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WELCOME

ISSUE 40

Empowering students to make informed career decisions

"Everyone, everywhere, should have an equal opportunity to succeed in science," says Christopher Burnett, Digital Content Specialist for LabXchange (p 4). This is why LabXchange has created CareerXplorer – an interactive online platform that allows students to explore careers in STEM. "We want every student to know that there is a place in science for them," continues Christopher, who tells us about the fun students can have participating in interactive career simulations to discover what role in STEM they would like to pursue. "Too many learners are exposed only to traditional career paths in science, and if they feel that they do not fit neatly into one of these roles, they abandon a future in science altogether. We want to empower students to make fully informed decisions about their futures!"

Elsewhere in this issue, researchers from a wide range of STEM and SHAPE fields share the highlights of working in their respective roles, exposing young people to the huge variety of career opportunities available to them. Would you like to find fossils as a palaeontologist (p 28) or look at lakes as a limnologist (p 24)? Have you ever considered a career in human rights law (p 62) or haematology (p 46)? Read on to learn about all these opportunities and more!

The Futurum team

Brett Langenberg
Founder/Managing Director

Chris Dowell
Project Manager

Lewis Simpson
Project Manager

Isla Foffa
Editor

Joe Aslett
Assistant Editor

Sophia Kerby
Senior Graphic Designer

Our writers

Rania Bouka, MSc

Rebecca Landon, MSc

Kate Wilkinson, MA

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Contact

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

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Christopher Burnett, Digital Content Specialist for LabXchange, tells us about CareerXplorer, the organisation's interactive career platform.



COVER STORY

LabXchange

04



Empowering students to Xplore careers

By helping all educators and learners to access quality STEMM resources, Harvard Online's **LabXchange** aims to empower students to make informed decisions about their futures. Its **CareerXplorer** platform enables just that, providing interactive career simulations that show students what STEMM roles actually involve – and where young people's interests could take them. **Christopher Burnett**, LabXchange's Digital Content Specialist, tells us about this unique tool – and the fun students can have exploring it!

What is LabXchange's mission?

To paraphrase Dr Robert Lue, LabXchange's founder, we believe that everyone, everywhere, should have an equal opportunity to succeed in science. For us, that has meant curating a catalogue of high-quality learning and teaching resources that educators and learners of all ages can access for free, regardless of their physical location, personal connections or background.

Why has LabXchange established CareerXplorer?

We want every student to know that there is a place in science for them. Too many learners are exposed only to traditional career paths in science, and if they feel that they do not fit neatly into one of these roles, they abandon a future in science altogether. We want to empower students to make fully informed decisions about their futures!

CareerXplorer facilitates the discovery and exploration of a diverse range of careers in science, technology, engineering, mathematics and medicine (STEMM), bridging the gap between school curricula and career skills. In an interactive and engaging way, students are able to learn about unique science careers and directly connect their abilities and interests to relevant career skills. This, in turn, helps them chart an actionable path toward achieving their target career.



How was CareerXplorer developed?

Career exploration has existed as a natural extension of STEMM learning since LabXchange launched. As we set out to build a library of science resources, we made sure to include videos featuring researchers in their labs, biographical narratives from a range of scientists, and content spanning topics from cellular biology to data science. Now, with CareerXplorer, we take it a step further and connect these resources directly to the corresponding career skills.

From the start, close collaboration with STEMM professionals has been crucial to the development of CareerXplorer. To really be useful to learners, the tool needed to be robust, informative, trustworthy and accurate. The only way we could reach that high standard was by working directly with industry experts, who review and validate every career profile. Our career simulations are similarly developed with the guidance and real-world expertise of industry professionals to ensure authenticity and accuracy.

Equally important, of course, has been working with learners and educators, who have provided feedback at every



stage of CareerXplorer's development. We have interviewed career counsellors to understand common challenges and questions, worked with educators to co-develop teaching resources that align with common curricula and educational standards, such as the US's Next Generation Science Standards (NGSS), and we have consulted with students to learn what it is they really want to get out of a career exploration tool.

Why is it important that CareerXplorer is interactive and exploratory?

Our goal with CareerXplorer was to make a tool that students would actually enjoy using! When learners only read about a career, they get a surface-level understanding of it – a basic description, a salary range, a sterile list of duties. But reading that a biological technician "supports lab research" does not actually help the learner understand whether they would personally enjoy culturing cells, running data analyses or managing a lab. Rather than presenting learners with broad generalisations about careers, CareerXplorer relies on interactive career simulations to allow learners to evaluate their genuine interest in a career by exploring what someone in that role actually does on a day-to-day basis. Another key principle of CareerXplorer – which echoes LabXchange's broader mission – is that a hands-on approach allows learners to explore a career without requiring prior experience, special technical equipment or professional connections. For learners in underserved communities who may not have access to real-world internships or a network of STEMM professionals, this is especially beneficial.

What insights do the CareerXplorer career simulations provide?

LabXchange has been building virtual lab simulations and interactives for over six years, and the CareerXplorer team

> ***"CareerXplorer facilitates the discovery and exploration of a diverse range of careers in STEMM and bridges the gap between school curricula and career skills."***

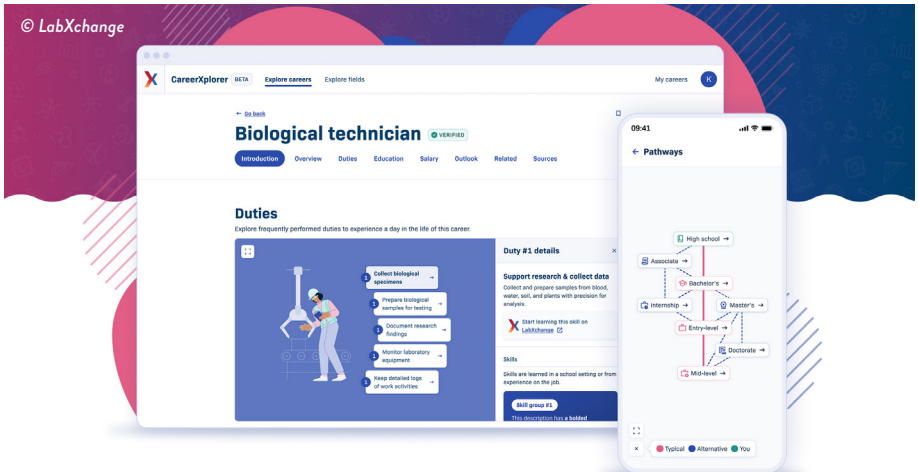




has worked hard to ensure that the career simulations build on our extensive experience and learnings.

These simulations place learners directly into realistic, relatable workplace scenarios, where they engage with the same equipment, tasks and decisions that STEMM professionals encounter in real life. In the biological technician simulation, for example, learners are tasked with conducting an experiment to identify a coral reef–friendly sunscreen. Through the simulation, they learn about culturing cells, collecting data and interpreting their results. These are all things that a real biological technician might do in their work.

Empowering students to test drive a role gives them valuable insight into what the career really looks like and how much (or how little!) they may enjoy engaging with the day-to-day tasks. Most importantly, the beginner-friendly and risk-free environment of a simulation encourages students to really explore careers for their own benefit and curiosity, rather than for a grade or another external pressure.



What role do STEMM professionals play in CareerXplorer?

STEMM professionals have played a massive role in ensuring the authenticity of CareerXplorer's career profiles and simulations. CareerXplorer is designed to reflect the reality of what STEMM professionals encounter in their daily work, and input from experts allows us to highlight the skills that are the most important for learners to focus on developing. Alongside their direct feedback, STEMM professionals have also shared their personal stories in the form of interviews, which go into more detail about their unique educational journeys and provide insight to learners interested in pursuing that career.

How is CareerXplorer helping teachers to support their students?

CareerXplorer's career profiles put all the relevant information in one place, allowing educators to direct curious learners to explore careers that pique their interest. At the same time, each of our simulations comes with a standards-aligned teaching guide offering detailed suggestions for classroom use, including timing, discussion prompts and project-based activities

that connect the simulation to relevant subject content. Each guide also includes a customisable learner-facing worksheet.

Apart from testing out the career simulations, we would encourage readers to simply spend some time exploring the career profiles, especially the interactive duties guide and education pathways elements.

The duties and skills guide identifies the five most frequently performed duties by someone in the role, with each duty broken down into specific skills. The skills are linked to relevant learning resources on LabXchange, so students can learn more about a skill – or even directly practise it.

The education pathways feature allows students to visualise the most common educational paths taken to reach a career. Different careers have different educational requirements, yet there are often many ways to get from Point A to Point B. This is all laid out in an interactive interface in which learners can see degree and experience requirements, relevant subjects, recommended extracurricular activities and internships, and courses that are important for pursuing the career.



What has CareerXplorer achieved, so far?

CareerXplorer is still in its beta phase, and we are actively gathering feedback on all aspects of the tool. The comments that we have received from educators, career counsellors, learners and industry professionals so far have been overwhelmingly positive and incredibly helpful to us as we continue to improve CareerXplorer. Educators value having all the information in one place, which makes it easy to share with their students, and learners appreciate the authentic insights into real careers.

Building these interactive career simulations involves extensive collaboration between many different people – instructional designers, educators, graphic designers and STEMM professionals, to name just a few – to ensure that the simulations are accurate to the career, pedagogically sound, mentally engaging and simply fun!

What does the year ahead look like for CareerXplorer?

In the year ahead, we will be focused on releasing new career profiles to flesh out our catalogue. With over 18 profiles currently available and more than 20 in the works, we are excited to continue expanding the range of careers represented on CareerXplorer.

Because every profile is reviewed and validated by career experts in their respective field, it is not a quick process – but a very important one to conduct thoroughly. Additionally, we aim to create more robust connections between career skills and relevant learning resources on LabXchange. If a learner is interested in becoming a biological technician, we want them to be able to practise micropipetting or using a microscope, which are skills that are already available in simulations on LabXchange.

Finally, we want to gather more feedback. Educators, learners, career counsellors, STEMM professionals and others interested in science career development are encouraged to try out CareerXplorer for themselves and reach out to us with their thoughts.

