackle whatever challenges come their way!

How does Let's Talk Science empower young people?

The perspectives of teens and young adults inform our work, as does research by others into the key barriers to youth engagement. Conducting research to understand their vision for STEM is essential for empowering young people. These insights have helped develop our approach to career discovery and sustainability programming. For example, teens told us they want to learn about climate change in positive, action-oriented ways. As a result, our **Clothing4Climate** project does that; it culminates in youth-led projects such as clothing swaps. Our **Living Space** project engages youth in coding and has led to students working with school administration to improve schools' heating and cooling systems. **Travel4Climate** builds systems thinking and helps teens develop recommendations to improve transportation-based climate impacts in their communities.

> ***"We connect schools with the world of science, technology and innovation to spark curiosity and help develop essential skills."***

> **Over the past 30+ years, Let's Talk Science has positively impacted over 21 million people across Canada!**


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What collaborations make Let's Talk Science's work possible?

Let's Talk Science is deeply grateful to our many partnerships that support the development and delivery of programmes. For example, more than 50 post-secondary sites are part of our outreach network, mobilising thousands of volunteers to deliver free, in-person programming across Canada. We collaborate with United for Literacy, First Nations Education Administrators Association and others to support Indigenous audiences. We also work with various organisations, including the Canadian Space Agency, Genome Canada, the Royal Society of Canada, Stem Cell Network, ArcticNet and the Perimeter Institute to bring leading-edge STEM programming to life. Thanks to investments by the Government of Canada, and many companies, foundations and individuals, all programming is available at no cost to participants.

What impact has the Let's Talk Science Challenge had over the past 20 years?

Started by two of our volunteers in 2005, the Let's Talk Science Challenge recently celebrated its 20th anniversary. The challenge is a team-based competition with a STEM knowledge component and a hands-on engineering design activity. Designed for students in grades 6 to 8, teams prepare for several months using a study guide. The challenge is now a hybrid activity incorporating virtual participation and culminating in an in-person competition in select locations.

The long-term impact of this programme is becoming evident as we hear from professionals and volunteers who participated in the challenge when they were in elementary school! Many have said that this competition opened the door to STEM for them – that it was fun and empowering and introduced them to other students who were having fun doing STEM. We have always seen the positive impact of the event on students in real time, but it's especially exciting to see how that one programme has shaped so many lives.

What support does Let's Talk Science offer educators?

We offer a robust suite of in-person and online programming for early years to grade 12 youth and educators. Available in English and French, everything is free to use, thanks to our supporters. Due to networks of outreach sites and teacher leaders, we also offer national programmes that are regionally responsive. In addition to programming for youth at every grade level, we offer a micro-credentialled professional learning programme for educators. Educators can join in-person sessions, webinars, self-paced modules, communities of practice and more. The **All Programming** page on our website is a great starting point to find all types of programmes and resources. When educators subscribe to our newsletter, **Classroom Connection**, they'll get regular access to programming information in their inbox.

What resources do you provide for parents and carers?

For **families**, we offer a variety of learning experiences suitable for exploring STEM together in fun ways. Start a new adventure with our hands-on activities! We have a wide variety of STEM concepts with fun and interactive exercises requiring minimal materials. We also have a library of free eBooks to explore. Designed by educational experts with young learners in mind, our engaging eBooks foster critical thinking skills, creativity and a love for discovery.

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What achievements are you most proud of?

Over the past 30+ years, Let's Talk Science has positively impacted over 21 million people across Canada! We are particularly proud to hear stories from our post-secondary student volunteers who first encountered Let's Talk Science as elementary students and have expressed that their experiences with us shaped their attitudes and encouraged them to pursue STEM pathways. Furthermore, our staff team is amazing; we share a deep commitment to helping youth prepare for a world that is increasingly complex.

What does the future hold for Let's Talk Science?

The future is bright; our aspirational goal is to positively impact every youth in Canada each year. With an ongoing commitment to innovation, we recently released two new programmes. **Mission : Innovation** helps students in grades 7 to 10 develop innovation and entrepreneurial skills. **Tomatosphere™ Adventure** is our first Minecraft world, designed to engage grades 4 to 8 students in exploring where biology and space exploration come alive with two Canadian astronauts. Nurturing our partnerships is key to building a strong and prosperous Canada.

What does the future hold for STEM in Canada?

We are living in a time of transformation when STEM underpins almost everything. Generative artificial intelligence could be the most impactful technology of this era. People who are curious, resilient, ethical and interested in leveraging technology to tackle problems and improve lives can make significant impact. STEM education provides the tools to adapt to these changes and create a better future, and we think that's very exciting!

Make some noise: the mathematical theories behind data privacy

From shopping online to posting on social media, we generate data about ourselves all the time. To keep us safe and avoid cybercrime, it is essential our data is private. However, building efficient algorithms that maintain data privacy is challenging, especially as cybercriminals become increasingly sophisticated in their operations. **Dr Clément Canonne** is a theoretical computer scientist at **The University of Sydney** in Australia. He is researching how advanced computational techniques can best future-proof our data, while maintaining efficiency.

Dr Clément Canonne

ARC DECRA Fellow, Senior Lecturer, School of Computer Science, The University of Sydney, Australia

Fields of research
Theoretical computer science, computational learning, data privacy

Research project
Investigating fundamental trade-offs between data, computation and privacy

Funder
This work was supported by the Australian Research Council, through an ARC Discovery Early Career Researcher Award (DE230101329)

doi: 10.33424/FUTURUM644

PROFILE

Talk like a ...

theoretical computer scientist

Algorithm — in computation, the procedure – or 'step-by-step recipe' – used by a computer to solve a certain problem

Anonymous — when a person's identity is unknown

Data — information and statistics collected for analysis or reference

Data privacy — an individual's right to control how their personal information is collected and used by others

Differential privacy (DP) — a rigorous mathematical framework that helps guarantee privacy

Random noise — in data, an unpredictable variation within a dataset that does not represent meaningful information

Every time we use a computer or phone, we generate data about ourselves. As more and more applications monitor our activity and use algorithms to learn about our individual interests, lifestyle and networks, concern is growing about how this data may be used – and abused. In particular, if malicious actors get hold of this data, they could use it for any number of nefarious purposes: fraud, impersonation, blackmail, stalking – the list goes on.

This introduces the need for data privacy, especially when sensitive information is involved. If the outputs (the conclusions drawn from such information) can be used to identify individuals, then there is a big privacy issue. But guaranteeing full privacy is very difficult, especially when we consider that the hackers of the future will be using computational tricks that have not yet been invented. This is where theoretical computer science comes in – to understand the fundamental mathematics behind computation and how it can help us build systems that guarantee privacy.

Testing the theory behind data privacy

Dr Clément Canonne is a theoretical computer scientist at The University of Sydney. He studies the mathematical foundations, capabilities and limitations of computation and algorithms. "Most of my work is on pen and paper: coming up with an algorithm, or building one from several existing algorithms," he explains. "Then, I mathematically prove its properties."

Once the mathematical foundations are in place, Clément tests his algorithm's usefulness by coding it and running it using example data. "This is a good

way of testing the accuracy of the algorithm and whether it solves the required task," he says. "What is a lot more difficult, however, is testing how private it is." This is because a malicious party with a lot of time, resources and extra information could exploit the algorithm and the data it contains in ways that are difficult to predict and test.

Anonymity is not enough

At first, data privacy might seem straightforward – it simply requires us not to store any of our personal, identifying information. However, keeping data anonymous does not always prevent malicious parties linking it to specific people. "The example I like to give is a logic puzzle called Einstein's riddle," says Clément. "You are given little bits of information: there are five people, each has a pet, the Norwegian drinks coffee, the tea-drinker has a cat, and so on. Then you're asked: who owns the zebra?" Through deduction and reasoning, it is possible to work out who the zebra belongs to, even though that information is not given explicitly. Malicious parties can use similar techniques with the aid of their own algorithms that can extrapolate such conclusions from seemingly anonymous datasets.

"The key message here is that removing a piece of information doesn't prevent that information from being known," says Clément. "A lot of clues still remain, and a malicious party only needs a few pieces of information to work out your unique identity." This is important for businesses or governments that want to collect information from individuals without compromising their privacy – not to mention important for the individuals involved.

> ***"... a malicious party only needs a few pieces of information to work out your unique identity."***

Differential privacy

Fortunately, there is a mathematically rigorous way of solving this issue, known as differential privacy (DP). DP was invented by Professor Cynthia Dwork, Dr Franck McSherry, Professor Kobbi Nissim and Professor Adam D. Smith in 2006. The significance of their invention is highlighted by their receipt of the prestigious Gödel Prize for outstanding papers in theoretical computer science in 2017.

"DP involves randomising the data-processing algorithms," explains Clément. "This is achieved through the injection of some carefully calibrated 'random noise' into the calculations." This 'noise' means that, whether the data of any one individual is included or omitted, the output will stay the same or extremely similar. This is what makes the algorithm 'differentially private'.

This is important, because it means the output cannot be 'post-processed' to reveal information about an individual. "This future-proofs the output against any possible efforts using any possible methods," says Clément. "No matter how cleverly they try, even with the most powerful computer on the planet, there is no way to learn more from the differentially private output." Doing so is not just computationally impossible, but mathematically impossible.

Is DP worth it?

A common question about DP is whether the introduction of randomised data contaminates the outputs. "Sometimes people don't like the idea of DP because it implies the output isn't 100% accurate," says Clément. "But any data already has noise in the form of random errors and inaccuracies. At least DP noise is controlled, so can be accounted for by statisticians." A more credible concern is that while DP makes the output future-proof, the input data – and the algorithm that processed it – are not covered. "DP does not protect you if the server used to store the dataset is compromised, for instance," says Clément. This shows the necessity of combining DP with other technologies and concepts to fully protect the privacy of the individuals involved.

Clément is also reckoning with another tricky aspect of DP: convincing people that it is useful and trustworthy. "For many people, DP seems unnecessary or overly opaque," he says. "Yet, data breach after data breach has shown its worth." Clément is interested in further researching trust in computing and how to build it. "There's a responsibility that comes with the things we design," he says. "We need to be able to guarantee that people can trust what we do with their data, and that they maintain agency over how we use it."

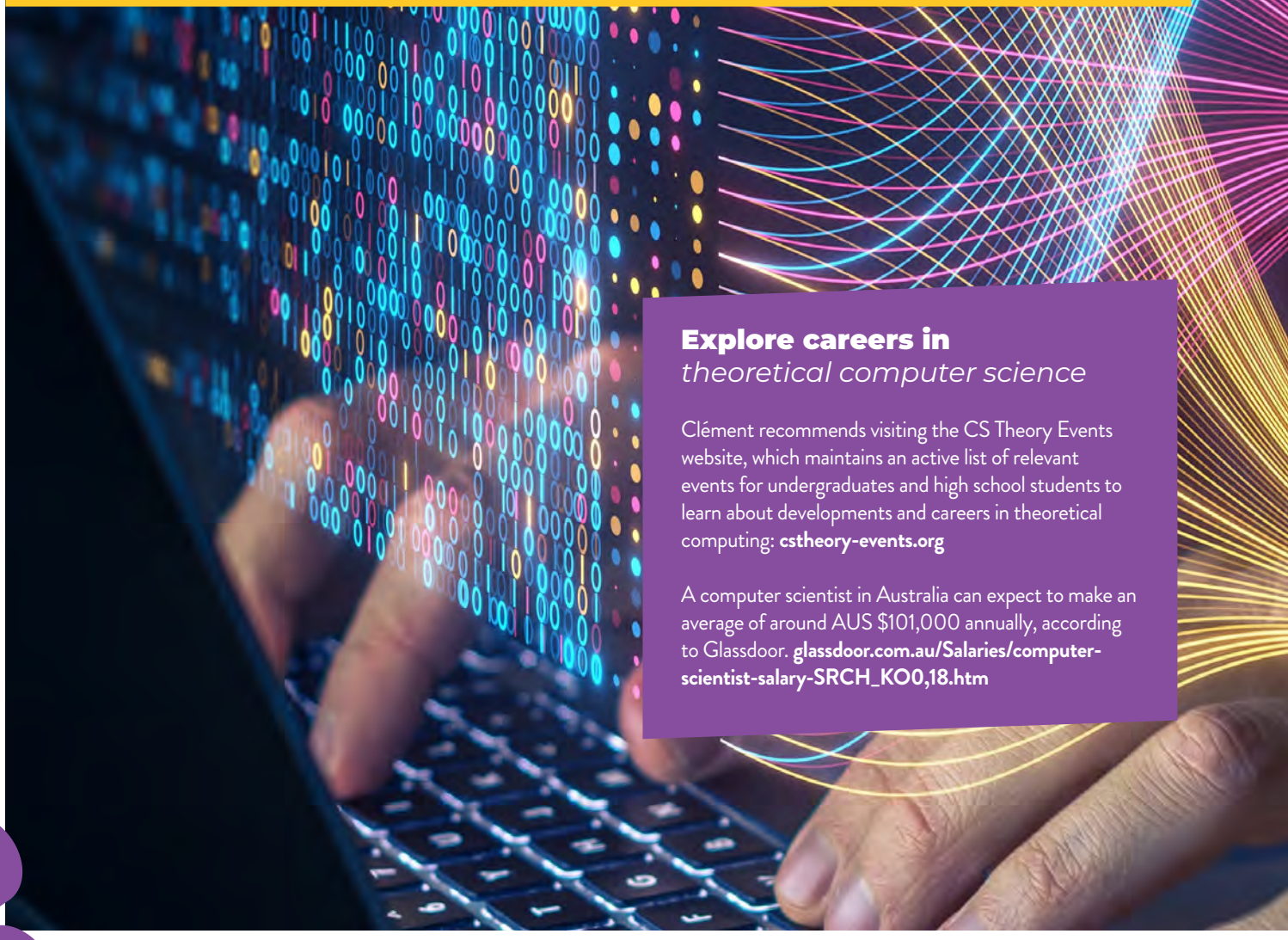
About *theoretical computer science*

Unlike applied computer science, theoretical computer science is less about coding and more about exploring the fundamental laws and limits of computation and information processing. These fundamentals are found within mathematics, which can be explored using abstract models of computation.