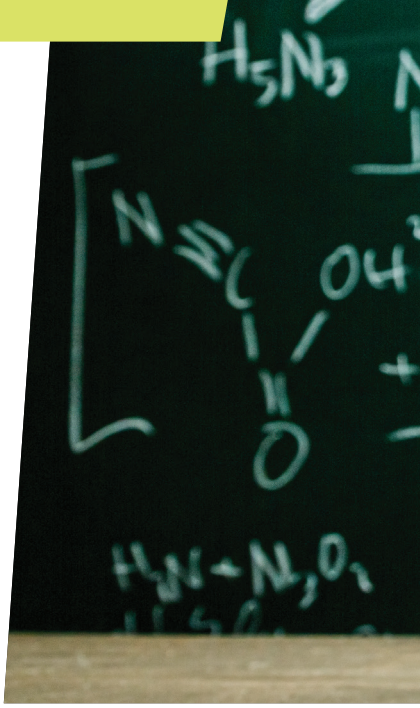
LabXchange

About LabXchange

LabXchange is an initiative of Harvard University's Vice Provost for Advances in Learning. It is a free online learning platform home to over 34,000 digital learning and teaching resources in subjects spanning science, technology, engineering, mathematics, and medicine (STEMM). Launched in 2020 with support from the Amgen Foundation, LabXchange develops digital educational content, including virtual lab simulations and interactive animations, and collaborates with more than 200 science education organisations to curate a catalogue of high-quality resources that are entirely free to use for learners and educators across the globe.

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What can philosophy teach us about chemical reactions?

Why do chemical reactions occur? Are molecules stable entities or constantly changing components in a dynamic system? These questions are best answered not by science, but by philosophy, says **Dr Ross Stein**. As an enzymologist, Ross studies chemical reactions with the aim of developing new drugs to treat diseases. And as a philosopher of science, he uses ideas from metaphysics to explore why these chemical reactions occur.



Dr Ross Stein

Independent scholar

PROFILE

Fields of research
Enzymology; philosophy of science

Research project
Exploring what metaphysics teaches us about chemical reactions

doi: 10.33424/FUTURUM720

Talk like a ...

philosopher of science

Chemical reaction — a process in which chemical bonds break and new bonds form, transforming one molecule into another

Enzyme — a protein that speeds up chemical reactions in living organisms without being used up itself

Metaphysics — the branch of philosophy that explores the fundamental nature of reality and asks why things happen

Philosophy of science — the study of how science works, including how scientific knowledge is developed and how scientific explanations can be understood

Process metaphysics — the philosophical view that change is a fundamental feature of reality, so entities such as molecules are constantly changing rather than remaining fixed

Substance metaphysics — the philosophical view that entities such as molecules are naturally stable, with change occurring because of external influences

Every second, countless chemical reactions take place inside your body. These reactions allow you to breathe, digest food, produce energy and fight disease. Understanding exactly how these reactions occur is essential for developing new medicines, but have you ever thought about why chemical reactions happen in the first place?

Dr Ross Stein is an enzymologist for a pharmaceutical company, where he investigates how enzymes speed up chemical reactions. Alongside his career in enzymology, Ross has a personal interest in philosophy. As an independent scholar, he explores metaphysics – the branch of philosophy concerned with the fundamental nature of reality – and applies this knowledge to understand more about chemical reactions.

How and why do scientists study chemical reactions?

"The chemical transformation of one molecule into another involves breaking chemical bonds between the atoms of a molecule and forming new bonds between these atoms to create new molecules," explains Ross. For example, when methane burns in oxygen, the carbon-hydrogen bonds in methane molecules and oxygen-oxygen bonds in oxygen molecules break, before new carbon-oxygen bonds form to produce carbon dioxide and hydrogen-oxygen bonds form to produce water. For this transformation to occur, several conditions must be met. "A molecule must gain enough energy, that energy must be directed towards specific chemical bonds, and the reacting molecules must be correctly positioned," says Ross.

One of the main ways scientists investigate enzymes is by measuring how quickly they carry out chemical reactions and how factors such as temperature or pH affect these reaction rates. This knowledge is particularly valuable because many diseases involve enzymes that work



too quickly or too slowly, so drugs work by interacting with enzymes to change their rates in the body. Ross's work as an enzymologist is helping scientists to understand diseases and develop new drugs to treat them.

What is metaphysics?

Metaphysics is a branch of philosophy that asks fundamental questions about the basic nature of reality. Ross's interest in metaphysics complements his scientific research into enzymes. "While science investigates *how* a phenomenon occurs, metaphysics asks *why* it occurs," he explains. "For example, scientific studies explain how chemical reactions occur, while metaphysical investigations explain why. What must reality be like for the chemical transformation of molecules to occur?" To explore this question, Ross draws on two approaches to metaphysics: substance metaphysics and process metaphysics.

How does substance metaphysics explain chemical reactions?

The word 'substance' has a special meaning in philosophy that differs from its everyday use. It can be traced back to the ancient Greek philosopher Aristotle and his concept of *ousia*, a Greek word often translated as 'substance' but more accurately meaning 'entity'. According to substance metaphysics, entities such as atoms, molecules, cells and organisms are naturally stable, and change is something that happens to them because of external influences.

"Substance metaphysics views molecules as inherently static – much like the ball-and-stick models of molecules used in chemistry classes," says Ross. "This is at odds with what chemistry actually teaches us." Substance metaphysics states that as energy is added (e.g., if the temperature is increased), a molecule will transform into another stable molecule. According to Ross, this view does not fully reflect what modern chemistry tells us because it treats chemical reactions as something that happen to molecules, rather than as part of their natural behaviour.

> **"While science investigates how a phenomenon occurs, metaphysics asks why it occurs."**

How does process metaphysics explain chemical reactions?

Process metaphysics can be traced back to the ancient Greek philosopher Heraclitus, who famously said that you can never step into the same river twice because it is constantly changing. Rather than seeing stability as the natural state, process metaphysics argues that entities are always changing and that stability is only temporary.

"Process metaphysics views molecules as inherently dynamic, with continuous internal motions that include rotations around chemical bonds, and torsions and vibrations of these bonds," says Ross. "The structure of the molecule is not fixed but comprises an ensemble of many structures." Process metaphysics views molecules as part of a larger reacting system that includes the solvent and other molecules in solution. It states that as energy is added, internal motions in the molecules become more pronounced until the reacting system progresses to a new state.

Ross believes that this dynamic view is more consistent with what contemporary chemistry teaches because it sees chemical reactions as part of the ongoing behaviour of the reacting system. "I view the chemical transformation of molecules from the point of view of process metaphysics, where the molecule is part of a chemical reactive system which includes the molecule, solvent and other molecules in solution," he says.

How has philosophy influenced Ross's science?

Although Ross's study of philosophy is separate from his day job as an enzymologist, it has influenced the way he approaches his scientific research. His knowledge of process metaphysics helps him understand why chemical reactions depend on the dynamic nature of enzymes. "My study of philosophy has made me a more critical thinker and made my scientific writing clearer and more precise," he says. "Philosophy stresses sound and logical arguments to support a specific position, which has carried over into how I think about scientific problems."

As the study of knowledge and existence, philosophy helps us ask deeper questions about why the world works the way it does. How could you benefit from an understanding of philosophy?

About *philosophy of science*

"Philosophy of science is the branch of philosophy that investigates the foundations, methods and purpose of science," says Ross. "Rather than doing science, it steps back to ask what science actually is, how it works and whether it reveals the true nature of reality."

Philosophers of science explore questions about how scientific knowledge is developed, how scientists investigate the world and how we understand scientific explanations. "Topics include the scientific method (How is science done?), questions about realism (Are molecules real? How can we know they exist?), and ideas about the laws of nature," says Ross.

For Ross, science and philosophy provide two ways of understanding the same reality. Science helps explain how phenomena occur, while philosophy helps us think about why they occur and what reality must be like for them to happen. "The sort of metaphysics I practise insists that whatever philosophical stance I take, it must be consistent with the findings of science," he says.

Studying philosophy can also help scientists develop important skills in critical thinking. Philosophy encourages people to question their assumptions and clearly explain why they believe what they believe. "The chief skill lies in being able to propose an explanation for something and then defend the explanation with clarity, backing up every assumption with sound arguments," says Ross.

Explore careers in *philosophy of science*

Many philosophers of science are academic researchers who work at universities to philosophically study scientific questions while also teaching students.

You could work as a scientist for a company, like Ross, and apply your knowledge of philosophy to your scientific research.

Learn more about careers in the field from the Philosophy of Science Association: **philsci.org**

Pathway from school to *philosophy of science*

At school, build a strong foundation in science subjects such as physics, chemistry and biology. Ross also recommends developing a broad education in subjects such as history and literature, as philosophy is focused on ideas and these subjects will help you explore how ideas develop and influence the world.

Some universities offer undergraduate programmes in philosophy of science. If this is not available, you could study a degree in philosophy while taking science courses, or vice versa.

Ross recommends gaining experience in philosophy of science by conducting research projects with professors in the field.

Download Ross's resources from futurumcareers.com/what-can-philosophy-teach-us-about-chemical-reactions



The ancient Greek philosopher Aristotle developed the concept of substance metaphysics. © *thelefty/Shutterstock.com*



Meet *Ross*

I've been interested in science and math for as long as I can remember. As a teenager, my other main interests were music (I played the trumpet in the school band and a rock group, and I had a pretty good album collection) and reading science fiction. I didn't do organised sports, but I played baseball and football with my friends.

My inspiration to become an enzymologist came from the biochemistry course I took during my junior year of college. The course was taught by an enzymologist, and I was lucky enough to work as a technician in his lab during my junior and senior years. This experience, along with his encouragement, set me on the course to become a scientist.

I've always been of a philosophical bent; I had considered studying philosophy in college. But it wasn't until 25 years later, when I found a copy of *The Reenchantment of Science* by process philosopher David Griffin in a used-book store, that my interest in philosophy was fully awoken. I bought the book, read it, and was hooked!

Through *The Reenchantment of Science*, I discovered process philosophy, with its emphasis on the centrality of change and flux in nature. I immediately saw how the metaphysical teachings of process thinkers might help me understand, at a deeper level, the mechanisms of chemical reactions. It seemed that process philosophy could allow me to move from understanding the *how* of chemical reactions to exploring the *why* – the metaphysical principles that underpin the chemical transformation of molecules.

Even after all these years, I still enjoy being in the lab doing experiments as an enzymologist. Part of what I enjoy about philosophy is the broad, open-ended problems and questions it presents. These broad ideas complement the more narrow, practical thinking of my role as an experimental scientist.

Without question, my favourite philosopher is Alfred North Whitehead, the 'father' of process philosophy. His writing can be very difficult, but it is worth the effort.

Outside of my work as an enzymologist, much of my free time is devoted to reading and writing philosophy. I also continue to play the trumpet in a community band and a small jazz combo. And whenever I can, I enjoy listening to live music.

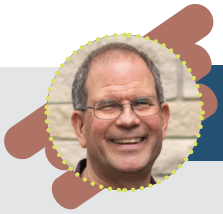
Ross's *top tips*

Read constantly and broadly, and think critically by recognising and questioning every assumption.

How can studying microplastics and micropollutants protect human health?



Microplastics have the rather unhelpful habit of attracting and transporting other micropollutants such as pesticides, dyes and pharmaceuticals, often causing them to accumulate in levels harmful to humans, animals and the environment. At **Kansas State University** in the US, **Professor Daniel Higgins** is using advanced microscopy techniques to investigate how micropollutants are attached to, transported by and released from microplastics, increasing our understanding of the risks they pose.



Professor Daniel Higgins

Department of Chemistry,
Kansas State University, USA

PROFILE

Field of research
Chemistry

Research project
Studying how micropollutant molecules accumulate on microplastic surfaces

Funder
The US National Science Foundation (NSF) supported this work through grant CHE-2502696. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the NSF.

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Talk like a ... chemist

Confocal fluorescence correlation spectroscopy (FCS) – a technique that measures how many fluorescent molecules are present and how quickly they move by analysing changes in the light they emit

Hydrophilic – water-seeking

Hydrophobic – water-avoidant

Lipophilic – fat-seeking

Microplastic – tiny plastic pieces (less than 5 mm) often from broken down plastic litter, fabrics or small beads in toiletries

Micropollutant – any harmful chemical or substance present in the environment at extremely low concentrations (typically micrograms or nanograms per litre)

Organic micropollutant – carbon-based micropollutants, often synthetically created by humans such as pharmaceuticals, pesticides or toiletries

Super-resolved single-molecule tracking (SMT) – a technique that tracks the movements and interactions of individual fluorescent molecules at extremely small scales

Micropollutants are everywhere – in the oceans, soil, air and even our drinking water and our bodies. They are normally found at extremely low concentrations, but can accumulate and harm humans and animals, causing cancer and other diseases.

"Organic micropollutants are commonly synthetic, carbon-based molecules created by humans, including pharmaceuticals, pesticides, dyes, adhesives and other chemicals that have been released into the environment," says Professor Daniel Higgins, a chemist at Kansas State University. "They are found at very low concentrations, often around a nanogram per litre of water." This is roughly equivalent to one drop of water in twenty large swimming pools. However, they can still be dangerous as many such molecules are lipophilic (fat-seeking) and so accumulate and concentrate in the fatty tissues of humans and animals.

Microplastics and micropollutants

Microplastics are tiny plastic pieces, from one micrometre to five millimetres in size. Primary microplastics are created that size, such as craft glitters, industrial powders and the beads found in body scrubs, while secondary microplastics are shed from larger plastic items, such as food and drink containers, as they break apart in the environment.

"When microplastics are exposed to sunlight, heat and Earth's oxidising atmosphere, along with the mechanical forces imparted by wind and waves, the particles become weathered, change size and shape, and transition from being hydrophobic to hydrophilic," says


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Dan. "This dramatically changes how they interact with other molecules like organic micropollutants."

Microplastics are micropollutants themselves, but the way they interact with other micropollutants makes them even more problematic. Firstly, many microplastics come from coloured textiles or packaging where dyes have been combined with the plastic. "As these plastics weather to become microplastics, the dyes incorporated in them may be released into the environment as new surfaces are formed on the plastic particles," says Dan.

Secondly, microplastics can transport other micropollutants. "Hydrophobic micropollutants readily accumulate on the hydrophobic surfaces of relatively fresh microplastics that have not yet undergone substantial oxidation, while hydrophilic micropollutants accumulate on heavily-oxidised hydrophilic surfaces of weathered microplastics," says Dan. "In both cases, the micropollutants can become concentrated to levels well above those found in the environment, leading to possible toxic responses if they are ingested and the pollutants are released."

Modelling microplastics and micropollutants

To study these processes, Dan and his students chose representative organic micropollutants and secondary microplastics that would be easy to study. "For a model micropollutant, we needed fluorescent molecules to detect and track at the single-molecule level," explains Dan. The team chose rhodamine B, a common dye often found in the environment. For the model microplastic, they chose polyethylene terephthalate (PET). "PET is commonly used in disposable food and drink packaging, which may be carelessly discarded or escape during transport to waste management facilities," says Dan. "PET is also widely used in textiles, like polyester clothing. As clothing becomes aged and worn, PET fibres are released directly into the environment." Dan's students used ultraviolet (UV) light to artificially age samples of PET microplastics. "Using UV light allows us to quickly produce changes similar to those caused by long-term exposure to sunlight and air under normal environmental conditions," he explains.

Microscopic molecule movements

Optical microscopes allow scientists to view tiny objects, such as individual molecules, using light. Typical optical microscopy, which uses visible light, needs objects to be spaced out by roughly 300 nanometres to tell them apart. However, super-resolved single-molecule tracking (SMT) uses fluorescent dye molecules such as rhodamine B which, when illuminated with a laser, emit bright yellow light, allowing the location of individual molecules to be determined to within as little as 20 nanometres.

Using this technique, Dan's students record videos of the molecules' movements. "These videos show tiny bright spots of light against a dark background, much like stars in the night sky, but they are moving," says Dan. "By recording these spots of light, we are 'tracking' the single molecules which tells us if the molecules are moving or where, when and how strongly they stick to the plastic surface."

Whereas SMT shows how individual molecules behave, confocal fluorescence correlation spectroscopy (FCS) observes many molecules simultaneously, better revealing how fast they move and how many are present. When fluorescent dye molecules move through a microscope's detection area, they produce brief bursts of light. A mathematical process called autocorrelation is used to analyse these bursts to learn about the molecules' movements. "FCS allows us to precisely determine how fast the molecules are moving, even if they are moving very rapidly, or if they interact with the plastic surface for only very brief periods of time," says Dan.

Findings and future steps

Dan and his students have discovered that the properties of microplastics vary across their surfaces, and at least two mechanisms cause interactions with micropollutants. "Unweathered (hydrophobic) plastic regions readily accumulate lipophilic molecules that are easily released when the plastic migrates into a different environment, such as when it is ingested by living creatures," says Dan. "Weathered (hydrophilic) regions allow the microplastics to be more readily dispersed in water, and provide sites for certain organic micropollutants to become strongly attached to the microplastics."

While there is still much research to be done, the team's results are highly valuable. "Our results provide new clues as to how micropollutants behave when they interact with microplastics," says Dan. "This helps us understand the true level of hazard posed by micropollutant-laden microplastics, while also providing ideas for how plastics may be altered to eliminate microplastics or better control their abilities to transport other hazardous chemicals."

About *chemistry*

Being a chemist means learning about and working with the building blocks of matter. Chemists explore the properties of matter, how different substances interact and what happens when changes take place. "The best part of being a chemist, or a scientist in general, is the thrill of discovering new knowledge," says Dan. "Whenever we perform experiments in the laboratory, we observe chemical phenomena that have either never been seen before, are not well understood or have not previously been explored by our methods."

Chemists may be involved in many different activities. "Most professional chemists work in industry and may spend much of every day in a laboratory or factory running chemical syntheses, monitoring chemical processes, making chemical measurements or creating computer models of chemicals, their reactions and their properties," says Dan. "Those working in national laboratories around the world do experiments, read scientific articles in their area of speciality and brainstorm creative ideas for new experiments, theories, synthetic chemicals and chemical materials." University-based chemists are often also involved in teaching and mentoring students.

Future chemists will address the challenge of making new plastic food and drink packaging that is safer for humans and can be more easily recycled or degrades more effectively if released into the environment. "Micropollutants of great concern these days are poly- and perfluoroalkyl substances (PFAS), also known as 'forever chemicals'," says Dan. PFAS are very useful chemicals, found in non-stick coatings, lubricants and fire extinguishers, but they are also lipophilic and hazardous to humans and animals. "Chemists in the future will be working to make new materials that have similar useful properties but are far less persistent in the environment and far less hazardous."

Download the team's resources from futurumcareers.com/how-can-studying-microplastics-and-micropollutants-protect-human-health

Pathway from school to *chemistry*

At school, focus on chemistry, mathematics and physics to build a strong base. "At university, students should take more in-depth courses in chemistry, biochemistry, math and physics," says Dan. "Strong backgrounds in computer programming, modelling and data science are also becoming increasingly important."

"Chemists need to be curious," says Dan. "They need to be able to think creatively and come up with new ideas that will help solve or better understand the world's existing and emerging problems. As modern chemistry is very much a collaborative science, they also need to be able to work closely with collaborators from chemistry and other sciences, and those from entirely different fields like business. Chemists must also be strong communicators who are able to explain complex chemical phenomena to other scientists, policy makers and the public."

Explore careers in *chemistry*

Chemists can work in medicine, academia, national laboratories, or the chemical, pharmaceutical or consumer products industries. Chemists solve problems, create new products, get involved in policymaking and standards-setting, or teach and train the next generation of scientists.

"The American Chemical Society (**acs.org**) and the Royal Society of Chemistry (**rsc.org**) are the most well-known professional chemistry societies and encourage student membership," says Dan. "They provide many helpful resources to chemists as they develop in their careers and many opportunities for networking."