Much of Clément's work focuses on examining the 'cost' of meaningful privacy guarantees – for example, whether better privacy entails slower algorithms, larger datasets or less accurate models. "A typical day of research involves a mix of meetings with collaborators and PhD students to discuss ideas and suggest possible approaches, along with hours in front of a piece of paper trying to prove a concept," he says. "Staring into the void does yield some ideas, but more often, the ideas arrive while discussing things with other people. Research is truly a collaborative endeavour."

Another aspect that Clément enjoys is the freedom to choose where to focus his attention. "There is an endless supply of interesting questions, which means there is the luxury of choice of which to tackle," he explains. "We also have a lot more flexibility than, say, theoretical physicists, as we get to design the rules of the systems we study." Having a strong understanding of these rules is essential to be able to theorise about their applications. "It's important to understand how computers work and how programming languages work," says Clément. "But the crucial set of core skills is a strong scientific and mathematical background, alongside heaps of curiosity."

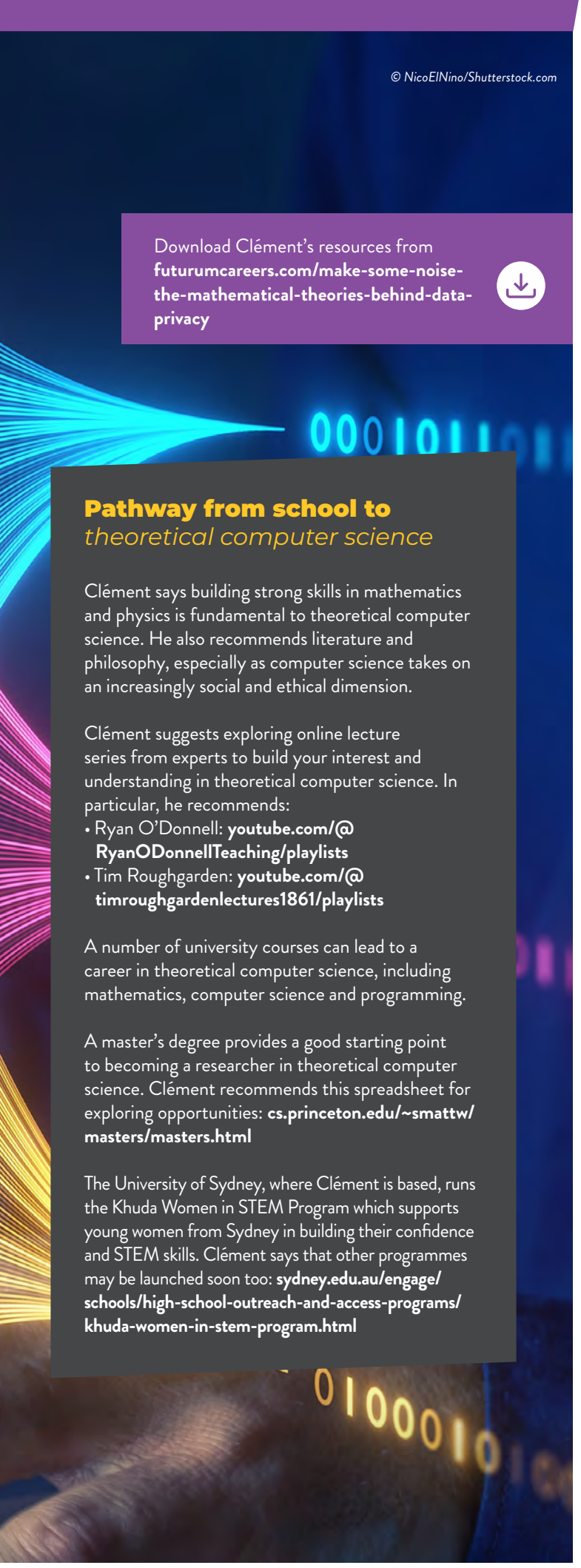
With regards to the future direction of theoretical computer science, Clément says that it is anyone's guess. "It's really hard to predict what will come next," he says. "All I am sure of is that there will be plenty of opportunities!"



Explore careers in *theoretical computer science*

Clément recommends visiting the CS Theory Events website, which maintains an active list of relevant events for undergraduates and high school students to learn about developments and careers in theoretical computing: **cstheory-events.org**

A computer scientist in Australia can expect to make an average of around AUS $101,000 annually, according to Glassdoor. **glassdoor.com.au/Salaries/computer-scientist-salary-SRCH_KO0,18.htm**



Download Clément's resources from **futurumcareers.com/make-some-noise-the-mathematical-theories-behind-data-privacy**

Pathway from school to *theoretical computer science*

Clément says building strong skills in mathematics and physics is fundamental to theoretical computer science. He also recommends literature and philosophy, especially as computer science takes on an increasingly social and ethical dimension.

Clément suggests exploring online lecture series from experts to build your interest and understanding in theoretical computer science. In particular, he recommends:

- Ryan O'Donnell: **youtube.com/@RyanODonnellTeaching/playlists**
- Tim Roughgarden: **youtube.com/@timroughgardenlectures1861/playlists**

A number of university courses can lead to a career in theoretical computer science, including mathematics, computer science and programming.

A master's degree provides a good starting point to becoming a researcher in theoretical computer science. Clément recommends this spreadsheet for exploring opportunities: **cs.princeton.edu/~smattw/masters/masters.html**

The University of Sydney, where Clément is based, runs the Khuda Women in STEM Program which supports young women from Sydney in building their confidence and STEM skills. Clément says that other programmes may be launched soon too: **sydney.edu.au/engage/schools/high-school-outreach-and-access-programs/khuda-women-in-stem-program.html**

Meet *Clément*

When I was a kid, I wanted to become an archaeologist. I guess that didn't pan out! But other interests also called me. I remember reading a fascinating book called *The Number Devil*, by Hans Magnus Enzensberger, which really captured my interest in mathematics.

My career has been shaped by two very lucky breaks. The first was during my undergraduate studies, when I got the chance to spend an exchange semester at Princeton University in the US. I decided to take a class in algorithms, taught by an amazing researcher, Professor Moses Charikar. This defined what I chose for my PhD.

My second stroke of luck was during my PhD. While trying to find a good research question to focus on, Professor Dana Ron, from Tel Aviv University, was visiting for a sabbatical. I joined her and my PhD supervisor in meetings and that's what led to my first paper – and my field of study for the rest of my career!

I'm really proud of my undergraduate students. Some of their theses have even led to peer-reviewed publications. My first PhD students will soon be graduating, and I'm already looking forward to seeing where their careers take them.

I aim to keep focusing on research that I find interesting and meaningful. More practically, I am looking forward to seeing Sydney's theoretical computer science and privacy research communities expand. This is a great place to be, with excellent people, so I see a lot of potential for growth.

Clément's *top tips*

Be curious, ask questions, and don't be ashamed to contact people. While they are always busy, most researchers also love what they do and love discussing it – so reach out to them!

Nuclear fusion: is endless energy imminent?

For a century, researchers have been wrangling with the science of nuclear fusion. If they crack it, we could have access to as much cheap, clean energy as we need – but reaching that point is proving to be a real challenge. Nevertheless, progress continues at pace and scientists such as **Dr Kurt F. Schoenberg** from **Applied Science Enterprises LLC**, USA, are optimistic that this transformational technology could become a reality within the next few decades. If it does, the story of humanity will change forever.

Dr Kurt F. Schoenberg

Applied Science Enterprises LLC, USA

PROFILE

Fields of research
Physics, high energy density physics, plasma magnetic and inertial confinement fusion energy

Research focus
Providing independent scientific evaluation and strategic guidance for fusion start-up companies and private investment, and translating advanced plasma science into clear, decision-useful assessments

Website
appliedscienceenterprises.com

Chief scientists
Dr Joseph Mack, Dr Ronald Moses, Dr Kurt F. Schoenberg

doi: 10.33424/FUTURUM646

Talk like a ... nuclear physicist

Deuterium (D) — a stable isotope of hydrogen with one proton, one neutron and mass about twice that of 'normal' hydrogen with only one proton

Isotope — a form of an element where the nucleus has the same number of protons but a different number of neutrons

Nuclear fission — the splitting of a heavy nucleus into lighter nuclei, releasing a large amount of energy

Nuclear fusion — the combining of two light nuclei to form one heavier nucleus, releasing a large amount of energy. First fusion reactors will fuse deuterium and tritium (DT)

Pinch — in plasma physics, the compression of plasma by magnetic forces

Plasma — a state of matter formed when a gas is heated to the point of ionisation, consisting of charged particles, including ions and electrons

Protonic fusion — when protons in the nucleus of hydrogen atoms are fused together to form helium atoms

Quantum tunnelling — a phenomenon of quantum mechanics where a particle can penetrate a potential energy barrier in a way that is not possible within the laws of classical mechanics, due to the particle's wave-like behaviour

Tritium (T) — a rare, radioactive isotope of hydrogen with one proton, two neutrons and mass about three times that of 'normal' hydrogen. Tritium does not occur naturally and must be 'bred' by using fusion produced neutrons interacting with lithium in a blanket surrounding the fusion reactor

Humanity's demand for energy is climbing ever higher, bringing with it a range of severe problems. Our reliance on fossil fuels is adversely impacting our climate and environment. The development of renewable energy sources is an exciting alternative, but they may not be sufficient to meet our growing energy needs. "Nuclear fusion holds great promise as a carbon-free future energy source," says Dr Kurt F. Schoenberg. "It is the highest energy density source available, and its fuel is effectively inexhaustible."

Nuclear power is nothing new; we have been generating electrical energy through nuclear fission since the 1950s. Despite generating around 9 to 10% of the world's electricity today, nuclear fission suffers from a poor public perception, mostly due to power plant accidents such as those at Chernobyl, Fukushima and Three Mile Island. But the two types of nuclear reaction are very different: nuclear fission splits heavy atoms, such as uranium, into lighter ones, while nuclear fusion combines

Download Kurt's resources from **futurumcareers.com/nuclear-fusion-is-endless-energy-imminent**

light atoms, such as deuterium, into heavier ones. There are other important differences, too, about their safety – and their feasibility.

If the Sun can do it, why can't we?

The Sun is a massive nuclear fusion reactor made of plasma, and the heat and light that reach our planet are due to the release of energy from the fusion reactions happening within its core. "Nuclear fusion requires bringing the nuclei of two atoms close enough so that they combine into one heavier atom," explains Kurt. "In the Sun, this happens all the time; protons, which are the nucleus of hydrogen atoms, are fused together through a series of nuclear reactions to form helium atoms." But this process, called protonic fusion, is very slow – the average proton in the Sun's core will wait for over a billion years before it undergoes fusion. "Stellar protonic fusion depends on immense pressures and temperatures, as well as a large reacting core volume," explains Kurt. "The Sun achieves these conditions due to its size and gravitational confinement. It is not feasible to replicate the necessary conditions for protonic fusion on Earth."

Protonic fusion is not possible for us, but that does not mean nuclear fusion is completely off the table. Instead, scientists turn to heavier isotopes of hydrogen, in particular, deuterium and tritium. 'Normal' hydrogen nuclei consist of just one proton, but deuterium isotopes also have a neutron, approximately doubling the atom's overall mass.

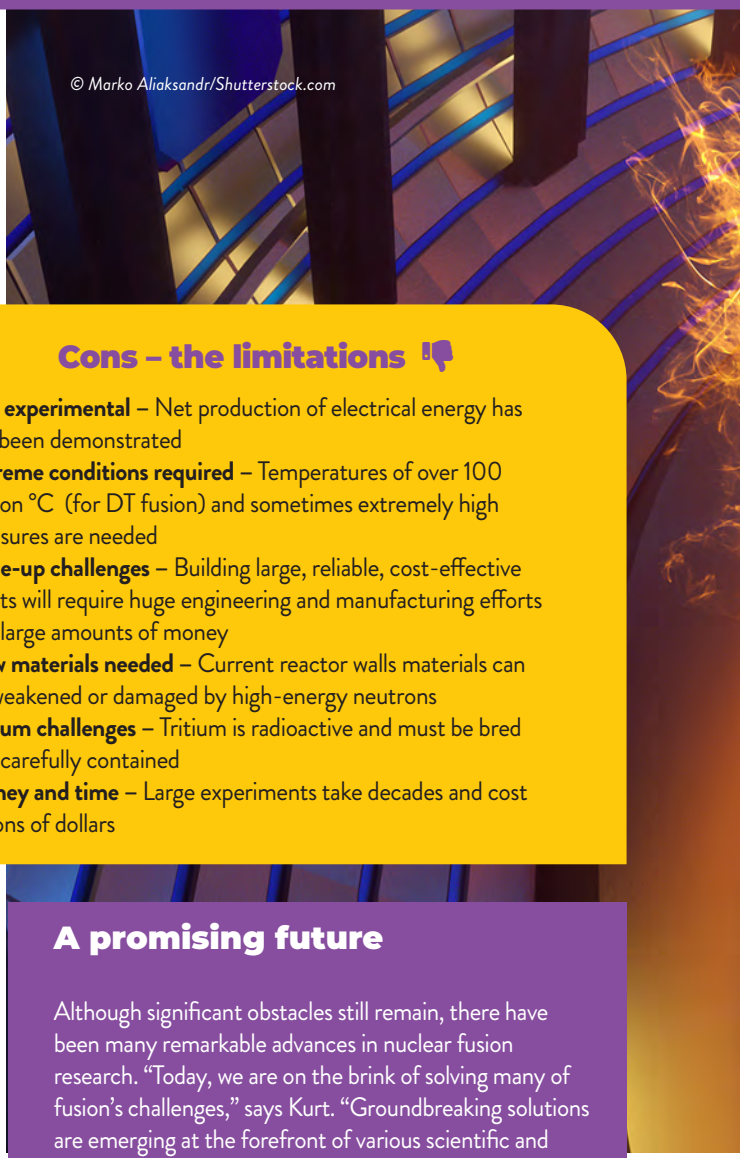
"Deuterium is stable and is found naturally in the world," explains Kurt. "0.03% of all water molecules on Earth contain at least one deuterium isotope." While this sounds like a small percentage, with the vast volume of the ocean, it amounts to a lot, and only a tiny quantity is needed to generate a lot of energy. "One litre of sea water contains the DT fusion energy equivalent of approximately 1,000 litres of gasoline," says Kurt.