"There are many student-centred organisations, such as Alpha Chi Sigma and Phi Lambda Upsilon in the US for students in college or graduate school," continues Dan. "These provide many opportunities and are excellent venues for meeting others and networking. For example, the Kansas State University local chapter of Alpha Chi Sigma provides extensive opportunities for students to become involved in outreach activities."

Meet *the team*



Mohammad Motiur Rahman

My high school science teacher inspired me to study chemistry. His ability to observe and explain daily phenomena was fascinating.

Every day in the lab is a dynamic, hands-on adventure! My role is an exciting mix of two worlds: as a teaching assistant, I get to help undergrads discover their own spark for chemistry, and as a research assistant, I dive deep into my own research. It's collaborative, fast-paced and never boring!

Every experiment I run and every challenge I solve brings me closer to my ultimate dream: becoming an independent researcher who can bring positive changes in society to make our future lives more liveable.

Mohammad's *top tips*

1. Look for the daily magic, not just formulas. Chemistry isn't just equations on paper; it's the secret code behind everything happening around us every second.
2. Treat lab setbacks like a puzzle. Real scientists don't get things right on the first try! Learning through trial and error is half the fun, and solving a tricky problem feels amazing.
3. Dream big about impact. Chemistry gives you the power to tackle huge real-world challenges.



Olawale Aina

I grew up in Lagos, Nigeria, and my grandfather, a retired geochemistry professor, used to take me on walks along the Lagos Lagoon. He'd explain how years of industrial pollution had changed the oily sheen on the water. Those walks planted a question in my head: What is actually happening to our water, at the smallest possible level?

I previously studied environmental management and toxicology, which shapes how I approach my chemistry research: always connecting the small details back to the bigger environmental picture.

I study how organic micropollutants stick to the surface of microplastics. Using SMT, I can watch individual molecules, and that level of detail helps explain why microplastics act like tiny sponges and delivery trucks for pollution in rivers, lakes and oceans.

I want to keep working at the intersection of chemistry and environmental protection, using science to answer real-world pollution questions to help communities like the one I grew up in.

Olawale's *top tips*

1. Stay curious about the 'why' behind things you notice in the world around you.
2. Don't be afraid to change direction once you find the question that really grabs you.



Sorour Salehi

I did not grow up knowing I wanted to be a chemist. Over time, I became fascinated by the idea that things we cannot see can explain so much of what happens around us. Now, I get to connect that curiosity with an environmental problem that affects all of us: plastic pollution.

I enjoy the independence I have as a researcher. I have space to think, try new ideas, make mistakes, troubleshoot problems and slowly find my own way of doing research.

Research can be frustrating, but it teaches you patience and how to keep going when the answer is not clear. For me, turning small observations into new understanding is one of the most rewarding parts of being a scientist.

Sorour's *top tips*

1. As a high school student, you do not need to know what you want to do – I'm still figuring out what I want my long-term career to look like!
2. Do not judge yourself by whether every class or experiment feels easy. Being a good scientist means being curious enough to keep asking questions when you do not know the answer.

Plant power: how can phytoremediation help tackle pollution?



For decades, industrial activity has been polluting our soils, waters and air with toxic metals. This threatens wildlife, contaminates food supplies and puts human health at risk, but a potential solution has been growing around us all along. **Dr Naira Ibrahim** from **Jackson State Universit**y in the US is investigating the power of plants to absorb toxic metals from contaminated environments. Through her research, Naira has discovered that some remarkable plants may not only be able to help restore damaged ecosystems, but could also play a role in human medicine.



Dr Naira Ibrahim

Associate Professor of Environmental Science, Department of Biology, Jackson State University, USA

PROFILE

Fields of research
Environmental science; phytoremediation

Research project
Studying the genetic basis of phytoremediation in *Nerium oleander* and exploring its potential health benefits

Funder
US National Science Foundation (NSF)

doi: 10.33424/FUTURUM728

Talk like an ...

environmental scientist

Genetic sequencing — a method used to read the order of DNA building blocks to understand genetic information

Heavy metals — metals that can be harmful to living things when present in high amounts, such as lead, cadmium and zinc

Ornamental plants — plants grown mainly for their appearance, such as for gardens, landscaping or decoration

Phytoremediation — the use of plants to remove, reduce or control pollutants in soils, water or air

Enhanced weathering — a method of speeding up natural rock breakdown so that they absorb more carbon dioxide from the atmosphere

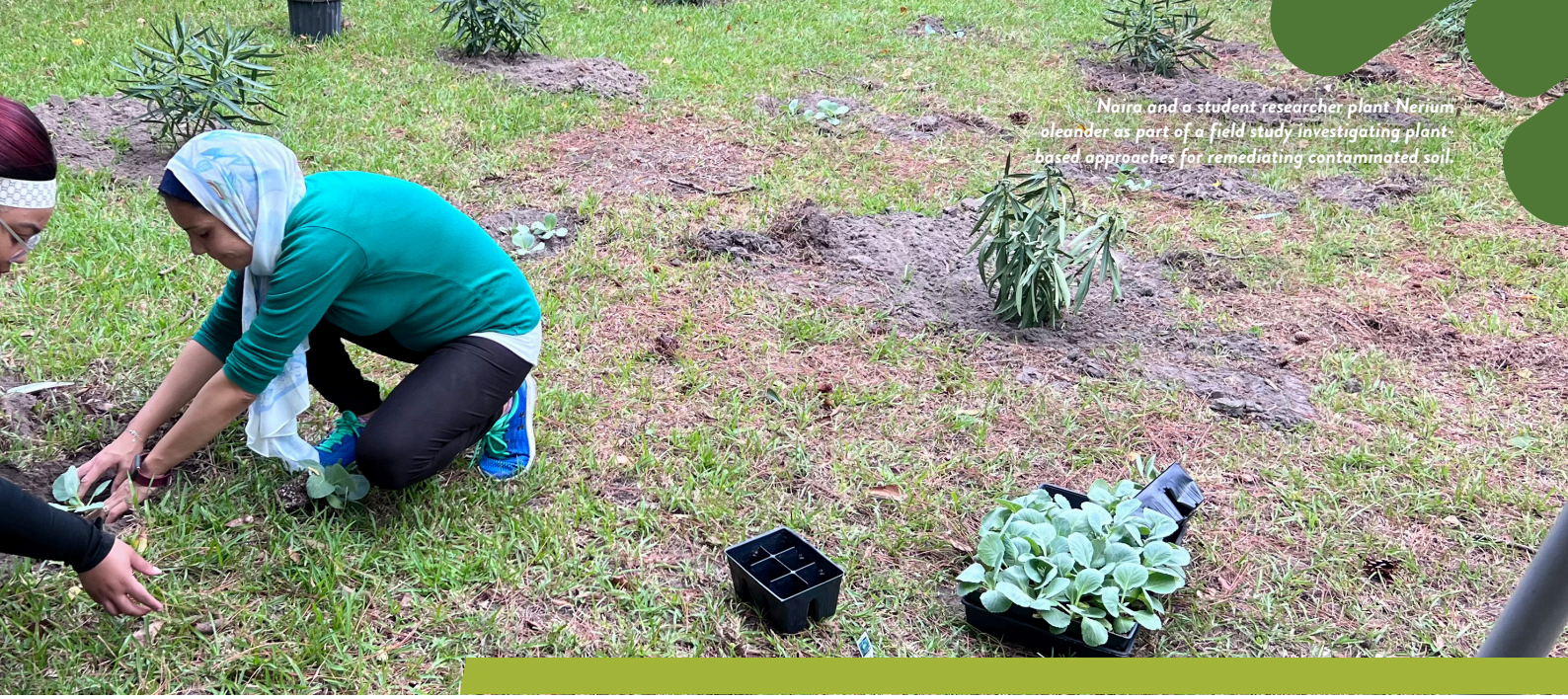
From industrial waste and oil spills to mining and agriculture, human activities release a wide range of pollutants into the environment, including toxic metals such as cadmium (Cd), lead (Pb) and zinc (Zn). These can linger for decades, contaminating food crops and drinking water and increasing the risk of serious health problems, including damage to the brain, kidneys and nervous system. So how can we clean up these stubborn pollutants without causing even more harm?

"Phytoremediation is a sustainable, nature-based technology that uses plants to remove, stabilise or detoxify pollutants from soil, water and even air," says Dr Naira Ibrahim from Jackson State University. "Certain plants have the remarkable ability to absorb contaminants such as heavy metals through their roots and either store them safely within their tissues or transform them into less harmful forms."

Nerium oleander

Naira is investigating the phytoremediation potential of ornamental plants. "Some plants act like natural filters, extracting pollutants such as toxic metals from contaminated environments while continuing to grow and improve soil quality," says Naira. "Compared to conventional methods such as excavation or chemical treatment, phytoremediation is more affordable, environmentally friendly and sustainable. It requires less energy, produces minimal waste, preserves soil structure, enhances biodiversity and creates green spaces instead of disturbing ecosystems. It also provides long-term environmental benefits while reducing clean-up costs for communities."

Naira's research is focused on *Nerium oleander*, an evergreen shrub with pink, red or white sweetly-scented flowers. This plant has specialised transport proteins which enable it to absorb toxic metals through its roots. "Once inside the plant, these materials are transported into different tissues – including roots, stems and leaves – where they are safely stored within



Naira and a student researcher plant Nerium oleander as part of a field study investigating plant-based approaches for remediating contaminated soil.

cellular compartments, minimising damage to the plant itself," says Naira. "Our research has shown that *N. oleander* is highly tolerant of contaminated environments because it possesses natural defence systems that protect it from heavy-metal toxicity."

Enhanced weathering

Naira is interested in how phytoremediation can be boosted when combined with enhanced weathering, an innovative climate-change mitigation strategy that accelerates a natural geological process. "Finely crushed silicate rocks, such as basalt, are applied to agricultural or contaminated soils where they react with rainwater and atmospheric carbon dioxide (CO_2)," explains Naira. "This reaction permanently stores carbon in stable mineral forms, removing it from the atmosphere and improving soil fertility."