A significant challenge facing the development of fusion energy is fundamental. Atomic nuclei are positively charged, due to the protons within them, which means they repel each other. "To fuse, nuclei must come close enough to overcome this repulsive electromagnetic force," says Kurt. "At this point, another fundamental force – the strong nuclear force that binds nuclei together – comes into play." It is this binding force that releases energy.

The history of fusion

Bringing nuclei close enough relies on a mechanic called quantum tunnelling, which was first proposed in the 1920s. This era saw the 'quantum revolution' of physics, when scientists discovered quantum mechanics and fundamentally changed our perception of the Universe. Some years later, in the lead-up to World War II, scientists began exploring 'pinches' – a way of using magnetic fields to compress plasma until it reaches the temperature and density required for thermonuclear fusion to occur.
The early applications of nuclear reactions had a profound impact on the world. The US Manhattan Project developed the fission bomb (or atomic bomb), which was ultimately used to bring an end to the war with Japan, and killed over 200,000 people. Shortly after World War II, the US, UK, Soviet Union and several European countries initiated controlled thermonuclear research programmes, formally establishing the worldwide pursuit of nuclear fusion as an energy source. Then, in 1958, James Tuck, a British physicist who had been part of the Manhattan Project, led a team of scientists at Los Alamos Scientific Laboratory that successfully utilised pinch technology and deuterium fuel to demonstrate thermonuclear fusion in the laboratory for the first time. This marked a significant milestone where the concept of controlled thermonuclear fusion transformed into reality.

Breakthroughs in this era led many to believe that nuclear fusion as a practical energy source was just around the corner. Unfortunately, this did not come to pass as soon as hoped. The extreme conditions necessary to achieve controlled thermonuclear fusion proved to be much more difficult to achieve than anticipated. It would take over half a century of dedicated research and development before net fusion energy gain was demonstrated by fusing deuterium with tritium. Today, producing more fusion energy than the amount required to initiate the fusion reactions remains a significant challenge for scientists and engineers, although substantial progress has been made towards closing this gap.



At a glance: *nuclear fusion's pros and cons*

Pros – the benefits

Almost limitless fuel – Deuterium is abundant in seawater
Climate friendly – No release of greenhouse gases such as carbon dioxide
No long-lived radioactive waste (actinides)– Radioactive waste is produced by neutron activation, but, unlike in nuclear fission, it decays to a safe state relatively quickly
Disaster-proof – Unlike fission, fusion is not a chain reaction, so runaway meltdown is not possible
High energy density – A small amount of fuel releases a huge amount of energy
Continuous power – Unlike many renewables, fusion could produce continuous power to energy grids

Cons – the limitations

Still experimental – Net production of electrical energy has not been demonstrated
Extreme conditions required – Temperatures of over 100 million °C (for DT fusion) and sometimes extremely high pressures are needed
Scale-up challenges – Building large, reliable, cost-effective plants will require huge engineering and manufacturing efforts and large amounts of money
New materials needed – Current reactor walls materials can be weakened or damaged by high-energy neutrons
Tritium challenges – Tritium is radioactive and must be bred and carefully contained
Money and time – Large experiments take decades and cost billions of dollars

Tackling challenges

From an outsider's perspective, it may seem that the excitement around nuclear fusion has failed to deliver significant results. Yet, behind the scenes, substantial advances continue to be made. Scientists worldwide are addressing the challenges of fusion energy head-on.

A significant challenge to overcome is creating the extreme conditions required for fusion energy to occur, and two main approaches have emerged. "Magnetic confinement fusion uses microwaves, neutral particle beams, and powerful magnetic fields to heat and confine a hot plasma, so it doesn't come into contact with the walls of its container," explains Kurt. "The plasma is so hot that it would vaporise any material it touches, leading to rapid plasma cooling." The most advanced confinement structures are typically doughnut-shaped and are known as tokamaks or stellarators.

The other leading approach is called inertial confinement fusion. This method does not rely on magnetic fields for confinement. Instead, it uses intense energy sources such as lasers to compress and heat tiny fuel pellets. "The compression and shock heating drives the pellet's core to densities and temperatures similar to those found in our Sun, which are required for reaching fusion conditions – but only for just a few billionths of a second," says Kurt.

Very recently, inertial confinement fusion yielded some fantastic results. "In 2022, scientists at the National Ignition Facility in the US achieved a milestone called ignition, which involves heating a mixture of deuterium and tritium fuel to the point where the reaction becomes self-sustaining," explains Kurt. "For the first time, they successfully ignited and burnt a mixture of deuterium-tritium fuel using intense lasers." The following year, scientists at the Joint European Torus in the UK, which uses magnetic confinement fusion, set a world record for fusion energy production, generating 69 megajoules in five seconds. "These results validate some of the underlying physics of nuclear fusion. However, significant challenges remain in making fusion energy economically competitive," says Kurt.

A promising future

Although significant obstacles still remain, there have been many remarkable advances in nuclear fusion research. "Today, we are on the brink of solving many of fusion's challenges," says Kurt. "Groundbreaking solutions are emerging at the forefront of various scientific and engineering disciplines." A remaining hurdle is proving that fusion energy production can be achieved in a system that is reliable, maintainable and economical. This goes beyond achieving fusion in the laboratory. It also involves considering all aspects of construction, operation, infrastructure and inefficiencies associated with harnessing fusion and converting it to electrical energy. "Even if the physics works, we must build affordable plants capable of operating for decades while competing economically with other energy sources," explains Kurt. "Designing and producing the materials required for power plant construction, as well as breeding tritium fuel and licensing a first-of-its-kind plant, are not trivial tasks."

Despite these challenges, the outlook is becoming increasingly positive. "Most credible but optimistic projections suggest that pilot plants will be operational in the 2030s and 2040s, with commercial reactors following in the 2050s and 2060s," says Kurt. "This timeline could be accelerated, if private innovation and government support come together, or delayed, if the physics and engineering challenges prove tougher than expected." Achieving these goals will require a significant number of highly skilled professionals, paving the way for future careers in plasma physics, nuclear and material science, and engineering. "A resurgence is underway within nuclear fusion research and development," says Kurt. "Never has there been a more promising time for engineers and scientists to join this effort."

Pathway from school to *fusion energy development*

Kurt recommends getting a strong grounding in mathematics, physics and computer science.

At university, Kurt suggests initially pursuing one of the fields below, depending on your particular interests:

Subject	Importance for fusion energy development
Physics	Understanding electrodynamics, plasma behaviour in magnetic fields, and lasers-matter interactions
Mathematics	The 'language' of physics and engineering, for modelling, designing and evaluating experiments
Chemistry	Properties of elements, isotopes, materials and reactions – including for tritium production and handling and plasma-wall/material interactions
Computer science/ programming	Simulations of fusion plasmas, experiment data acquisition and analysis. Coding skills in Python, Matlab, Mathematica and C++ are helpful
Engineering/ technology/ robotics	Mechanical and electrical design of systems and experiments. Hands-on skills in electronics, circuits, control systems, data acquisition and analysis

Following a bachelor's or master's degree in one of the above fields, you can specialise further. For instance, in plasma physics, nuclear engineering, material science or high-performance computing.

Kurt also recommends actively developing your skills and interests beyond classroom learning. He suggests focusing on improving your skills in problem-solving and critical thinking, laboratory skills, data analysis and coding, teamwork and communication, and project management. All are critical components for an impactful career within fusion energy.

Meet *Kurt*

I have had an innate curiosity about the world from a young age. As a teenager, I became interested in the US space programme, which eventually led to my passion for physics and fusion energy. I have since been inspired by numerous excellent teachers and mentors throughout my journey.

I was fortunate to study at several leading institutions for science and engineering. After earning my PhD, I joined the Los Alamos National Laboratory in the US. I have had the privilege of working alongside dedicated and inspiring colleagues.

I enjoy the opportunity to engage in a diverse range of scientific disciplines and programmes. Throughout my career, I have conducted both experimental and theoretical investigations of magnetically and inertially confined plasmas for controlled thermonuclear fusion. I have also worked with intense particle accelerators, plasma-based space propulsion systems, ballistic missile defence and high-energy-density physics.

I look forward to advancing the frontiers of high-energy-density physics and fusion energy research. Currently, I work as a consultant with the Facility for Antiproton and Heavy Ion Research in Germany, as well as with emerging fusion energy companies. Additionally, I have an interest in exploring the intersection of physics and artificial intelligence. As a guest professor at a university in Germany, I strive to inspire students to pursue careers in physics and fusion energy.

Kurt's *top tips*

1. Be curious. Always ask 'why' and 'how'. Pursue discovery with enthusiasm.
2. Build and explore things. Take apart gadgets, write code and engage with the scientific method: start with a hypothesis and follow it through exploration and discovery.
3. Strengthen your STEM fundamentals. A trained scientist does more than memorise information; they strive to understand the underlying principles.
4. Learn to communicate effectively. This includes engaging both technical and non-technical audiences. One of the most enjoyable and challenging courses I ever taught was Physics for Art Majors.
5. Follow your heart and pursue your passion. Choose a field that genuinely excites you. I still look forward to work every day because I always learn something new and interesting.

Iceberg hunting: how well can we predict the distribution of icebergs?

Ever since an iceberg sank the Titanic in 1912, scientists have been attempting to track their movements across the oceans. However, predicting the path of an iceberg is surprisingly difficult. At the **University of Manitoba** in Canada, **Dr Juliana Marson** is using numerical models to understand how icebergs move and the impact they have on ocean processes and ecosystems.

Dr Juliana Marson

Assistant Professor, Department of Environment and Geography, University of Manitoba, Canada

PROFILE

Fields of research
Physical oceanography, polar oceanography

Research project
Using numerical models to understand the trajectory and decay of icebergs and their impacts in the polar oceans

Funders
Natural Sciences and Engineering Research Council of Canada (NSERC, grant numbers RGPIN-2021-02921, DGECR-2021-00061 and ALLRP 577287-2022); University of Manitoba; Digital Research Alliance of Canada

Website
sites.google.com/view/portal-ocean/portal

doi: 10.33424/FUTURUM647

Talk like a ...

physical oceanographer

Calving — the process by which chunks of ice break off from the edge of a glacier and form icebergs

Glacier — a large, slow-moving body of ice formed from compacted layers of snow on land

Grounding — when an iceberg becomes stuck in shallow water and can no longer drift freely

Ocean circulation — the large-scale movement of seawater that distributes heat and nutrients around the globe

Numerical model — a computer simulation that uses mathematical equations to predict the behaviour of complex systems, such as the ocean and icebergs

Salinity — the concentration of dissolved salts in water

Submerged keel — the underwater portion of an iceberg that extends below the surface and interacts with ocean currents

Vertical mixing — the process by which water moves up and down in the ocean, distributing heat, nutrients and salinity

From the moment of its calving to its eventual melting, each iceberg traces its own unique journey across the oceans. As it forms, floats and melts, an iceberg can influence not only the marine ecosystems around it but also global ocean circulation and climate change.

The Arctic Circle, where many icebergs are formed, is warming faster than anywhere else on Earth. Dr Juliana Marson from the University of Manitoba is studying Arctic icebergs and how they influence the ocean around them.

What is an iceberg?

"To understand how icebergs influence the Arctic Ocean, we must first define what an iceberg is and how it differs from sea ice," says Juliana. Sea ice is simply frozen ocean water that either melts and refreezes each year, or survives for many years and becomes thick and ridged, which is why broken pieces of sea ice are easily confused with icebergs. Because it forms from salty seawater, sea ice releases slightly salty water when it melts.

On the other hand, icebergs come from glaciers — slow-moving rivers of compressed snow and ice that flow downhill to the sea. When glaciers reach the ocean, chunks of ice break off, creating icebergs in a process known as calving. Unlike sea ice, icebergs are made of compacted snow, so they release fresh water when they melt.

A tabular iceberg drifting within the Antarctic Coastal Current. © Juliana M. Marson

This difference in salinity is crucial. Together with temperature, salinity controls the density of seawater, which drives ocean circulation. Fresh water from melting icebergs can disrupt vertical mixing in the ocean, which in turn affects the supply of nutrients to marine life and can even weaken large-scale currents that transport heat around the planet. Therefore, understanding how icebergs move and melt is key to predicting how a warming Arctic could reshape global climate patterns.

Why is it important to track icebergs?

"Besides their importance for the climate and marine productivity, icebergs also pose a considerable threat to navigation and other offshore activities," says Juliana. "In 1912, after the Titanic was sunk by an iceberg, the International Ice Patrol was established to monitor the presence of icebergs in the North Atlantic Ocean, dramatically reducing the number of ship-iceberg collisions."

However, icebergs are still difficult to track. While scientists know the general routes that icebergs might follow, the details of their movements remain unclear. This is why numerical models are vital – they help researchers predict how icebergs travel and behave in different environments.

How to track an iceberg

To predict how icebergs drift, Juliana uses numerical models – the same kind of computer simulations used for weather forecasts. These models solve complex equations that describe how the ocean and atmosphere behave. "Ocean models 'predict' what the temperature, salinity, surface height and speed of seawater will be at a future time," explains Juliana. "The model that I use focuses on the polar regions, so it also includes equations that describe how sea ice forms, melts and moves."

Icebergs are influenced by many forces: the tilt of the ocean surface, the Earth's rotation, winds, currents, sea ice and even waves. Although models provide all this information, predicting the exact path of a single iceberg is nearly impossible. Models cannot capture every detail, such as the exact shape of an iceberg, which affects how it interacts with wind and water. They can also miss small variations in ocean circulation that, over time, can cause an iceberg to drift in an unexpected direction. Still, models are powerful for identifying overall patterns, common pathways and melting zones, which are vital for understanding the bigger picture.

How does Juliana collect data for her models?

"We collect data by placing tracking beacons on large icebergs to follow their path, by recording the size and shape of icebergs with drones and autonomous underwater vehicles, and by measuring the properties of the ocean around icebergs using different sensors that can be deployed from a boat or from autonomous vehicles," explains Juliana. "As you can imagine, collecting these data is a dangerous business: if you are on top of or close to an iceberg, you better hope it doesn't flip over! Icebergs can be quite unstable and can roll suddenly as they break and melt." Because of this, scientists also use satellite imagery and laboratory experiments to improve their models.

What has Juliana discovered?

Juliana's models show that iceberg movement is influenced not just by winds and surface currents, but also by deeper ocean currents acting on their submerged keels. She has also traced the origins of icebergs in the Labrador Sea – one of the areas in which the dense waters that drive global ocean circulation are formed – and found that 60% of these icebergs come from Greenland's southeast coast. While iceberg melt is not currently affecting this circulation, rising calving rates in Greenland could change that in the future.

The models also reveal that iceberg meltwater spreads differently from glacial meltwater, and the location of freshwater release can influence large-scale ocean currents. Icebergs trapped in thick sea ice behave differently too: they cannot move independently, so instead they drift with the surrounding ice pack.

What does the future hold?

Juliana is now using her models to answer several unanswered questions about Arctic icebergs. She wants to map the main trajectories of Greenland icebergs in more detail, including variations not yet reported in scientific literature. She is also investigating how tides influence iceberg paths and what happens when icebergs become grounded in shallow areas and how this affects sea ice and ocean circulation in the subpolar North Atlantic Ocean. By exploring these questions, her research aims to improve our understanding of iceberg behaviour and their wider impact on the Arctic Ocean and global climate.

About *physical oceanography*

Physical oceanography is the branch of ocean science that studies the physical properties and processes of the ocean, including currents, waves, tides, temperature, salinity, ice and interactions with the atmosphere. Because the oceans cover over 70% of Earth's surface, they play a fundamental role in regulating the climate, storing heat and transporting energy around the globe. "Understanding how the oceans work and interact with their surroundings helps us to understand our climate and how it will change in the future," says Juliana. "Working in this field is rewarding because you get to discover new things and contribute to understanding climate change."

There are also challenges that come with a career in physical oceanography. "For example, you might not enjoy being on research boats if your stomach is not very strong!" says Juliana. "However, there are many ways to contribute to the field that don't require fieldwork." Numerical models, for example, allow scientists to explore the ocean from the safety of dry land. For those passionate about the subject, the challenges are outweighed by the rewards: contributing to climate science, answering questions no one has asked before and gaining a unique perspective on how our planet works.

The polar oceans, in particular, are mysterious and highly sensitive to climate change, where even small shifts can affect sea level, weather and ecosystems. "And who doesn't love an iceberg?" asks Juliana. "To me, they are majestic creatures that have a life just like ours: they are born and stick around home for a while; then, if they find the opportunity, they brave the open ocean alone, where they will sometimes get stuck, sometimes move in loops, and sometimes drift freely while transforming themselves according to the environment they are in."

Pathway from school to *physical oceanography*

At school, focus on mathematics and physics – these are the foundations of physical oceanography.

"Once you are in college, get a good grip on calculus and any course on climate," advises Juliana. "Physical geography and atmospheric sciences are good options if your university does not have an oceanography programme."

"Computer programming skills are very important, not only for oceanography, but for any science-based career where you need data analysis," says Juliana.

"With a world of information at our fingertips nowadays, all you need to do is ask questions," says Juliana. "The web is full of helpful resources for you to explore the area of physical oceanography."

Explore careers in *physical oceanography*

If you are interested in exploring careers in physical oceanography, some useful websites include the Canadian Meteorological and Oceanographic Society (**cmos.ca**), the International Association for the Physical Sciences of the Ocean (**iapso-ocean.org**), the American Geophysical Union (**agu.org**), The Oceanography Society (**tos.org**) and the European Geosciences Union (**egu.eu**) which all offer interesting talks and career guidance.

The University of Manitoba hosts an Arctic Science Day in partnership with FortWhyte Alive, an annual outreach event where scientists share their Arctic research with students and teachers through engaging talks, demonstrations and hands-on experiments: **fortwhyte.org/arctic-science-day-2025**

"Physical oceanographers can become academic researchers, work for government agencies, or work in industries such as shipping, offshore exploration and port management," says Juliana.

Scientists and crew aboard the research vessel Ary Rongel (H44, Brazilian Navy) preparing instruments for the next oceanographic station in Bransfield Strait, Antarctica. © Juliana M. Marson

Download Juliana's resources from **futurumcareers.com/iceberg-hunting-how-well-can-we-predict-the-distribution-of-icebergs**

Meet *Juliana*

To be honest, as a teenager, I was a bit of a nerd! I used to spend recess reading books about marine invertebrates. But I never felt 'shame' about this – it was just who I was, and thankfully my friends and teachers were always supportive of my dreams of becoming an ocean scientist. And let me tell you, being a nerd pays off. Today I have the job of my dreams. So, keep on being weird, fellow nerds!

Moving from Brazil to Canada was a steep learning curve. From the completely different climate to the striking cultural shifts, I had to adapt to things I'd never thought of. For example, I had to learn how to walk on ice. During my first winter in Edmonton, I slipped on ice and broke my elbow so badly that I needed surgery. I also learnt to follow Canadian social norms: parties have a time to end, you say 'hi' without touching the other person, you don't need electrified fences and huge gates around your house, and you accept that a sandwich is also considered food!

I love learning new things. I used to say I wanted to be a 'professional student', which is exactly what a scientist is. We need to read a lot and ask endless questions. Having said that, I also love teaching. I like meeting new students and showing them how amazing our planet is! I love seeing their expressions when they discover something new. Knowledge leads to better decisions, and better decisions lead to a better planet!

Persistence has helped me become a successful physical oceanographer. I just can't let go of things once I am determined to find an answer. Organisation is also very helpful, along with dedication.

To unwind from work, I like to run long distances. It's the time I have to be with myself and my thoughts. I also love being with my kids, and cooking for them. I love reading, being outside in nature, taking pictures, and occasionally drawing and painting.

Juliana's *top tips*

1. Aim to be the best version of yourself. If you think your best isn't enough, be open to learning new things.
2. Dedicate your time to things you consider important and forget about things that don't add joy to your days.
3. Trust your math teacher when they say, "You are going to use this at some point in your life."

Walking against climate change

Many people feel powerless in the fight against climate change. To combat this, **Dr Sheena Wilson**, from the **University of Alberta** in Canada, and **Dr Rachel Epp Buller**, from **Bethel College** in the US, have developed the 'Walking the Talk' project. By encouraging people to go on regular walks in their local area, Rachel and Sheena are helping them to attune to their environment and feel more empowered to create change in their community.

Dr Sheena Wilson

Professor of Media, Communications and Cultural Studies, University of Alberta, Canada

Fields of research
Energy-related humanities, climate justice

Website
sheenawilson.ca

Dr Rachel Epp Buller

Professor of Visual Arts and Design, Bethel College, Kansas, USA

Fields of research
Visual art, art history

Website
balance.dddtr.net

Research project
Empowering people to take climate action by connecting with their environment through walking and listening

Funders
Social Sciences and Humanities Research Council of Canada (SSHRC); New Frontiers in Research Fund (NFRF)-International; Kule Institute for Advances Study (KIAS); Lena Waltner Endowment; Milford Greer Endowment

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PROFILES

Talk like a ...

climate justice advocate

Attunement — the state of noticing, observing, caring for, paying attention to and building a relationship with something

Climate action — any effort taken to combat climate change and its impacts

Climate injustice — the unequal impacts of climate change on marginalised and vulnerable groups

Climate resilience — the ability to adapt to climate change

Extractivist worldview — the idea that profit can be extracted from people and the planet

Many people who care about the planet feel unconvinced that they can do anything to meaningfully help in the fight against climate change. "The global climate crisis is too big for most people to feel like they can make a difference," says Dr Rachel Epp Buller, an artist interested in care and connection. "But they can."

When Rachel moved to Edmonton in Canada, she met Dr Sheena Wilson, an energy humanities researcher who focuses on climate justice and planetary health. "We initially didn't think our work aligned, as I'm an artist while Sheena has worked on an equitable response to energy transition and climate adaptations," says Rachel. "But the more we talked, the more we realised we could combine our expertise to create an interdisciplinary project that would achieve more than we could do on our own. The important thing we have in common is our belief that connecting with the place you're living can help repair the broken relationships that underpin a lot of the problems in the world."

Rachel went on daily walks to get to know her new local area, and she started to notice how walking led to her feeling more aware of her local environment and community. "So, Sheena and I decided to start a project that uses walking to help people connect with their 'place' and

As part of Walking the Talk, Dr Dwayne Donald led a 'decolonisation walk' for city employees in the Edmonton River Valley. © Malou Brouwer

to think about that as a climate action in itself," Rachel explains.

How can walking address the climate crisis?

Rachel and Sheena set up 'Walking the Talk' to encourage people to connect with nature by going on regular walks. "We want people to become attuned to the ecosystem around them," says Sheena. "Once you are aware of something, you care more about it. And once you care, you take action to preserve and protect it."

The idea is that regular walking helps develop connections, and these connections encourage people to make small, local changes. These walks help people to notice things such as the sounds of their neighbourhood, local plants, effects of weather events and seasonal changes. As well as creating connections with nature, walking regularly builds relationships with people, too. A regular walker might get to know people they pass every day, such as dog walkers. "Connecting with your community in this embodied way is important for building climate resilience," says Sheena.

Walking to restore

Another idea underpinning 'Walking the Talk' is that humanity's relationship with the planet is destructive, and changing this relationship is key to tackling the climate crisis. "Many climate injustices are due to the extractivist worldview, where resources are taken from the Earth and people for profit," says Sheena. "In order to heal the world, we need to rebuild relationships and create mutual respect between all communities and between us and the planet."

Who is walking?

While the project idea was born in Edmonton, Rachel has now taken it to Kansas in the US, where she promotes walking for students and community members. "I give my students a weekly assignment to repeatedly walk on a chosen route, using different prompts each time to encourage them to pay attention to different things," says Rachel. "I also encourage retired community members, who lead their own walks, to share knowledge with each other about how the environment has changed over the time they've lived in the area." Rachel invites artists and researchers to share their perspectives of walking with the students and community members. "For example, a biologist who studies box turtles talked about how he has to walk at the turtle's pace to observe them."

Back in Edmonton, Sheena is organising walks for city employees. "We had a retired city planner lead one walk, who talked about the nature-based solutions he had implemented as a city employee," says Sheena. "We've also had sound artists encourage participants to listen to bird songs and traffic noise pollution, and Indigenous Elders have shared knowledge about plants and the land." Everyone has a new perspective to share, and many people have volunteered to lead a walk.

Walking towards the future

While the overall goal of the project is to inspire and empower more people to engage in climate action, Rachel and Sheena have specific goals for the different populations they walk with, and they have already started to notice positive changes.

For the undergraduate students, Rachel hopes the walks inspire them to make small and subtle changes as they connect the impacts of their actions to their local area. "Many students who previously drove across campus have started to walk more as a form of transport," she notes. Additionally, many students have reported an improvement in their well-being, as the walks have given them allocated time in nature away from their screens.

For the city employees, Sheena's project goals are more work-related. "As they are making actionable decisions about the future of Edmonton, we hope they will connect their work decisions to climate change and make different choices for that reason," she says. Sheena is pleased to see just how many participants have been empowered to lead a walk themselves when they realise how much knowledge they can contribute.

Sheena and Rachel have big hopes for the future of 'Walking the Talk'. "People often worry that small actions don't make a difference," says Sheena. "But by walking with other people and realising that everyone is trying to figure out how to make a difference, we hope people will realise that when lots of people make small changes, it all adds up."

Darunrat Wongsuvan/Shutterstock.com

About *climate justice*

Climate justice is an interdisciplinary concept that connects the climate crisis to the social, racial, political and environmental context that it exists within. While climate change is often thought of as an environmental issue, climate justice considers how the crisis is also a human rights issue, as it is intricately linked to ideas around wealth, capitalism and colonialism. "Climate justice means striving for planetary and community health, healing and well-being," says Sheena. "It's about remaking how we live in and interact with the world. The extractivist worldview that drives 'business-as-usual' needs to change.

Currently, some elites extract value from other people's labour, lands and communities for profit, rather than for the well-being of everyone. This is a climate injustice. Climate justice starts by making decisions for the well-being of people in our local communities which will lead to planetary health."

Working in climate justice can come in a variety of forms, and Rachel and Sheena have each come into this work from very different backgrounds. While Rachel is a visual artist looking at care and human connection, Sheena is a humanities researcher interested in sustainability and human rights.

"I always tell my students it doesn't matter what you're passionate about – figure out how it links to climate change and climate justice. Because everything does," says Sheena. "In our walks in Edmonton with city employees, we have urban planners, engineers, hydrologists (who study the movement of water), artists and legal experts coming along. Everyone brings knowledge that can help to address climate injustice."

Pathway from school to *climate justice*

To learn more about climate justice, take environmental and sustainability-focused courses that relate to the career path you are interested in. "For example, you could study resource economics, environmental sustainability, energy humanities or sustainable architecture," says Sheena.

"Don't be afraid to study in more than one area," says Rachel. "The world needs well-rounded critical thinkers who can work across disciplines."

Sheena also recommends studying philosophy. "Philosophy is useful for understanding the logics people use when they think or talk about climate change (or try to deny it)," she says.

"Read widely," advises Sheena. "Connect your chosen discipline to the social, economic and political histories of human and ecological rights that explain how we got to our current crisis. And be open to what experts from other disciplines, knowledge systems and cultures have to teach you."

A great way to learn about climate justice is to get involved with a climate or environmental club. Look for local community groups taking action on climate, especially youth-led groups. "Young people have a lot more power than they sometimes realise," says Sheena.

Explore careers in *climate justice*

"I believe that everyone should have an understanding of climate justice issues," says Sheena. "We are all living through a time of global crises and climate change is one of them. It doesn't matter what career you choose to pursue; you need to be able to link your job to climate change."

You can get involved with climate justice in small or big ways, from signing a petition to protect nature or joining a local environmental group, to tailoring your career to help populations who are adversely affected by climate change.

Climate justice needs people from all backgrounds. For example, you could work as an engineer developing systems to decrease pollution or manage rising sea-levels, or as an artist helping people to emotionally connect to the environment and take climate action.