Beyond capturing carbon, enhanced weathering can improve soil health by releasing essential nutrients for plant growth and helping trap toxic metals, reducing their movement into groundwater. Combining this with phytoremediation could offer a powerful strategy for restoring polluted land. "When grown in soils treated with enhanced weathering minerals, *N. oleander* benefits from improved soil fertility and healthier growing conditions," says Naira. "Meanwhile, the rock amendments help reduce heavy-metal mobility while the plant actively extracts contaminants."

The genetics behind *N. oleander*

To understand what makes *N. oleander* such an effective natural clean-up tool, Naira is investigating the genes that allow the plant to absorb, transport and safely store toxic metals. The research combines plant biology, environmental science, genomics, microbiology and bioinformatics to uncover how the plant responds when it encounters pollution.

Using genetic sequencing, Naira can identify which genes are activated when *N. oleander* grows in contaminated soils and which microbes improve the plant's ability to enhance the soil. Additional techniques, including imaging methods such as X-ray fluorescence and analysing root-associated microbes, reveal how plants and microorganisms work together to enhance the soil.

"Combining these techniques allows us to identify which genes become active when plants are exposed to heavy metals and how microbes contribute to improving phytoremediation efficiency," says Naira.

Plant power – environmental and medical applications

Early findings show that when *N. oleander* is planted in contaminated soils, it switches on a range of genes that help transport toxic metals, defend against damage and protect its own cells in stressful conditions. Naira's research also highlights the importance of interactions between plant genes and beneficial soil microorganisms.

"In the future, this knowledge could help scientists develop improved phytoremediation plants through selective breeding or biotechnology, leading to faster, safer and more efficient cleanup of contaminated land and water," says Naira. "Ultimately, this research has applications in environmental restoration, sustainable agriculture, climate resilience, public health and even future space agriculture."

The research has also revealed exciting hidden potential beyond environmental cleanup. "*N. oleander* produces several bioactive compounds with antimicrobial, antioxidant and anticancer properties," says Naira. "Our current research is investigating whether extracts from this plant can inhibit the growth of colorectal cancer cells."

Community engagement

In Mississippi, where decades of intensive industrial activity have contributed to environmental contamination, Naira is working with communities to explore sustainable solutions. "We are collaborating with local stakeholders, students and environmental partners to evaluate contaminated sites, monitor soil and water quality, and identify sustainable remediation strategies," says Naira. "We are aiming to reduce environmental pollution, improve ecosystem health, support community resilience and provide scientific data that can guide future environmental management and policy decisions."

Looking ahead, Naira is exploring how genetics and microbes can make phytoremediation even more effective. "One of my long-term goals is to develop environmentally sustainable technologies that simultaneously clean contaminated soil and water, improve agricultural productivity, reduce greenhouse gas emissions, and protect public health," she says. "I also hope to continue mentoring students from diverse backgrounds and preparing the next generation of scientists to solve complex environmental challenges through interdisciplinary research."

About *environmental science*

The choices we make and the actions we take shape the future of our planet, and if you are curious about how to make positive changes to our environment, then environmental science may be the career for you. Environmental science explores how land, water, air, plants, animals and people are all connected, and what happens when those connections are disrupted.

"Environmental science allows us to solve global challenges including pollution, climate change, biodiversity loss and water quality," says Naira. "It offers exciting careers in research, government, industry, conservation, biotechnology and environmental consulting." Opportunities in the field are as varied as the many different environments on our planet, including specialising in wildlife conservation or marine biology, developing renewable energy sources or sustainable agricultural methods, or tackling pollution using plants, like Naira.

Within those areas, roles can also be incredibly varied. For Naira, "A typical day includes teaching, supervising laboratory research, analysing environmental and genomic data, writing grant proposals, publishing research and collaborating with scientists." An important part of her work is mentoring students from diverse backgrounds and creating opportunities for them such as supporting her work with communities in Mississippi.

Naira is keen to emphasise the interdisciplinary nature of environmental science and how it brings together knowledge and expertise from many different fields. She says, "Environmental science combines plant biology, genetics, microbiology and environmental chemistry to develop sustainable solutions for pollution, climate resilience and healthier communities."

Environmental science is evolving quickly, and newer developments in the field involve the use of artificial intelligence, satellites and drones. Future environmental scientists may even get to play an important role in space exploration by creating sustainable ecosystems for space agriculture using tools such as phytoremediation that have been discovered here on Earth.

Pathway from school to *environmental science*

"Students should study biology, chemistry, environmental science, mathematics, physics, computer science, data analysis and statistics," says Naira. "Environmental problems are interdisciplinary and require teamwork, persistence, critical thinking and strong analytical skills."

Naira encourages students to seek out internships or work experience opportunities, or volunteer to support research projects.

Explore careers in *environmental science*

Explore the American Society of Plant Biologists (**aspb.org**), the Institution of Environmental Sciences (**the-ies.org**) or the American Geophysical Union (**agu.org**) for useful resources, career advice and opportunities to attend events and meet professionals in the field. You could even consider joining as a student member.

You can learn more about the work of Naira and her colleagues in the Department of Biology at Jackson State University here: **jsums.edu/biology**



Download Naira's resources from **futurumcareers.com/plant-power-how-can-phytoremediation-help-tackle-pollution**

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Naira presenting her research at the Future Energy Summit, highlighting sustainable approaches to environmental remediation and energy-related environmental challenges.



Meet *Naira*

As a teenager, I was fascinated by plants and nature. Learning how plants interact with the environment inspired me to pursue environmental science and phytoremediation research.

I enjoy discovering new knowledge while mentoring students and helping them become independent scientists.

I am motivated by developing sustainable solutions that improve environmental and human health while inspiring the next generation of scientists.

Key to my success have been persistence, curiosity, collaboration, continuous learning and mentoring.

To unwind from work, I enjoy spending time with my family, gardening, reading scientific literature and spending time outdoors.

Naira's *top tips*

Never stop asking questions. Work hard, seek mentors, stay curious and remember that every scientist begins by learning one step at a time.

How can hydrogels remove heavy metal pollution from wastewater?

Industrial processes often generate wastewater that is contaminated with pollutants such as heavy metals and toxic chemicals. Before this water can be released into the surrounding environment, it must be treated to remove these harmful substances. At **Universidad de Guadalajara** in Mexico, **Dr Ruben Octavio Munoz Garcia**, **Dr Diego Alberto Lomeli Rosales** and **Dr Juan Carlos Sanchez Díaz** are developing innovative hydrogels that can remove toxic heavy metals from wastewater.



Dr Ruben Octavio Munoz Garcia

Associate Professor, Department of Chemistry



Dr Diego Alberto Lomeli Rosales

Associate Professor, Department of Chemistry



Dr Juan Carlos Sanchez Díaz

Professor, Department of Chemical Engineering

Centro de Ciencias Exactas e Ingenierias, Universidad de Guadalajara, Mexico

Fields of research

Chemistry; hydrogels

Research paper

A Poly(Acrylic Acid)-Based Hydrogel Crosslinked with Hydroxypropylcellulose as a Clarifying Agent in Nickel(II) Solutions. (2025) **doi: 10.3390/gels11070560**

Funder

Universidad de Guadalajara (PROSNII-2026)

doi: 10.33424/FUTURUM726

PROFILES

Talk like an ...

environmental chemist

Adsorption – when molecules from a gas or liquid stick to the outer surface of a material

Carboxylate group – a negatively charged chemical group (formed when a carboxylic acid group loses a hydrogen ion) that can attract and bind positively charged heavy metal ions

Heavy metal – a metallic element with a relatively high atomic weight and density that can be toxic to living organisms and pollute the environment

Hydroxypropylcellulose – a modified form of cellulose used to improve stability

Ion – an atom or molecule that has an electrical charge because it has lost or gained electrons

Polymer – a long, chain-like molecule made from thousands of smaller molecules

Sodium hydroxide – a highly corrosive powder used in many cleaning products

Solvent – a liquid that dissolves another substance to form a solution

Wastewater – a byproduct generated by many industrial processes that often contains pollutants

All over the world, our waters are being polluted by toxic heavy metals that pose a threat both to aquatic ecosystems and human health. Many industries, such as chemical manufacturing and textile production, release wastewater into their surrounding environments and local sewage systems. Although there are regulations designed to prevent this pollution, many factories and manufacturing plants still release untreated wastewater that is full of heavy metals.

"This wastewater can pollute soil and groundwater and contaminate rivers and lakes," says Dr Ruben Octavio Munoz Garcia from from Universidad de Guadalajara. "In some cases, heavy metals have even been found in fish." Drinking contaminated water and eating contaminated fish can cause serious health problems, including kidney and blood diseases.

Alongside his colleagues Dr Diego Alberto Lomeli Rosales and Dr Juan Carlos Sanchez Díaz, Ruben is improving a technique for

Download the team's resources from futurumcareers.com/how-can-hydrogels-remove-heavy-metal-pollution-from-wastewater

removing heavy metals from contaminated wastewater.

How to treat industrial wastewater

"Current methods for treating industrial wastewater are often expensive, generate secondary waste and require large amounts of energy or chemicals," says Diego. "Many of these methods are also not particularly effective at removing low concentrations of heavy metals."

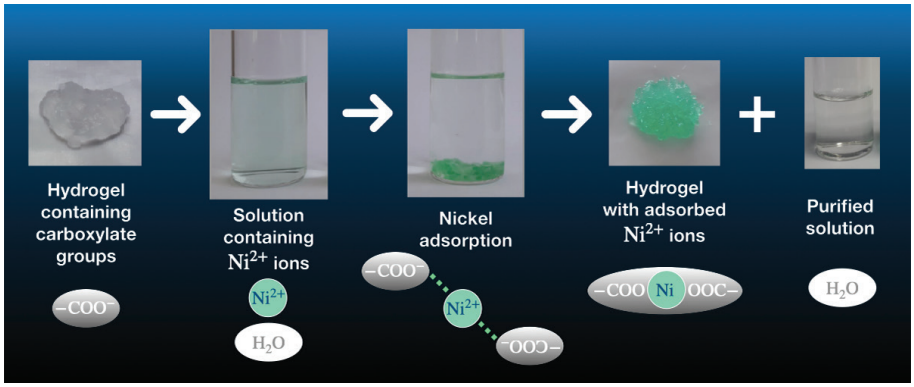
To overcome these limitations, Ruben, Diego and Juan are developing a new wastewater treatment technique based on hydrogels – three-dimensional networks of polymers that can hold large amounts of water while maintaining their structural integrity. "To remove heavy metals from wastewater, hydrogels are placed in a solution containing heavy metal ions," explains Juan. "After a short period of time, the swollen hydrogel is taken out of the solution, removing the adsorbed heavy metals from the water."