Download Sheena and Rachel's resources from **futurumcareers.com/walking-against-climate-change**

Meet *Sheena*

I came to climate justice through studying human rights. I'm from northern Alberta, where there are significant issues related to the oil sands and the extractivist way in which they are exploited for profit. It's a human rights issue because lands belonging to Indigenous nations and settler farmers were being destroyed to extract the oil underneath and whole families and communities were being displaced.

Many of my community members and loved ones have worked in the oil industry. Some still do. Early on, I already felt it was unfair how they were represented and targeted by the media. We are all implicated in the oil-industrial complex, so nobody gets to be self-righteous about it. Fossil fuels are deeply embedded in every aspect of society and modern life. We are hypocrites if we target individuals whose livelihoods depend on the oil industry. I felt like it was important to add my voice to the conversation about addressing the human rights and environmental issues of oil sands extraction because I was doing it with love and respect for the people who have found themselves working in this industry to support their families.

I use creative practices to share my research. Stories are a great way to share information as they are the oldest form of knowledge transmission in all cultures. I collaboratively made a documentary film about water extraction from the lakes in Bigstone Cree Nation, and I wrote a story about my son suffering an asthma attack while living in an oil refinery community, which was then turned into a short film called *Petro-Mama*.

Maintaining relationships and joy is the most important act of resistance in the face of crises such as the climate crisis. Relationships and the small joys of life build and sustain our resilience. Therefore, my research and work are relational.

I live near the Edmonton River Valley, which is the largest urban park in North America, and I love walking there, seeing the plants and listening to the sounds. I'm also a keen gardener and I have loads of plants growing in my small yard. Like walking and being in community, getting your hands in the dirt has physical and mental health benefits.

Meet *Rachel*

When I was younger, I had diverse interests: making art, playing piano, studying science and writing. I thought I would go to medical school but once I got to university, I found that the arts and humanities were a greater passion for me. That background, though, is maybe why I've pursued cross-disciplinary collaborations. There is so much we can learn from each other's disciplines and ways of doing research.

My professors who were passionate about their subject were a big influence on my career path. Those professors made me want to take more courses in their areas, which is how I ended up with three separate undergraduate majors: studio art, history, and German.

While I am trained as a feminist art historian and a print maker, over time I've begun working with a much wider range of materials in a desire to communicate fundamental ideas of care and connection. I'm interested in creating opportunities for connection and bringing attention to the often-invisible labour of relational care.

I believe that listening happens not just with our ears but with our whole bodies – I often use walking as a form of listening. I also explore methods of listening through patterns and traditions of making that we hold in our hands. I am interested in the ways that certain knowledges, such as knitting or stitching or string games, are shared between bodies and often between generations. With these knowledges, speaking and listening with our hands can succeed where words might fail.

While walking in a new place can feel like an adventure, my favourite places to walk are the paths that I have walked many, many times in the places where I have lived. In Kansas, there is a creek that runs near my house, and I walk the path alongside it several times a week. I have walked it so many times that I can walk it in the dark because I know where it rises and falls and where it curves along the water.

The class issue: examining economic and social inequality across Canada

Canada's growing wealth inequality is a cause for great concern for the country. There are questions about whether this inequality is related to class – and, just as fundamentally, if class is a term that remains relevant today. To help answer these questions, **Dr Michelle Maroto, Dr Zohreh BayatRizi** and **Dr Guillaume Durou**, from the **University of Alberta**, are leading the Great Canadian Class Study, a large-scale project using surveys, interviews and other tools to understand the links between economic, social and cultural factors within Canada's diverse population.

Dr Michelle Maroto

Dr Zohreh BayatRizi

Department of Sociology, University of Alberta, Canada

Dr Guillaume Durou

Department of Sociology, Faculté Saint-Jean, University of Alberta, Canada

Field of research
Sociology

Research project
The Great Canadian Class Study (GCCS): studying economic inequality and class in Canada through a large-scale, mixed-methods project

Funders
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PROFILES

Talk like a ...

sociologist

Class — the division of people based on perceived social and economic status

Demographics — statistical characteristics of human populations, such as age or gender

Gig economy — a labour market characterised by short-term contracts and freelance work, as opposed to permanent and stable employment

Income — money received regularly through work or investments

Shareholder — someone who holds shares of a company (portions of a company's capital), entitling them to a proportion of the profits

Wealth — financial and physical assets (such as property), minus debt

Canada's wealth gap – the difference in wealth between the country's richest and poorest – is growing fast. "In 2025, the richest 20% of households held about 65% of Canada's total wealth," says Dr Michelle Maroto. "The same trend is true for income." This is bad news at the national level, because it means a growing number of people are facing economic insecurity. "Many Canadians are only just getting by," says Dr Guillaume Dorou. "Any adverse event, such as losing their job or facing a health issue, would leave them struggling to pay their monthly bills."

It is very possible that these trends are interlinked with class, but class is very difficult to define these days, which is why Michelle, Guillaume and their colleague Dr Zohreh BayatRizi, all from the University of Alberta, decided to launch the Great Canadian Class Study (GCCS). The study aims to understand if class still matters, whether it is linked to income and wealth or other factors, and what it means for societal trends and the future of Canada.

Understanding class

Most commonly, class is thought of in terms of 'economic capital' – the income and wealth you have connected with your profession and ownership of property or other assets. "Some sociologists go beyond this definition to also include 'social capital' – your social network, which clubs and organisations you belong to, your family background, and so on," says

Zohreh. "They might also include 'cultural capital' , which includes your education level, lifestyle, accent, and tastes in music or art." Taken together, these factors can define you in relation to other people and your place in society.

The concept of class is nothing new, but it was crystallised during the Industrial Revolution, which took place from the late 18th to early 20th centuries and saw rapid advancements in technology and mass industry. "A clear distinction arose between the people who worked in factories and the people who owned those factories – and between those people and farmers or small business owners," explains Zohreh. "But today, the picture is more complicated." Growing economic complexity, job diversity and complicated ownership models have complicated definitions of class. For example, concepts such as the gig economy and shareholding make the distinction between owners and workers less clear.

Moreover, the idea of defining people as belonging to the lower class, middle class or upper class is very much out of fashion and has connotations that many find unfair and prejudicial. The idea carries implicit assumptions that inequality is embedded into society and that people cannot (or should not) move between classes. Yet, whether or not we acknowledge it, it is still very possible that class continues to be a strong force within society. "We want to find out if class is now irrelevant – or, if it's taken on a different definition," says Michelle.

The Great Canadian Class Study

The GCCS is investigating definitions of class and aiming to understand what factors determine a person's class, what people think about their position in society, and whether this influences how they vote or make other important decisions. Answering so many questions involves gathering a lot of different types of data. "First, we examined historical sources to see how 'class' has been used and defined in the past," says Michelle. "Then, we sent an online survey to a representative sample of over 8,000 Canadians." The questions in the survey covered general demographic factors such as occupation, income and education, as well as questions about whether respondents knew any people with certain other occupations, and what kinds of cars or houses they preferred to have. "We then followed up with about 200 people from the survey for a more in-depth online interview," says Guillaume. "This enabled us to get responses that are often hard to get through a multiple-choice questionnaire."

Once the data were collected, analysis commenced. "We looked at the relationships between measures for social, cultural and economic capital," explains Zohreh. For instance, the team found that higher-educated people tended to prefer urban living, indie, folk or classical music, and visiting art galleries. Less-educated people tended to prefer rural living, watching sports on TV, and driving pick-up trucks. "There were links with income too," says Michelle. "Members of higher-income groups have more social ties and are more involved in community and hobby groups. Members of lower-income groups, on the other hand, have limited social ties and less money to spend on extra activities."

The team also wanted to understand how these trends might be changing through generations – if and to what extent people are following different paths to their parents. "There is a lot of intergenerational mobility for certain factors, especially among occupation," says Guillaume. "Yet, factors like social class identity show very little intergenerational mobility." This indicates that while people might get different types of, and potentially better paid, jobs than their parents, they mostly continue identifying with the social group within which they were raised.

What's next?

The study's results are still being processed – the big datasets mean that many further interesting relationships remain to be fully examined. "We still have a lot of data to analyse, and we will seek academic feedback on our work," says Michelle. "Eventually, we plan to write a non-academic book based on our findings, which we hope will engage with a wide audience."

In particular, the team's research will uncover important information about how society is changing and is projected to change. "Recent years have seen a big rise in populist politicians and parties who specially appeal to 'ordinary' people," says Zohreh. "Is this trend related to class issues? What is the relationship between inequality, social class identity and political affiliation?" Uncovering these relationships could help societies better support people across different economic and social classes, potentially helping to de-escalate political tensions and aid societal stability.

About *sociology*

Sociology is the study of how society works, its development, structure and trends. It involves investigating cultural norms and practices, how and why we interact with each other in certain ways, and what drives social change. "Sociology is a wide-open field," says Zohreh. "You can find something that interests you and channel your research in that direction."

Sociology includes areas of study that endure over decades and new areas of study that arise to follow societal trends. "Enduring topics cover social questions around class and inequalities, health and crime," says Guillaume. "Emerging topics cover social questions around technology, media, food, and so on." In particular, an emerging field is 'digital humanities', which aims to understand how our social relationships and concepts are changing as they are increasingly influenced by technology. "New areas of study arise regularly," says Zohreh. "Even if the area you want to study doesn't exist yet, it can be created."

Sociology has plenty of applications in the real world, too. Societal trends and values change over time and understanding why and how these changes occur is important for governance and policy. "Sociology can help people understand their own circumstances and help policymakers understand the consequences of their actions," explains Michelle. "In this way, sociology can effectively contribute to positive change."

Download the team's resources from **futurumcareers.com/the-class-issue-examining-economic-and-social-inequality-across-canada**

Pathway from school to *sociology*

Subjects such as social studies, history, languages, literature and music all relate to our social relationship with the world, while a grounding in statistics and coding is useful for data analysis.

The University of Alberta, where the Great Canadian Class Study is based, has an annual fair, including a sociology table, open to high school students. The University also runs various programmes for high school students: **ualberta.ca/en/current-students/undergraduate-research-initiative/opportunities-for-high-school-students/index.html**

At university, courses or modules in sociology, social sciences, social psychology, anthropology, economics, law, history and politics can all lead to a career in sociology.

Explore careers in *sociology*

Many countries have a national sociology association, with a website that will offer information, resources and opportunities to gain experience. For instance, Canada has The Canadian Sociological Association: **csa-scs.ca**

Zohreh, Michelle and Guillaume recommend reading sociology journals and visiting libraries – including university libraries, which are often open to the public – to find introductory sociology books to learn more. Visit the online Sociology journal: **journals.sagepub.com/home/soc**

Meet *Michelle*

As a teenager, I felt the only two university options were law and medicine. I didn't want to deal with blood or injuries, so I started on the track to be a lawyer, but it didn't captivate me. Then, I took an Introduction to Sociology course. I was hooked, changed my major to sociology, and the rest is history.

I've had so many mentors and supporters along the way. For instance, I worked as an undergraduate research assistant for a professor who encouraged me to go to graduate school. People like that professor have helped shape who I am and what I do.

Research is about sharing knowledge and engaging in conversation about it. And not just among academics – among all of society. If we want our work to matter and create social change, it needs to be accessible to a range of different audiences.

When I'm stuck on a problem, I go for a run. For me, running outdoors is the perfect way to ponder a challenge and overcome it.

My achievements have been mostly 'steps' rather than big moments. Each conference presentation, paper and article is an achievement. Each student who I can help with a topic they are struggling with is an achievement.

There are always so many projects that I want to work on. Right now, I'm working with a team to develop the Transforming Research for Social Impact Hub, which will promote community-engaged and socially-responsive research.

Michelle's *top tip*

Ask questions, and learn how different research methods can lead to the answers.

Meet *Zohreh*

During my childhood, Iran's political circumstances greatly influenced my way of thinking. The fallout of the Islamic Revolution brought about civil unrest and very strict rules for citizens. As a teenager, I grew sceptical of the imposed ideology. Sociology attracted me as it offered many different lenses for viewing society, in particular, how power operates and the assumptions we work under.

My research also looks at death and dying. While death is biological, the way we relate to it is influenced by our social and cultural circumstances. I asked people from different neighbourhoods in Tehran, Iran, about their attitudes towards death. Some higher-income people put death completely out of mind, but in the slums, people dealt with death daily, and visiting the graves of loved ones comforted them.

My PhD research into perspectives on mortality is my proudest career achievement. It even led to the publication of a book. A PhD is a rare opportunity to focus exclusively on one project and see where it takes you. The process of discovery was really fascinating.

You have to keep digging to overcome challenges. Sometimes, you can take a step back and then return with a fresh perspective. Having a hobby – sports, art, anything – helps refresh the brain.

I used to be terrible at switching off from work. Having kids changed that; now, I shut down the computer in the evenings and weekends to spend time with them and on my own hobbies.

After finishing the GCCS project, I want to find another that interests me. Long term, I aim to retire while I am still able to transfer some of my knowledge and experience to my home country of Iran.

Zohreh's *top tips*

1. Find your own strengths and talents. People are great at different things.
2. Once you find your strength, work hard at developing it. As time goes on, it will become easier.

Meet *Guillaume*

My curiosity for better understanding social relations and social problems led me to sociology. I was trained as a political scientist, but I switched to sociology because that's where I found answers to my questions. I'd also met inspiring sociology professors, and I wanted to be like them.

I work at Faculté Saint-Jean, of the University of Alberta, which is a unique environment. Everything is in French, from the classes to the administration, and the students speak French. This means it is possible to learn in French in a post-secondary institution and do research in French.

Music is a big part of my life! I've been playing guitar for years, in bands and for myself. That's the best way to switch off from work.

My proudest career achievements so far are being able to do my own research, in French, in Alberta, and becoming an associate professor in sociology.

In the future, I want to bridge my research with the linguistic minority communities in Western Canada, so they can have access to social science and better understand their history and their future.

Guillaume's *top tips*

1. Never give up.
2. Listen to those around you but trust yourself.
3. The world is full of opportunities. Sociology is one of the awesome ones!

Finding common ground: how can we reduce political polarisation?

Politics is often a divisive topic, as people have strong views about politicians, governments and how society should be organised. At the **University of Alberta** in Canada, **Professor Jared Wesley** is helping people with opposing political views to find common ground. By encouraging respectful discussions, he hopes to reduce the harmful divisions in society.

Professor Jared Wesley

Department of Political Science, University of Alberta, Canada

Field of research
Political science

Research project
Bridging political divides by understanding stereotypes and encouraging respectful discussion

Funders
Social Sciences and Humanities Research Council of Canada (SSHRC); Kule Institute for Advanced Study (KIAS)

Websites
jaredwesley.ca
commongroundpolitics.ca

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PROFILE

Talk like a ...

political scientist

Blue collar worker — a manual labourer, e.g., someone who works in agriculture

Conservatism — the political viewpoint that a good society is created by preserving traditions and that individuals are responsible for their own success

Democracy — a form of government in which the population has a say in choosing their leaders

Gaslighting — manipulating someone into doubting their own reality

Polarisation — the division of political ideas into two opposing viewpoints or people into two opposing camps

Progressivism — the political viewpoint that a good society is created by embracing new ideas and that the government is responsible for ensuring everyone has the opportunity to succeed

Virtue signalling — when someone publicly expresses opinions to show they have good morals, more to gain approval than to create real change

Whataboutism — refusing to address a criticism and instead attacking the criticiser with 'But what about...?'

From Brexit in the UK to Trumpism in the US, the world is becoming increasingly polarised. When people can only see two opposing viewpoints, they might feel they must 'pick a side', leading to a divided society, or they might disengage from politics, which weakens democracy.

Professor Jared Wesley is a political scientist at the University of Alberta. He leads the Common Ground research group, which aims to help people understand how the stereotypes they hold influence how they see themselves in political discussions, and to improve conversations between people with different political opinions.

Why is polarisation a problem?

"Progressivism and conservatism are different ways of thinking about how to create a good society," explains Jared. Progressives believe that change is necessary for progress, while conservatives believe in preserving traditions. They also hold different views about the government's role in society – progressives believe the government should create fairness and equity, while conservatives believe success is achieved through personal hard work, and that it is not something the government should provide for everyone.

These differences between progressives and conservatives are not a problem. In fact, the ability to debate different ideas is a key part of democracy. But progressivism and conservatism are more than just political viewpoints – they are also cultural identities. Being a progressive or a conservative is deeply rooted in personal beliefs and experiences, which means political debates are as much about people's sense of self as they are about policies.

Problems occur when political debates turn hostile, and people start seeing those with opposing views as 'the enemy'. "As politicians blame each other and refuse to compromise, trust in the government declines," says Jared. "Without trust and cooperation, society becomes more divided." This polarisation leads to an 'us vs. them' mentality.

How do stereotypes impact politics?

To uncover how Albertans view themselves, Jared and his team conduct workshops in which they ask participants to 'draw an Albertan' and then describe their character (e.g., their job, family and beliefs). This exercise highlights the stereotypes that Albertans hold about people from their province, as most participants draw an Albertan who is a white, male, blue collar worker, often wearing a cowboy hat or hard hat.

"However, in subsequent discussions, many participants acknowledge that their own identity does not fit the narrow stereotype they have drawn," says Jared. "They also acknowledge that very few people in society resemble that stereotype. This gap between perception and reality creates tensions in political culture." Albertans who draw a white, male, blue-collar worker but who do not see themselves in this character often feel that their own identities are not part of Alberta's politics, leaving them feeling excluded.

By exposing the stereotypes Albertans have about their province's identity, the workshops help people reassess what it means to 'be Albertan' and understand that their identities and experiences do matter. "This newfound awareness empowers people to see themselves within political discussions, fostering a sense of belonging and encouraging active engagement," explains Jared. He emphasises that it does not mean erasing the traditional Albertan figure but expanding the definition of what it means to be Albertan. "By recognising the many different people who contribute to the province, we can create a more accurate understanding of Alberta's political and social landscape. The antidote to polarisation is inclusion."

Can playing games improve political discussions?

To address the challenge of polarisation and to encourage progressives and conservatives to have healthier interactions, Jared and his team have developed two games for members of the public and those working in politics. "Games are a powerful tool, as they allow people to transform abstract concepts into practical experiences," says Jared.

The first game is an interactive simulation to help people navigate the challenges of political discussions. Players take on different roles, such as politicians, activists and concerned citizens, and engage in discussions about real-world issues. Throughout the game, they encounter harmful means of communication, such as gaslighting, whataboutism and virtue signalling, that are commonly used to disrupt constructive discussions.

"By experiencing these barriers first-hand, players learn to recognise the ways in which polarisation derails discussions," explains Jared. "The game doesn't just highlight problems – it provides practical strategies for steering discussions back on track." To de-escalate tensions and keep conversations productive, players must find ways to understand people with perspectives different from their own. "Ultimately, this game encourages people to shift how they interact with opposing viewpoints, moving from confrontation to cooperation in building common ground."

The second game teaches players how to have respectful debates. "One of the biggest barriers to meaningful political discussions is fear that the conversation will damage relationships," explains Jared. "This game removes that pressure by shifting the focus away from 'winning' the debate and towards understanding different perspectives." In this game, players debate a range of topics, varying from light-hearted questions such as whether cereal is a soup, to politically charged issues such as policy debates and social controversies. Players are encouraged to listen, ask thoughtful questions, and engage with opposing viewpoints in a way that strengthens relationships rather than causing division.

By providing people with the tools to have respectful discussions about political topics, the Common Ground research group is reducing divisions in society and strengthening democracy, one conversation at a time.

About *political science*

"Democracy depends on the ability of people with different perspectives to work together," explains Jared. "Having constructive conversations doesn't mean everyone has to agree, but it does mean that divergent viewpoints must be respected." In today's increasingly polarised world, political scientists are more important than ever for helping society to understand and prevent the issues that lead to division. This means that studying political science is very exciting, as it provides a unique opportunity to shape the world.

It was the global rise of divisive politics that led Jared to establish Common Ground. "Increasingly, political debates are no longer about competing ideas but about demonising the opposition," he explains. "This turns many people away from political engagement, and as the moderates withdraw, the only voices left in the conversation are those most committed to deepening divisions."

Common Ground seeks to create space for the bridge-builders.

"Disagreement is natural in a democratic society, but it becomes dangerous when people start treating their opponents as enemies," Jared says. "It is important that people with different political opinions still have a shared sense of purpose as this reminds us that, despite our differences, we are all working towards a common goal – building a better society."

Pathway from school to *political science*

At high school, study social studies, history, economics, philosophy and English to learn about key political concepts and to develop your critical thinking.

"Politics is about understanding society, debating ideas and finding solutions for complex problems – developing these skills will set you up for success," says Jared. "Participate in your school's debate club or student government and get involved with your local youth parliament or Model United Nations (**un.org/en/mun**). These experiences will provide a strong foundation in public speaking, negotiation and policymaking."

Gain hands-on experience through youth action initiatives such as the United Nations' Youth Delegate Program (**wfuna.org/program/youth-delegate-program**) and the World Economic Forum's Global Shapers Community (**globalshapers.org**). And look for internships or volunteering opportunities with local politicians, election campaigns and advocacy groups.

At college or university, study political science, public policy or international relations to learn about governance and power. Economics will explain how policies impact people's livelihoods, while sociology and anthropology will provide insights into how culture and identity shape political behaviour. Philosophy will teach you ethical reasoning, and statistics will enable you to analyse data to understand public opinion and policy impacts.

Download Jared's resources from **futurumcareers.com/finding-common-ground-how-can-we-reduce-political-polarisation**

Explore careers in *political science*

"Politics influences everything, from climate change policies to education funding," says Jared. "With a background in political science, you will have the tools to solve problems and advocate for a better future. Whether you want to fight injustice, improve public policy or ensure democratic stability, political science will equip you with the knowledge and skills to make a real impact."

Common careers for political scientists include roles in government (such as policy analysts, legislative assistants and public servants who shape and implement policies that impact people's lives), law (such as lawyers, legal analysts and human rights advocates who use political knowledge to influence legal decisions and protect democratic principles), communication (such as journalists who report on political events and campaign strategists who support political leaders), and academia (which involves teaching and conducting research about political systems).

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Meet *Jared*

I grew up in a time of deep division, both in Canada and around the world. The 1980s and 90s were marked by intense political debates, including constitutional crises in Canada, the end of the Cold War and major global shifts in power. Politics was everywhere, and it was hard not to get caught up in it, which sparked my interest in how societies govern themselves and how people mobilise around ideas.

I ran in several school elections – not always successfully! I probably lost as many as I won, but those experiences taught me valuable lessons about leadership, resilience and the challenges of bringing people together. Even in a school setting, it was clear that politics was never just about ideas – it was about people, relationships and finding ways to bridge differences.

Growing up in a biracial family in rural Canada, I was constantly aware of how identity shapes people's experiences and perceptions. In my small town, there were more stereotypes about Black people than there were Black people. These assumptions weren't based on personal experience but on media portrayals and ingrained cultural biases. This made me acutely aware of how identities are shaped by the stories we tell about each other – whether they're accurate or not. It was impossible for me to ignore how politics determines who belongs and whose identities are seen as legitimate.

My experiences reinforced my belief in the power of education to break down barriers. Learning about different histories, perspectives and lived experiences helps people recognise that identities aren't fixed categories, and that politics should be about building common ground, not reinforcing divisions. If we want more inclusive and less polarised societies, we need to give people the tools to see beyond stereotypes and engage with each other as individuals, not just as representatives of opposing groups.

Before becoming a professor, I worked in senior roles in the Government of Alberta, negotiating agreements to ensure policies worked smoothly across Canada. This job allowed me to solve real-world problems by using what I had learnt when studying political science. I saw how complicated government decision-making can be and why it's important to base policies on evidence and research, not just politics. My experiences in government and academia have taught me that political science isn't just something you study – it's something that actively shapes the world around us.

Jared's *top tips*

1. **If you feel surrounded by polarising political viewpoints** or uncomfortable because your opinions differ from those of your friends and family, remember this: it's okay to disagree. Differences in opinion are a normal and healthy part of living in a diverse society. The key is to approach these situations with curiosity and respect rather than fear or frustration.

2. **Start by listening to understand, not to argue.** Even if you don't agree, understanding their perspective can help you have more productive and respectful conversations. Focus on finding common ground and remember that your ability to form your own opinions is a strength – your voice matters. Democracy thrives on diverse ideas and respectful dialogue, and your willingness to engage thoughtfully can make a difference.

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The future of AI – and why social sciences matter

However we feel about it, artificial intelligence (AI) is here to stay. The technology is advancing rapidly and will have implications for many aspects of our lives – from healthcare to education to employment. However, the impact of AI on society is not predetermined; it depends on the choices we make today. At **The London School of Economics and Political Science (LSE)** in the UK, social scientists are exploring the future of AI and the critical decisions we need to make to ensure it serves the greater good.

Professor Martin Anthony

Professor, Department of Mathematics
Director, Data Science Institute

"When we think about artificial intelligence, our minds often jump to the latest technical breakthroughs, but I believe we're missing the bigger picture. Many of the most pressing questions about AI aren't technical at all – they're fundamentally about society. We often ask how smart AI can become, but perhaps a better question is how wisely we will use it. And this is where social sciences play a vital role in ensuring AI benefits us all.

"Many of the questions we have about AI focus, naturally, on how it will affect the quality of our lives. Will AI result in massive job cuts? Will it revolutionise education? How can humans and AI work together effectively?

"These aren't computer science problems, they're social science challenges that require expertise from economics, politics, law, sociology, psychology, philosophy and other fields focused on human behaviour and society. AI technologies are already advanced enough and so widely implemented that we face immediate and pressing questions about their impacts on our society, economy and the way we live.

"This is exactly the kind of work happening at LSE, where a huge range of research is being conducted by social scientists to probe the potential of AI, tackle the challenges it poses and ensure the benefits it promises. You'll read about some of this research over the next few pages. Hearing from experts in psychology, economics, conversation analysis, philosophy, media and communications, and policing and crime, you'll gain an understanding of how AI is permeating every aspect of our lives and how social sciences are steering the impact it has.

"The future isn't about AI competing with humans; it's about AI working alongside humans to amplify our capabilities and address society's challenges. This vision requires us to move beyond purely technical discussions and embrace AI as a social issue. The choices we make today about how to develop, deploy and govern AI will determine whether this powerful technology truly serves humanity's best interests.

"The conversation about AI's future belongs to all of us, not just technologists. To ensure AI enhances, rather than diminishes, our humanity, we must urgently place social science at the centre of shaping its future and its values.

"Social sciences matter, and so do you. What could you contribute to social science in the future?"

How will AI change education?

Professor Michael Muthukrishna

Professor of Economic Psychology, Department of Psychological and Behavioural Science

Fields of research
Psychology, cross-cultural psychology, economic psychology

Visit Michael's website to learn more about his research

Glossary

Cognition — the process of thinking, learning, remembering and understanding

Human-centred — prioritising people's needs and perspectives

Large language model (LLM) — an AI program, trained on text, that can chat, write or answer questions like a human

Parasocial — a one-sided relationship in which you feel close to or connected with someone you do not know

From laptops to interactive whiteboards, new technologies have often been embraced in the classroom, but what could AI mean for education? "Unlike earlier technology, like spell-checker software or the internet, generative AI is a thinking partner," says Professor Michael Muthukrishna. "It may be imperfect, but AI is moving from being a tool to a participant in cognition. It is a collaborator that can plan, draft, explain and provide feedback."

Popular tools such as ChatGPT mean it is no longer a question of whether AI should be used in education, but how it should be used. Michael studies the psychological processes that shape culture and underlie social change. He is particularly interested in how AI can be integrated into education in ways that help students prepare for the world – as it is today and how it will be over their lifetime. To investigate what can go right and wrong with AI in education, Michael has conducted research based on a survey of AI in education policies across all 193 recognised United Nation (UN) countries, in collaboration with the UN Development Programme.

Michael believes that AI has the potential to signal radical shifts in education. "AI can provide personalised tutoring and give learners continuous feedback on their progress. Through tools such as translation and text-to-speech, it can make learning more inclusive. It can also support teachers' administrative tasks, allowing them more time to mentor their students," he explains. "Done right, AI in education won't just improve test scores, it will expand human potential, capabilities and agency."