How hydrogels work

"The ability of hydrogels to adsorb heavy metal ions depends on the number of active binding sites," explains Ruben. "Increasing the number of these binding sites enhances the adsorption potential of the hydrogel." Another way to make hydrogels more effective is to improve their structural integrity. This can be done by a process known as crosslinking.

"Crosslinking is the chemical process in which two or more polymer chains are bonded together," explains Diego. "The structural integrity of the hydrogel is provided by the three-dimensional polymer network formed through crosslinking." Without crosslinking, the polymer chains would simply dissolve in the water. By bonding the polymers together, they form interconnected networks that swell in water rather than dissolving.

The amount of crosslinking in a hydrogel determines how stable it is and how much water it can adsorb. A hydrogel with lots of crosslinking will be structurally stable but able to hold less water. On the other hand, a hydrogel with less crosslinking will be able to hold much more water, but is more likely to deform and release the captured water. Ruben, Diego and Juan are investigating new methods for creating hydrogels that can adsorb large amounts of water while maintaining their structural integrity.



The team's hydrogel decontaminated a solution containing nickel ions, turning green in the process.

> ***These carboxylate groups act like tiny molecular claws, surrounding and tightly holding heavy metal ions.***

How to make hydrogels more effective

"We incorporated cellulose into our hydrogels to improve their structural stability during the adsorption process," says Juan. "It acts as a reinforcing component, helping the hydrogel retain its shape during adsorption." Cellulose is the structural component of plant cell walls and is the most abundant natural polymer in the world, making it an affordable and sustainable material.

Cellulose has a highly organised molecular structure and tight internal hydrogen bonds, making it incredibly tough and durable. However, this toughness also means that it cannot dissolve in water or organic solvents, making it difficult to incorporate into hydrogels. To overcome this problem, Ruben, Diego and Juan used a modified form of cellulose called hydroxypropylcellulose in their hydrogels.

Turning cellulose into hydroxypropylcellulose involves breaking just enough of its hydrogen bonds to make it soluble in water and solvents while maintaining some of its structural integrity. This solubility allows it to easily graft onto the polymer chains that make up a hydrogel, transferring its structural strength to the hydrogel. Hydroxypropylcellulose allows the hydrogel to maintain its structure in industrial treatment pumps where there is high water pressure and rapid flow.

How a hydrogel captures heavy metals

Ruben, Diego and Juan used a polymerised form of acrylic acid as the backbone of their hydrogel. "We converted the carboxylic acid groups on these polymers into negatively charged carboxylate groups by treating them with sodium hydroxide solutions," explains Ruben. "These carboxylate groups act like tiny molecular claws, surrounding and tightly holding heavy metal ions."

The combination of carboxylate traps and hydroxypropylcellulose reinforcement made the team's hydrogel particularly efficient. "In our lab, we performed adsorption tests on our hydrogel in a solution containing nickel ions," says Diego. "Our hydrogel decontaminated the green nickel solution after a quick adsorption process, turning green itself in the process." The hydrogel adsorbed up to 80% of the nickel ions present in the solution, showing how effectively it can remove heavy metals from water.

Ruben, Diego and Juan hope that their innovative hydrogels will allow industries to clean their wastewater more effectively and at a lower cost, protecting surrounding environments, local wildlife and nearby communities.

How can we make paper mills more sustainable and efficient?

Paper mills are incredible machines that churn out thousands of tonnes of paper every single day. Despite this output, engineers are constantly looking for new ways to improve the paper production process. Working in collaboration with **Veolia** and **Holmen Paper** at **RISE Research Institutes of Sweden, Luis Carlos Felix Tapia** is part of a team that has developed a new process for treating and recycling wastewater in paper mills to make them more efficient, sustainable and cost effective. The original concept and project were conceived by **Luis Fernando Delgado Zambrano**, a former researcher at RISE.



Luis Carlos Felix Tapia

Project Manager; Senior Research and Development Engineer, RISE Research Institutes of Sweden



Luis Fernando Delgado Zambrano

Project scientific leader



Fernando Morgan-Sagastume

Project advisor; Senior Process Specialist, R&D AnoxKaldnes MBBR Technologies, Veolia Water Tech



Mathias Bohman

Project participant; Senior Development Engineer, Holmen Paper



Thomas Welander

Senior Advisor, R&D AnoxKaldnes MBBR Technologies, Veolia Water Tech

Fields of research
Chemical engineering; industrial water management; sustainable packaging and materials

Research project
Sustainable process water treatment for the paper industry (SupWat)

Funder
Swedish Research Council for Sustainable Development – FORMAS (Diary number: 2023-02054)

doi: 10.33424/FUTURUM730

Talk like a ... chemical engineer

Aerobic — an organism that requires oxygen to survive

Anaerobic — an organism that does not require oxygen to survive

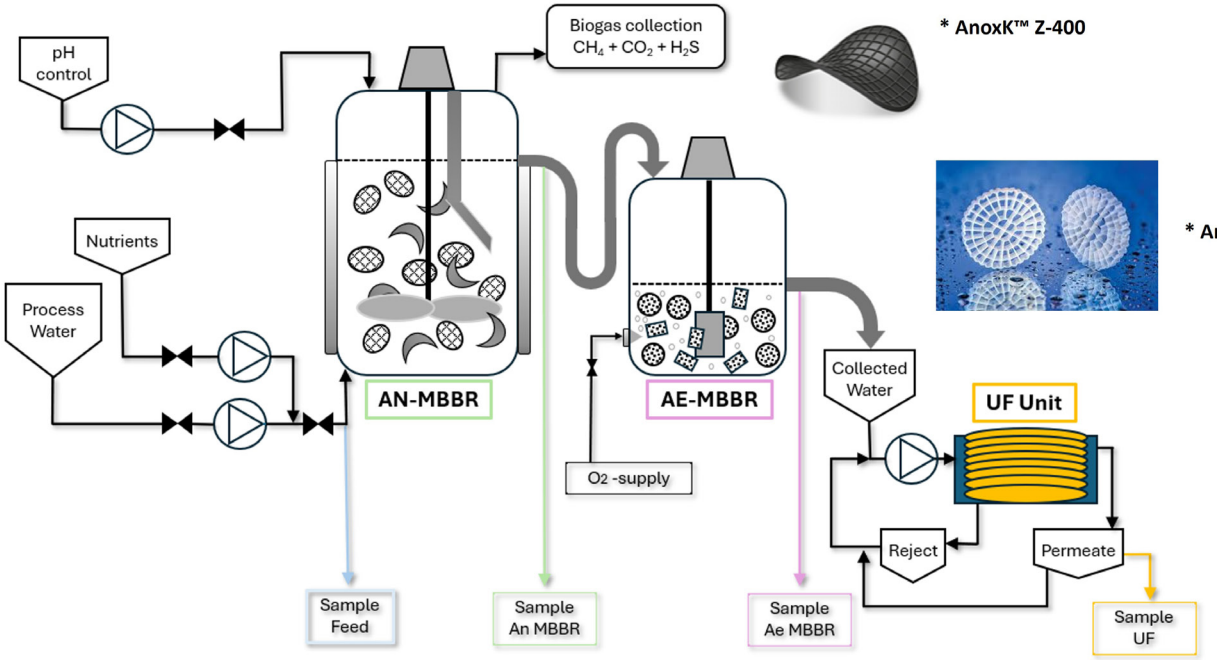
Cellulose — the primary structural component of plant cell walls

Paper mill — a factory that produces paper

Have you ever wondered how paper is made? First, logs are chopped into tiny woodchips, which are then cooked in hot water and chemicals. This process turns the chips into a watery, mushy pulp made of cellulose fibres. The pulp is then cleaned to remove the chemicals and diluted with lots of water to create a mixture that is 99% water and 1% cellulose fibre.

This mixture is then sprayed onto a fast-moving mesh screen and, as the screen moves, the water drains through the mesh, leaving behind a huge, soggy sheet of cellulose fibres. The sheet is then squeezed through hot, metal rollers which press out any remaining moisture and smooth out the surface. When the sheet is fully dry, it is cut into smaller sheets to make paper.

All of this takes place inside giant, complex machines that have been carefully designed to be as productive as possible. Even so, engineers are constantly figuring out new ways to improve these paper mills and make the process more efficient, cost effective and sustainable. For example, A team led by RISE Research Institutes of Sweden –



* AnoxK™ Z-400

* AnoxK™ 5

* (AnoxKaldnes - Veolia)

including research and development engineer Luis Carlos Felix Tapia – together with Veolia and Holmen Paper, have developed a new method for treating and recycling wastewater from papermaking. Originally conceived by Luis Fernando Delgado Zambrano, formerly at RISE, the project aims to improve the efficiency and sustainability of the Swedish pulp and paper industry.

Reusing water

The process of making paper requires an immense amount of water, which is used to dilute the pulp and clean off the chemicals. So, rather than sucking fresh water in from the surrounding environment and dumping wastewater back out, paper mills use a closed water-circulation system to recycle process water. In fact, up to 95% of the water used in these machines is recaptured, treated and pumped back to the start of the system.

Although these closed systems make the paper mills much more sustainable and environmentally friendly, reusing water can affect the efficiency of the process and the quality of the final product. "In paper mills, water is used to transport both the cellulose fibres and the chemical additives," explains Luis. "Unfortunately, this leads to an increased amount of chemicals and unremoved contaminants flowing around the machine." This issue is even more prominent in recycled paper mills where contaminants from the recycled paper are also released into the water stream.