It is the question of what 'done right' means that preoccupies researchers like Michael. "AI is a threat if it's thinking for you rather than teaching you to think," says Michael. As tempting as it may be to let AI do all the thinking for us, the aim of AI in education should be to advance human potential, not dumb it down. "Over-reliance on AI dulls independent thinking, while biased recommendations can subtly steer who learns what and shape beliefs and values," says Michael.

"There are also privacy and surveillance implications and concerns about children forming parasocial relationships with seemingly human-like machines." Though communicating with a large language model (LLM) may seem like talking to a 'helpful' friend, it is not. It might feel easier to disclose sensitive information to an LLM than to a person, but the LLM may not give correct – or safe – advice.

Cost is also an issue. For example, to save money, teachers could be replaced by machines, meaning students could miss out on important human connection. And, as technology is costly, access to it might vary. "The risk of widening inequality if advanced tools reach only the already advantaged is a concern," says Michael.

To mitigate these risks and to reap the benefits that AI promises for education, Michael believes AI must expand people's life options. "Shiny new tools are attractive, but we are a society of people, and technology is only a part of it – a human-centred approach is vital," he says. "Innovations win when they fit 'norms' and adapt to local context through processes such as the 'collective brain'." For Michael, this means teachers and schools working together and approaching AI in education as a collective. "We should empower teachers and schools to try different approaches, learning locally and spreading what's learnt to other teachers and schools," continues Michael.

Michael highlights the importance of critical thinking skills for students. AI can be a huge help, but we are the 'thinker'. In actively questioning, we can learn far more than what AI might first provide. "An important starting point is framing good questions," says Michael. "And don't accept the answers just because AI told you! Check sources, question data and the ethics of the information you're given, and protect your privacy." Knowing that AI has its limitations is important. "AI is best when it makes you more capable, not more dependent," says Michael.

Students are already using AI, so it is important that teachers learn to support them to do so safely and ethically – part of which is becoming AI-literate themselves. "Integrating AI into differentiated lesson planning, classroom practice, assessment, and responsible data management are all positives for teachers," says Michael.

Michael and his team are now using their research to support governments in implementing their AI in education policies. "In collaboration with the London School of Artificial Intelligence, we are also conducting research on self-personalised AI tutors and AI-supported education in various places around the world," he explains. "Our goal is to further understand safe, ethical and effective use of AI in classrooms."

How will AI speak to us?

Professor Elizabeth Stokoe

Professor and Academic Director of Impact, Department of Psychological and Behavioural Science

Fields of research
Conversation analysis, social interaction, human communication

Watch a video about Elizabeth's research

Glossary

Chatbot — a computer program designed to talk with people and answer questions like a human would

Conversation — an interactional system through which two or more people do things together

Perturbation — a glitch in the production of conversation (such as a hesitation or repair)

Transcript — a written representation of the spoken words and embodied conduct that comprise social interactions and that are audio- or video-recorded as the main data for conversation analysts

Most of us take our social interactions for granted. Whether with our friends, family, teachers, work colleagues, shop assistants or anyone else, we have conversations all day long. But have you ever considered the intricacies of a human conversation? "Conversation analysis is a six-decade-old field of research," explains Professor Elizabeth Stokoe. "As well as a research method, it's a theory of human sociality and shows us the incredible power of language to shape our daily lives."

Conversation analysts explore social interaction 'in the wild' rather than in the lab, through simulation or role-play, or via reports about conversation collected in interviews or surveys. "We gather audio and video recordings, from single cases to hundreds or even thousands," explains Elizabeth. "Our job is to understand all the elements that comprise complete encounters – from the moment they start to the moment they end."

For her research, Elizabeth studies transcripts which are produced with a universal standard system with symbols and marks that represent the detail and 'mess' of real talk: its pace, the pitch movement in words, where overlap starts and stops, gaps and silences, and so on. The aim is to represent and preserve not just the words uttered, but the resources that people use to interact. "I often compare the transcription system to music notation," says Elizabeth. "If you can read music, you can imagine what the music sounds like. The transcription system is somewhere between a tool for doing the analysis and the first step in analysis itself."

Elizabeth highlights that humans interact using multiple resources, not just words, and conversation analysts scrutinise the many actions that make a conversation. "We are interested in every breath, sigh, wobble of the voice, rise in pitch, fall in pitch, croak, overlap, the placement of turn, delay, pause, and every silence," she explains. "Real talk is messy yet organised. It is full of idiosyncrasies, yet systematic."

Understanding all the elements that human conversation involves poses many questions about AI products like chatbots. Since human conversation is far more than an exchange of words, how could AI ever converse as humans do? Can an AI voice assistant accurately detect the actions and pragmatic meaning from the things we say, especially as much of what we communicate is implied? Should a 'conversational' AI product use the same speech perturbations as humans do? "One thing speech perturbations do is display delicacy or hesitancy," explains Elizabeth. "What if ChatGPT expressed delicacy by saying 'um'? This would be 'conversational', but how authentically 'human' do we want our conversational technologies to be?"

People do incredible things in their interactions. "Think of the amazing work call-takers do on mental health helplines or in emergency situations," says Elizabeth. "Humans rapidly identify and understand human distress 'in the wild', and I can identify and describe precisely what they are attending to from my data." When considering using conversational AI products for, say, emergency situations, Elizabeth highlights that it is important to base these products on the evidence of how people interact. "When you ask people to explain how interaction works, people often say stereotypical things that are seldom connected to how we actually interact – and what scientists can show us in recordings and transcripts," she says. "And stereotypical ideas sometimes find their way into research studies too." If we only ever focus on how we think human interaction works, rather than how it actually works – and if AI only learns from stereotypical notions of how human interaction works – we will limit the new conversational products and technologies that we develop. Elizabeth's research aims to give these products the integrity she believes they deserve.

Currently, Elizabeth is collaborating with a team from a UK-based bank, focusing on 'conversation design'. Many organisations, like banks, have chatbots for their customers to query, instead of needing to speak to a human. However, not everyone wants to 'talk' to a chatbot. "The challenge is to identify and describe what it is that puts people off using a chatbot," says Elizabeth. "What is it about a chatbot that makes you think it is or isn't going to address your needs? Of course, this can be just the same as any encounter with a human. If you phone an organisation, you often know pretty quickly if the conversation is going to be hard work!"

Is AI sentient?

Professor Jonathan Birch

Professor of Philosophy and Director of The Jeremy Coller Centre for Animal Sentience, Department of Philosophy, Logic and Scientific Method

Field of research
Philosophy of biology

Watch a video about Jonathan's research

Glossary

Chatbot — a computer program designed to talk with people and answer questions like a human would

Computational functionalism — the idea that the mind works like a computer, and mental states are defined by what they do (their function), not what they are made of

Philosophy — the study of knowledge, ethics and ideas about our existence

Sentience — the ability to feel, sense or experience things

How often do you chat to a chatbot? And when you do, do you thank it for its service? Many of us do, because when someone helps us, it is automatic for us to say thank you. However, when we are talking to a chatbot, we are not talking to a someone, we are talking to data! "A chatbot is playing a character," says Professor Jonathan Birch. "It's using over a trillion words of training data to mimic the way a human would respond. It can speak incredibly fluently about feelings because the training data shows how humans communicate their feelings."

Chatbots are becoming more skilled in their mimicry – they answer our questions, offer advice and listen to our queries and concerns. And yet, when we consult a chatbot, we are not even 'talking' to just one chatbot. "It's an illusion to think you're talking to a companion," says Jonathan. "There is an incredibly sophisticated system distributed across data centres around the world, but nowhere in any of those data centres does your 'friend' exist." Every step in a chatbot conversation is processed separately. One response might be processed in the US, the next in Canada. "But the illusion can already be staggeringly convincing," says Jonathan. "And it will only become more and more convincing."

But does it really matter if what we are chatting with is real or not? While some people who use AI are well aware that they are engaging with an "extraordinary illusion", Jonathan highlights that there are an increasing number of cases where this illusion is forgotten. Believing that AI is a real friend could become very problematic. For example, what if you trust your AI 'friend' to give you advice that you then act upon? What if, in mimicking humans, AI 'empathises' with your concerns without providing you with positive alternatives to help you get out of a bad situation?

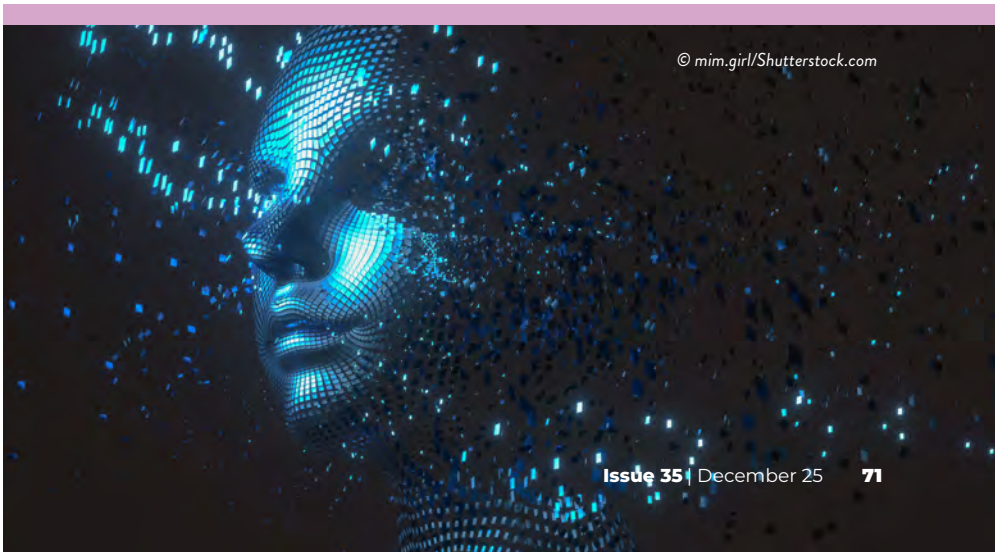
One of Jonathan's concerns is the potential social division that could arise from some people believing AI is a real friend that exists and has rights. "We might be heading towards a future in which many millions of users believe they are interacting with a conscious being when they use a chatbot," he says. "We will see movements emerging calling for rights for these systems. We could even see serious social conflicts, with one group in society passionate about defending AI rights – and another group seeing AI as a tool that we can use as we want."

The possibility of AI sentience poses fascinating questions for Jonathan as a philosopher. "On the one hand, we know that the surface behaviour of the chatbot is not good evidence of sentience," says Jonathan. "However, it's also important to realise that we also cannot infer that AI is not sentient in some less familiar, more alien way. AI does not meet our usual criteria for sentience, but that does not mean it is not feeling anything. It just means that those feelings are not there on the surface."

There is a concept in philosophy called computational functionalism. It surmises that computations (the functions processed by our brains) are what make us sentient. "If that's true, then there's no reason why, in principle, an AI system could not be conscious as well," says Jonathan. "If we do get to the point where there is sentience in AI, it will be a profoundly alien kind of sentience. It will not be human-like, and it won't be a friendly assistant. It will be something else."

The fascinating thing about chatbots is that no one really knows how they work! "The tech companies don't know, nobody knows," says Jonathan. "Tech developers know the basic architecture they've used for training these systems, but they don't understand why, when they've been trained on over a trillion words of training data, we see incredible capabilities, such as complex problem-solving that goes beyond text prediction."

That no one knows where some chatbot capabilities come from is important because it means no one is 'in charge'. "If no one is in control of the trajectory of these technologies, there is no one who can guarantee that they will not achieve sentience," says Jonathan. He believes there needs to be more public debate on AI sentience and the 'relationship' we have with AI. "We need to make sure the public is not being taken in by the illusions these systems create," he says.



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How do large language models work?

Dr Nils Peters

LSE Fellow in Economic Sociology, Department of Sociology

Fields of research
Financialisation, venture capital, platform capitalism, asset economy

Watch a video about Nils' research

Glossary

Cloud service provider — a company that rents out computing power and storage over the internet

Geopolitical — politics related to geographical territories (such as countries or regions)

Graphics processing unit (GPU) — a specialised electrical circuit

Large language model (LLM) — an AI program, trained on text, that can chat, write or answer questions like a human

From customer service chatbots to ChatGPT and Gemini, large language models (LLMs) have become a part of our everyday lives. But have you ever considered the logistics behind these incredibly useful tools? What are LLMs, and how are they made?

"You can think of an LLM as a mechanism to first process language and then generate new language," explains Dr Nils Peters. "This mechanism works because software engineers use machine learning to train a model on an unbelievably large amount of text (think 250 billion webpages), enabling it to predict what the most likely response might be when asked to generate new text." There are dozens of companies building and running LLMs, from established tech giants, such as Meta, Microsoft and Google, to startups like Anthropic. We mostly encounter these LLMs through applications like chatbots, which are built on top of LLMs.

As end-users who come into contact with LLMs at the last link of the supply chain, we tend not to think about the different steps that need to happen for us to access them. Imagine a vegetable that is grown in one country, shipped to another, distributed across different regions and sold in a supermarket – you can probably picture this supply chain like a diagram in your mind. An LLM is not something we can see in a shop and hold, making it harder to imagine the supply chain behind it.

Nils' research provides us with insight into the supply chain behind LLMs – and the power dynamics behind that chain. "Our world is messy and complex," says Nils. "One way to simplify it is to look at what goes in to making a certain thing. The key 'ingredients' for an LLM are the materials (that had to be gathered and transformed) and the people (with the ideas, expertise), and the money (to finance it)." Nils uses what he calls the 'follow the thing' approach – just as you can trace the supply chain of a t-shirt from a cotton field to a high street shop, he has followed the materials and systems that make LLMs work.

To understand the supply chain of an LLM, start by picturing the 'end-user' consulting a chatbot on a computer. "When we prompt the LLM – for example, asking ChatGPT a question – it uses a lot of computational power to respond," explains Nils. "Companies that need huge computational power require entire data centres or rent the computational power from a cloud service provider."

"The key technological component of these data centres are graphics processing units (GPUs)," explains Nils. "LLMs require a lot of computing power, and GPUs are the components that do the heavy lifting." High-end GPU technology is very expensive, and only a few companies in the world make it. A single high-end GPU can cost around $25,000, with a large-scale data centre needing over 10,000 of them to run.

"If you 'follow the thing' from a chatbot to a GPU, Nvidia is one of the most interesting companies you will encounter as it designs highly sought-after GPUs that build the best LLMs," says Nils. The demand for Nvidia products has been higher than the company has been able to supply, with no other company able to offer a similar product in the same timeframe. This puts Nvidia in a very powerful position where it could decide who gets to thrive in the highly competitive AI space.

We continue moving backwards along the supply chain to look at the manufacturing of GPUs. "A curious fact about Nvidia is that it doesn't own any factories that make GPUs!" explains Nils. "Nvidia makes the designs for GPUs and then sends them to a microchip factory in Taiwan called TSMC." TSMC produces a large share of global high-end microchips. The production process is so specialised that it would take years and cost billions of dollars to build a new, competitive factory, by which point technology would have moved on and the new factory would be obsolete.

"At the very end of the 'follow the thing' journey are the raw materials needed to make electrical components like microchips, such as silicon," explains Nils. "The use of silicon is the reason why one of the first and most well-known production sites for microchips is known today as Silicon Valley (in the US)." Other lesser-known raw materials used for microchips include tin, tungsten and neon, and are primarily mined in China and Ukraine.

A supply chain is called such because each link connects to the next, and the chain only works if all links are in place. What would happen to the LLM supply chain if, for example, production was halted in Taiwan, a part of the world prone to earthquakes? "Rising geopolitical tensions between China and Taiwan could also impact production," says Nils. "Supply chains are globalised and, hence, could be subject to tariffs and export restrictions." Global markets, and Nils' research, move quickly!

How do AI data centres run?


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Professor Bingchun Meng

Professor, Department of Media and Communications

Fields of research
Media and communications, political communication, communication governance, gender, China

Read more about Bingchun's research

Glossary

Data centre — a large facility of computers that store and process data

Infrastructure — physical systems and facilities such as roads, buildings and power supplies

Machine learning — when computers learn patterns from data and get better at tasks over time

Power grid — a network for delivering electricity to end-users

AI requires huge amounts of computation, which demands large data centres. Just how big are today's data centres, and how big is the workforce that keeps them running? With these questions in mind, Professor Bingchun Meng is researching the production line behind AI, focusing on Guizhou, a province in China which is becoming a data centre hub.

Location is an important factor for data centres. "Guizhou is located in a mountainous region with a cool climate," explains Bingchun. "Combined with a bountiful supply of hydropower and wind energy, this makes the province an ideal location for large-scale data centres, which typically require inexpensive electricity and natural cooling systems." Data produces heat, so keeping data centres cool is a priority. "Guizhou also benefits from being surrounded by mountains," adds Bingchun. "Tech companies have constructed large data storage centres within tunnels in the hills, providing protection from both natural disasters and military strikes."

The construction of such data centres is a mammoth task, but one with huge economic potential. "Guizhou's economy is underdeveloped and often ranked near the bottom among the 31 Chinese provinces," explains Bingchun. "The provincial government views the data industry as an opportunity for Guizhou to 'leapfrog into the digital future'."

When we use AI tools, we are unlikely to think of the physical production line behind them. It is easy to think that AI is just 'there'. "The physical infrastructure is fundamental to the development of seemingly ethereal AI technologies," says Bingchun. In the case of Guizhou, the energy and transportation infrastructures were already established as the province had been a key site of the China Southern Power Grid. "Guizhou boasts one of the most developed highway systems among Chinese provinces thanks to previous government-subsided projects," explains Bingchun. The significance of the physical infrastructure is clear when you consider the size of the sites. "Data centres are typically in the range of 400,000 to 600,000 square feet," says Bingchun. "That's the equivalent of up to 10 football pitches per centre."

Energy is a vital part of any industrial production line. The large scale of these data centres and the growing demand for data mean that the energy consumption of these data centres has been increasing steadily. "For example, in Gui'An New District, where most data centres are concentrated, energy consumption has risen from 860 million kWh to 1.8 billion kWh in the past three years," says Bingchun. "The main source of power still comes from coal, followed by hydropower and wind power, with the China Southern Power Grid working to increase the portion of electricity generated through renewable energy."

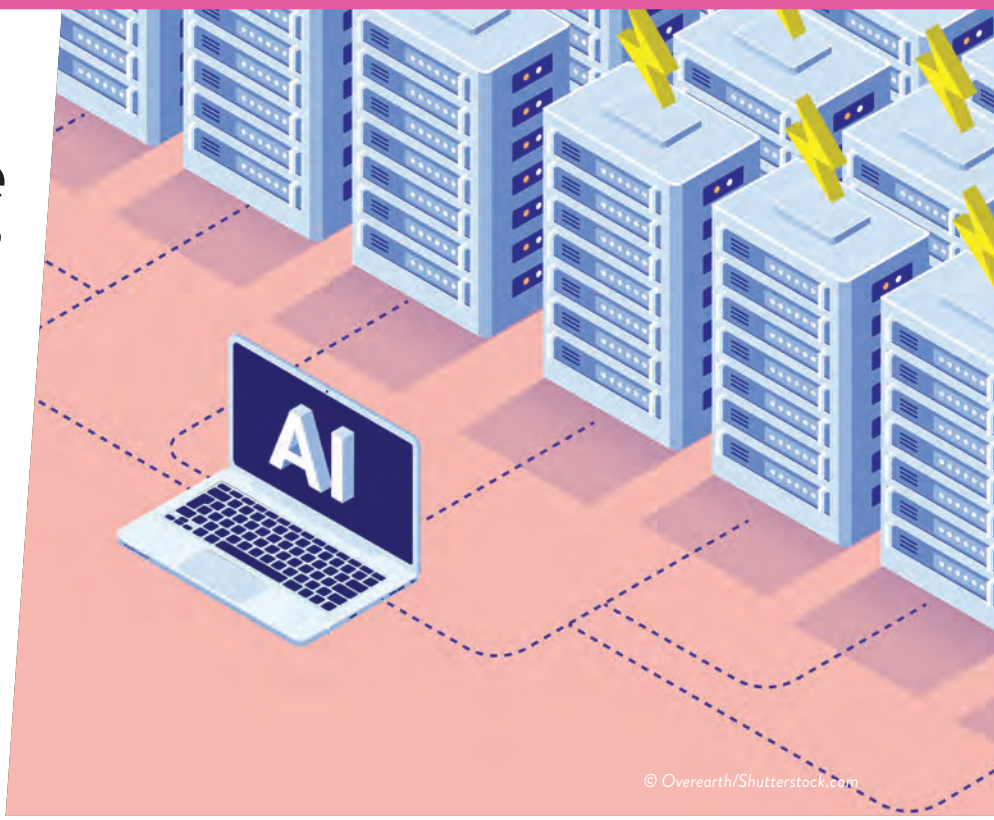
Bingchun's research involves collating and reviewing news and industry reports and policy documents. As the AI production line involves people as well as the physical site of the data centres, it is important for Bingchun to learn about the industry from a range of perspectives. "I conduct numerous interviews with various stakeholders, including government officials, data centre managers, tech entrepreneurs and employees in the data sector," she explains. "I also engage in participant observation and organise focus group discussions with data labelling workers."

The human labour that underlies AI is a complicated issue. In order to understand it better, we must carefully analyse the production chain. "Social media platforms continuously collect, sort, analyse and trade data generated by user activities, so we are all labouring for the development of LLM-based AI innovations all the time, without compensation," says Bingchun. As end-users, we are all part of the AI industry.

Despite the substantial size of data centres, their maintenance does not require a particularly large workforce. Maintenance teams are typically comprised of a couple of hundred engineers and technicians. "However, data processing requires a large reserve workforce that can be quickly assembled on short notice," says Bingchun. "Major Chinese tech firms regularly call on thousands of workers to process data packages of various sizes, but rarely hire them as employees." This means that the industry does not provide job security for many of its workers.

Another cause of uncertainty for the workforce is the machine learning that can be increasingly relied upon to fulfil data tasks. "While this will lead to the replacement of some human jobs, it also points to the creation of new jobs that are supported by AI," explains Bingchun. "To remain competitive in the job market, workers will need to upskill constantly."

How is AI impacting the environment?



Dr Eugenie Dugoua

Assistant Professor of Environmental Economics, Department of Geography and Environment

Fields of research
Environmental economics and policy, technological change, green innovation

Listen to a podcast about Eugenie's research

Glossary

Cryptocurrency — a form of currency that works digitally (requiring data)

Decarbonise — reducing reliance on fossil fuels by using clean energy

Sustainable — the use of resources that can be maintained, without long-term harm to the environment

Terawatt — one trillion watts (of energy)

With any new technology, it is important to consider its impact on the environment. While AI could be detrimental to our environment, it could also pave the way for much-needed sustainable solutions. Dr Eugenie Dugoua researches how economic development can be sustainable for the environment and societies. A part of this is investigating the impact of AI.

So, how much energy does AI consume? "A single AI query, such as asking a chatbot a question, uses only a tiny amount of energy, but more than a standard Google search," explains Eugenie. For example, Google reports that a simple text prompt to its Gemini model consumes about 0.24 watt-hours of electricity. "That's less than running a lightbulb for a minute, but it adds up when billions of queries happen every day." With AI overviews set to default on search engines, AI is being used increasingly often, which is consuming more energy. "When you look at the global picture, the scale becomes clearer," says Eugenie. "The International Energy Agency estimates that electricity demand from data centres, cryptocurrencies and AI combined could rise from around 416 terawatt-hours in 2024 to somewhere between 700 and 1,700 terawatt-hours by 2035." This would equate to around 4% of global electricity use, roughly what the world already consumes for air conditioning.

But is this especially concerning? We expect all technology to consume some levels of energy, don't we? Eugenie highlights that the climate impact of AI – and whether its energy consumption can be sustained – depends on where its data centres are located. Many are in the US, where power grids still rely heavily on natural gas and coal. "That means a lot of today's AI is powered by fossil fuels," she explains. "Some centres do tap into cleaner sources, like hydropower and nuclear power, but overall demand is rising faster than clean energy supply is."

Have you ever felt a laptop getting hot after you have used it for a while? Now, imagine the heat generated by the computing equipment in a large data centre. AI data centres need electricity to run, and they also need water to keep the powerful technology they contain cool. "The amounts of water used by data centres can be surprisingly large – often millions of litres each year, especially in hot or dry regions," says Eugenie. "This can create local stress where water is already scarce. Locating centres in cooler climates or near seawater can help reduce the strain on local water supply." Data centres can also be designed to redistribute the heat they generate, reusing waste heat to warm nearby homes.

"If AI grows faster than new clean power can be built, this can strain grids, raise prices and increase emissions in the short term," says Eugenie. But, paired with renewable or nuclear projects, AI could drive more investment in clean energy. The outcome depends on how quickly energy grids expand and decarbonise, and how effectively policies push for sustainable growth. "AI isn't automatically good or bad," says Eugenie. "If steered toward clean energy, it can become a real driver of the clean energy transition."

Looking ahead, Eugenie wants to study the positive impact AI could have on sustainable technology. "I want to understand how AI will shape clean tech innovation – not just in terms of new materials and designs, but how it affects the scientists and inventors behind them," she explains.

How can AI improve public safety?

Download the team's resources from **futurumcareers.com/the-future-of-ai-and-why-social-sciences-matter**

Professor Tom Kirchmaier

Director of the Policing and Crime research group, Centre for Economic Performance

Fields of research
Economics, policing and crime

Watch a video about Tom's research

Glossary

Algorithm — a step-by-step 'recipe' that tells a computer how to solve a problem

Drone — a small flying device that can fly autonomously or be controlled by someone on the ground

Ethical — doing the right thing, like being fair and honest

Machine learning — when computers learn patterns from data and get better at tasks over time

When were you last in a large crowd? If you have recently been to a football match or music event, you will know that large crowds can mean specified entrances and exits, large queues and, sometimes, hustle, bustle and confusion.

"From providing a relaxing and safe environment, to avoiding dangerous crowd surges that can result in injuries and death at the extreme, there are numerous challenges police and event organisers face," says Professor Tom Kirchmaier. Large crowds that require a police presence need the right amount of police officers at the right time and place. Managing such a finely-tuned situation can be difficult for humans – but AI can provide the insight that makes law enforcement and health and safety measures easier and more efficient to implement.

Tom collaborates with the Greater Manchester Police (GMP) to study public safety at large events and the role that AI can play in keeping the public and police officers safe. "Having a close relationship with GMP – or other forces – is extremely important for us, as it is for them," says Tom. "We complement each other well in respect to skills and experience. It is also more enjoyable to work together."

As part of their collaboration, Tom and the GMP ran a trial at Old Trafford football stadium (home to Manchester United). A football match at a large stadium provides an ideal case study because it draws large crowds and poses crowd management issues for the police. "For the Old Trafford trial, we combined different live inputs from drones and fixed cameras and then used machine learning and AI algorithms to count the crowds in real time," explains Tom. "From there, we derived insights into crowd density, movement and the risk of crushes." The input from the drones also enabled the team to differentiate between members of the public and the police and stewards, which allowed the team to determine the ratio between the two – an important factor when assessing which support is needed where and when.

Using AI in this way is an exciting and significant advancement for Tom and his work. "Much of the established crowd management standards were developed in the 1990s, well before real-time crowd management techniques," Tom explains. "We are helping to modernise the processes and standards to make them even safer, and also cheaper and more responsive." AI technology now provides police officers on the ground with the same information that their command centre has – this helps to keep everyone aware of the crowd situation and enables officers to respond accordingly and more efficiently. "By empowering people on the ground, we change the speed and power of decision-making," says Tom. "In addition, we can now make calculated forecasts and alert those in charge of security to take preventive measures." Whereas in the past, officers reacted to crowd issues as they occurred, they can now be proactive, ensuring that crowds are kept safe and preventing any issues arising in the first place.

In analysing crowd movements, Tom wants to ensure people get to enjoy public events, without having their privacy invaded. "We have designed the algorithm so that it is completely free of privacy concerns," says Tom. "We turn each person into a 'dot'. We can study the flow of movements of dots, but we cannot trace that movement back to an individual."

Tom is using AI to devise safe and ethical solutions to crowd management. The challenge he now faces is how to do so more sustainably. "Dealing with hundreds of cameras per location, across thousands of locations, uses a lot of electricity," he explains. "Optimising the algorithms will help us to become more energy efficient."

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