Treating wastewater

Before they can reuse this contaminated water, paper mills must treat it to remove chemicals and dissolved organic materials. "Normally, this is achieved through a combination of mechanical treatment followed by biological treatments," says Luis. Mechanical treatments remove solid waste, such as large particles, sand or fragments of plastic, by passing the water through screens, allowing sediments to settle to the bottom of large tanks, less using microscopic bubbles to capture stray wood fibres and float them to the surface.

Biological treatments remove organic substances, such as dissolved wood sugars (starch) and complex wood resins, by allowing bacteria in the water to feed on them. Usually, this takes place in aerobic biological basins where microorganisms clump together, growing directly in the water (known as activated sludge basins) or as biofilms on plastic supports (known as carriers) that float in the water of a moving-bed biofilm reactor, or MBBR.

"Although aerobic biological treatment is effective, it is also energy-intensive, involves nutrient addition and creates a lot of sludge which has to be processed," says Luis. "Moreover, it does not enable energy recovery from the organic matter, limiting its overall sustainability." On the other hand, anaerobic treatment (using bacteria that do not require oxygen) provides opportunities to reduce energy consumption, nutrient requirements and sludge production. It also has the added benefit of potentially producing methane which can be used as biogas to help power the paper mill. "Although anaerobic treatments have many advantages, they typically require an aerobic step to completely remove the dissolved substances and contaminants," explains Luis.

Improving the system

"During the SupWat project, we used an anaerobic MBBR followed by an aerobic MBBR (AnoxKaldnes MBBR Technologies, Veolia) as the main biological treatment steps, then a final ultrafiltration step," says Luis. Using anaerobic treatment meant that less sludge was produced, and combining this with aerobic treatment allowed the system to remove dissolved substances more efficiently. Luis and the team at RISE tested this innovative system and found that it could help to improve the energy efficiency of the paper production process.

"It has been estimated that the drying section of the paper making process consumes 64% of the total energy," says Luis. "Higher concentrations of dissolved substances in the process water increase drainage time and thus energy consumption in the drying stage." Luis and his team showed that the removal of dissolved substances by their new system reduced drainage time, which could potentially lead to greater energy efficiency, performance and sustainability in Sweden's paper mills.

"I love the thrill of finding innovative solutions that will eventually lead to practical applications in the industry," says Luis. "I enjoy the combination of being in the laboratory and finding results that will be able to scale the processes into real paper mills."

Download the team's resources from futurumcareers.com/how-can-we-make-paper-mills-more-sustainable-and-efficient

What are lakes revealing about the impacts of permafrost thaw?



As a limnologist at **York University** in Canada, **Dr Jennifer Korosi** spends her summers collecting water samples and mud from the bottom of lakes in the Dehcho region of the Northwest Territories. By analysing these mud and water samples, Jennifer is uncovering how lakes in peatland environments are responding to permafrost thaw, helping communities to manage the impacts of climate change.



Dr Jennifer Korosi

Limnology and Paleoenvironmental Research Group, Faculty of Environmental and Urban Change, York University, Canada

Field of research
Limnology

Research project
Studying past and present changes in northern peatland lakes to understand the impacts of permafrost thaw

Funders
Natural Sciences and Engineering Research Council of Canada (NSERC); ArcticNet

Website
lprg.ca

doi: 10.33424/FUTURUM722

PROFILE

Talk like a ...

limnologist

Logger — an instrument that continuously measures water properties

Peatland — a type of wetland in which waterlogged soils prevent the full decomposition of organic matter

Permafrost — ground that remains frozen for two or more consecutive years

Sediment core — a tube of mud collected from the bottom of a lake

Sporadic discontinuous permafrost — land in which 10-50% of the ground is permafrost

Two-Eyed Seeing — combining Indigenous knowledge with western science

Watershed — the land that drains into a river or lake

As the world warms up, the permafrost underlying Canada's northern forests is thawing, resulting in dramatic changes to the landscape and significant impacts for communities in the region. Dr Jennifer Korosi, a limnologist at York University, is studying northern peatland lakes to understand the impacts of permafrost thaw on water quality.

How is permafrost thaw impacting peatlands?

"The sporadic discontinuous permafrost zone is very sensitive to increases in air temperatures, so climate warming is causing widespread permafrost degradation," says Jennifer. "As the permafrost thaws, peatlands collapse causing trees to lean over (what we call 'drunken trees'). And as the ground converts into wetland, the trees die due to the wetter soil conditions."

Jennifer and her team are examining the impacts of permafrost thaw on inland waters by studying the lakes around the Scotty Creek Research Station, an Indigenous-led field research station in the Dehcho region of the Northwest Territories of Canada. Run by the Łíídlı̨ Kų́ę́ First Nation in partnership with Sambaa K'e and Tthets'éhk'edélî First Nations, the research station allows environmental scientists to study sporadic discontinuous permafrost peatlands in collaboration with Indigenous knowledge keepers. "The station provides a space for



'Drunken trees' are a telltale sign of thawing permafrost, which converts forests into wetlands in sporadic discontinuous permafrost peatlands. © Jennifer Korosi

community members and academic researchers to learn from each other to understand how the lands and waters of the region are being transformed by climate change, and how communities can respond," says Jennifer.

How is Jennifer studying peatland lakes?

"Our work combines lake sediment coring with intensive lake field studies to better understand the structure and function of the lakes, and how they are connected to their watersheds," says Jennifer. She uses gravity coring to collect sediment cores, which involves lowering a tube from a boat to the bottom of a lake and allowing it to slowly sink into the mud. The top of the tube is then sealed, allowing the team to pull the tube back up through the water while keeping the sediment inside. "It's much like if you put a straw in liquid, seal the top with your finger, then lift the straw up," Jennifer explains. "Before we pull the tube fully out of the water, someone reaches under it and seals the bottom end to stop the mud from falling out."

But extracting the mud is only the beginning of the process. "Lake sediment coring is a quick process – we can core several lakes in a day," says Jennifer. "It then takes a year or more to analyse the cores back in the lab!" Mud builds up on the bottom of a lake over time, so the sediment at the top of the core is younger than the sediment at the bottom. This means sediment cores provide a history of the lake, and by analysing changes in the sediment throughout the core, Jennifer can uncover changes in the lake's conditions through time.

> **"We've learnt that each lake has a unique relationship to its surrounding landscape."**

For example, changes in sediment chemistry and the types of tiny fossils (e.g., algae, zooplankton and invertebrates) preserved in the sediment tell Jennifer how nutrient, temperature and light levels in the lake have changed throughout the past, how food web structures have evolved, whether there were past fires in the surrounding landscape, and if potential contaminants like mercury have increased in lakes. "All this information can be found in the lake mud!" she says.

To study how the watershed characteristics and weather conditions affect present-day lake conditions, Jennifer and the team put loggers in the lakes each year in early June. These continuously record measurements such as temperature, dissolved oxygen and light levels over the summer, before Jennifer returns in late August to collect them and retrieve the data. "We also collect water samples at the beginning and end of the summer to look at water chemistry and algal communities," she says. "We've been doing this for several years now, building up a long-term dataset of lake conditions and how they are changing from year to year".

What has Jennifer discovered?

"Lake responses to permafrost thaw are unique," says Jennifer. "All lakes in the region are being impacted by accelerating permafrost thaw, but we aren't seeing any consistent regional trends in how the lakes are responding." Her team's research indicates that fire is likely an important trigger for long-term lake change, which Jennifer suspects is because wildfires increase permafrost thaw.

As the peatland thaws, more nutrients and organic matter are being delivered to lakes via rivers, which is having various impacts on the lakes. Some, but not all, are turning darker in colour due to this organic matter.

"Overall, we've learnt that each lake has a unique relationship to its surrounding landscape," concludes Jennifer. She is continuing to investigate how lakes reflect changes in their watersheds so she can better predict how they will respond to permafrost thaw. "By working together with community members, we can use a Two-Eyed Seeing approach to gain deeper insights into how and why lakes are changing," says Jennifer. "I hope our research responds to concerns identified by communities about how their lands and waters are changing, and that they can use our findings in a meaningful way."

About *limnology*

Limnology is the study of inland waters. This includes lakes, ponds, rivers and streams, as well as wetlands like the permafrost peatlands Jennifer studies. Limnology is vital for conserving freshwater supplies and protecting aquatic ecosystems.

Jennifer's research falls in the subdiscipline of paleolimnology – the study of lake sediment cores to reconstruct environmental change over time. "Paleolimnology lets us look back in time (decades, centuries or millennia – depending on how deep the sediment core is) to track environmental changes and better understand how human impacts like pollution and climate change have altered lake ecosystems," she explains.

What does limnology fieldwork involve?

The Scotty Creek Research Station has not been immune to the effects of permafrost thaw – it has had to be relocated twice since it was first constructed in the 1990s as the peatland has collapsed, and it had to be rebuilt after being burnt down by a forest fire in 2022. The station is composed of permanent tents connected by a series of boardwalks that allow people to walk around on the wet peatland. There are no roads to access the station, so Jennifer and her team arrive by float plane. The station operates all year round, and in winter, researchers travel there by snow machine.

"A typical day of fieldwork involves hiking to the lakes from the station with our gear, then spending several hours collecting cores and water samples, before carrying everything back to base," says Jennifer. "It's hard work and involves a lot of heavy lifting, but fieldwork is the best part of the job!"

Fieldwork can also be challenging. The weather can be bad, equipment can break and the remote location means researchers can't just go to the store to get new supplies. "To overcome this, we prepare extensively for field seasons," says Jennifer. "We try to anticipate what might go wrong and have back-up plans in place to deal with them. But we can't anticipate everything, so the most important thing is to be able to think creatively and stay calm in stressful conditions."

Pathway from school to *limnology*

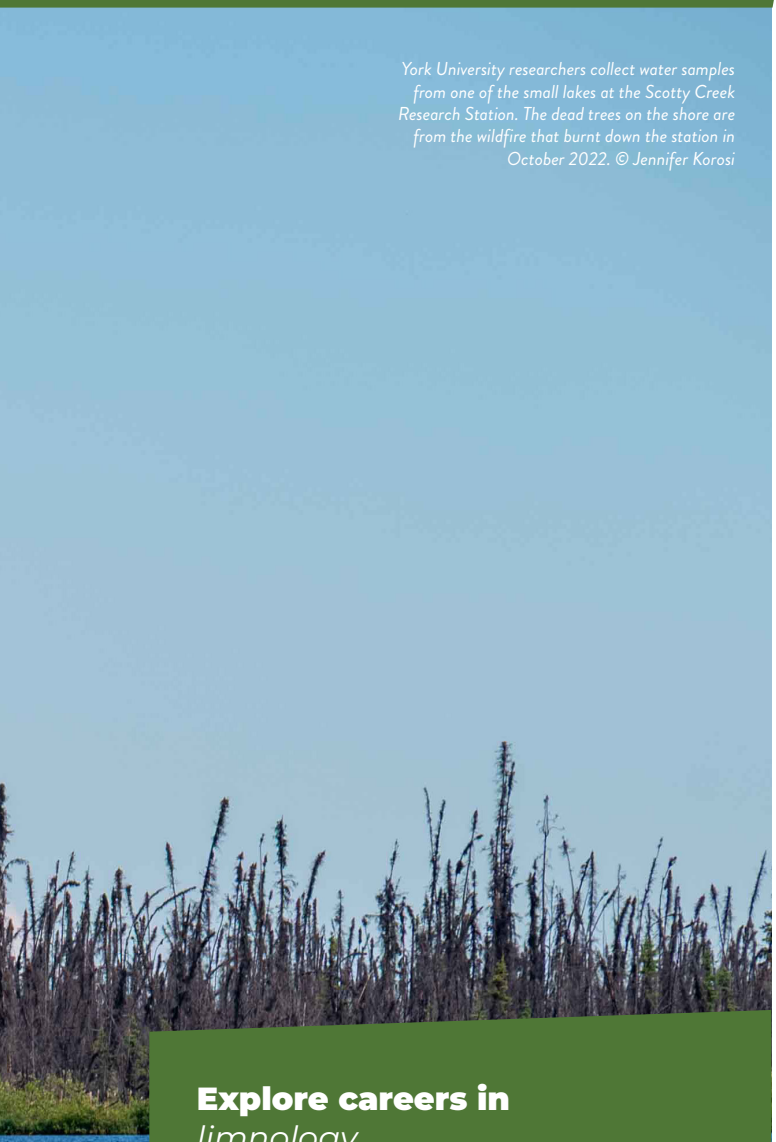
"Limnology is a field that integrates biology, chemistry, physics, physical geography, geology and social sciences to better understand and protect our inland waters," says Jennifer.

At high school, studying geography, biology and chemistry will teach you about water systems, while mathematics will give you the skills limnologists need to statistically analyse data.

"The most common university degrees for studying limnology are biology, physical geography and environmental science," says Jennifer. "There are also several environmental technician programmes at colleges that train students in limnological sampling."

"The most important advice I have is to spend time on or near the water," says Jennifer. "There is so much you can learn from lakes that you can't easily learn in a classroom. And if you are interested in field-based limnology work, learn to be comfortable working in bad weather!"

Download Jennifer's resources from futurumcareers.com/what-are-lakes-revealing-about-the-impacts-of-permafrost-thaw



York University researchers collect water samples from one of the small lakes at the Scotty Creek Research Station. The dead trees on the shore are from the wildfire that burnt down the station in October 2022. © Jennifer Korosi

Explore careers in *limnology*

"Limnology work has never been more important, as urbanisation and natural resource development accelerates in the context of a warming climate," says Jennifer. "We need people who can understand and appreciate the complexity of our inland aquatic ecosystems and help in the search for solutions."

Limnologists can find work with governments, conservation authorities, environmental consulting companies, not-for-profit organisations and research institutions.

Look for opportunities to volunteer with conservation authorities and lake stewardship societies to gain practical experience and meet like-minded people. For example, organisations such as Freshwater Conservation Canada (**freshwaterconservationcanada.org**) and the Canada Lakes Conservation Association (**canadalakesconservation.com**) run activities and events for community members.

Academic organisations provide information about limnology research and careers. Explore the websites of the International Society of Limnology (**limnology.org**), the Association for the Sciences of Limnology and Oceanography (**aslo.org**), the International Paleolimnology Association (**paleolim.org**) and the Society of Canadian Aquatic Sciences (**scas-scsa.ca**).



Meet *Jennifer*

In high school, I played hockey and soccer, and I was an avid reader. I've also always loved to be outside. As a teenager, I enjoyed hiking, camping and paddling – activities I still love today. I also now enjoy gardening, skiing and fishing – anything that gets me outside!

I took a limnology course during my undergrad in biology, and that was the moment I knew I wanted to be a limnologist. I got a summer research assistant position with the professor of that course, which involved three weeks of fieldwork taking sediment cores from lakes in the Halifax metropolitan area. I then did my undergraduate honours thesis with the same professor, studying zooplankton fossils in sediment cores from lakes in the Muskoka region of Ontario, which led me to graduate school.

I've been lucky to have so many amazing field experiences! One of my favourite memories is of a community event at the Scotty Creek Research Station. It was a beautiful day, and it felt meaningful for us to all come together, especially as it came shortly after COVID.

Permafrost thaw is a complicated issue. Bringing together people with diverse experiences and knowledge leads to better research, as well as research that is more likely to lead to tangible benefits for the communities who are most impacted by climate change. As a researcher from a university in southern Canada, I've learned so much from the Dene communities of the Dehcho who have taken care of the land since time immemorial.

I love to be out on the water. The landscapes of the Dehcho region are beautiful, and I feel very fortunate to spend so much time there. I am also passionate about freshwater conservation. I'm grateful to have a job where I can make a difference in raising awareness about the challenges facing our lakes and helping make better decisions about freshwater stewardship.

My favourite fact about lakes is that they have memory! The history of the lake, including how it formed and any disturbances it experienced in the past, influences how resilient a lake is to future stresses.

Jennifer's *top tip*

Don't be afraid to make mistakes. When I look back on my career path, the most important and transformative moments came from difficult times and when I made mistakes. Those mistakes will help you learn and teach you what is important to you and what you are capable of. So focus more on your personal growth rather than comparing yourself to others.

Time-travelling detectives: how are palaeontologists studying ancient organisms?

Fossils contain valuable clues about what organisms living hundreds of millions of years ago looked like and the environments they inhabited. However, revealing their secrets can be tricky. At the **University of São Paulo** in Brazil, **Dr Gabriel Ladeira Osés** is using an array of advanced techniques to study fossils, with each method revealing different pieces of the puzzle. He is particularly interested in soft-tissue preservation and early biomineralised animals – the first organisms to produce mineral-built body parts.





Dr Gabriel Ladeira Osés

Research Fellow, Laboratory of Archaeometry and Sciences Applied to Cultural Heritage, Institute of Physics, University of São Paulo, Brazil

PROFILE

Field of research
Palaeontology

Research project
Using imaging and compositional techniques to study fossils

Funders
São Paulo Research Foundation; National Institute of Science and Technology - Nuclear Physics and Applications; National Council for Scientific and Technological Development; Ceará Foundation for Support to Scientific and Technological Development

Website
sites.google.com/usp.br/lacapc/o-laboratório

doi: 10.33424/FUTURUM724

Talk like a ...

palaeontologist

Accelerator techniques — using particle accelerators to analyse fossils and determine their internal structure or chemical composition

Biomineralisation — the process by which living organisms produce minerals to form hard structures such as shells, bones, teeth or scales

Compositional techniques — techniques to identify the chemical signatures and elements, minerals, and organic matter that make up a fossil or rock

Diagenesis — the physical and chemical changes that happen to a fossil and surrounding sediment during and after the process of becoming rock

Fossilisation — the process by which the remains or traces of an organism become preserved through burial, mineral replacement and other geological processes

Imaging techniques — techniques to create detailed pictures of fossils to reveal their internal and external structures

Morphology — the form and structure of an organism or fossil, including its size, shape and physical features

Fossils hold clues about ancient life. However, during the journey from ancient past to present day they can undergo significant changes, making it difficult to untangle the secrets of the original organism.

"Palaeontologists are detectives," says Dr Gabriel Ladeira Osés from the University of São Paulo. "We use technology to decipher how fossils are preserved and to envisage original characteristics of the organisms."

Biomineralisation and Ediacaran fossils

The earliest known biomineralising animals evolved during the Ediacaran Period (635- 539 million years ago). Fossils of these organisms reveal that they developed hard mineralised tubes, an early form of skeleton. The biomineralisation process was similar to that used by organisms today, such as corals, shellfish and humans, to build hard body parts such as bones, shells and teeth.

We know these early biomineralised animals lived on microbial mats (slimy surfaces made of bacteria) in shallow, oxygen-rich seas. But many questions remain: "Some big challenges include understanding what groups they are related to, their original mineral composition, and



their biomineralisation and reproduction strategies," says Gabriel.

The clues to solving these mysteries can be found by investigating their fossils. "When an organism dies, the soft tissues are readily decomposed by microorganisms, while more resistant, biomineralised parts last longer," says Gabriel. "Some bacteria 'breathe' sulphur and iron instead of oxygen while eating organic matter, which leads to the formation of minerals at decaying carcasses, promoting soft-tissue preservation."

However, the process of diagenesis changes fossils over time. From the moment the organism is buried in sediment until a palaeontologist excavates the fossil millions of years later, pressure, heat, water and chemical reactions alter the fossil's shape and composition.

Investigating using imaging techniques

To untangle the diagenesis process and reveal the clues held by fossils, Gabriel uses a range of imaging and compositional techniques, including accelerator techniques. Imaging techniques such as ionoluminescence (IL), cathodoluminescence (CL) and ultraviolet fluorescence (UVF) reveal the structure of fossils by causing minerals in the fossils to emit visible light.

These techniques highlight the differences between the host rock and fossil structures, and IL and CL also provide clues about the chemistry of the minerals. Gabriel and his team have developed a method to create an IL map, showing how different parts of a fossil or rock light up to reveal subtle differences. UVF works in a similar way, highlighting fossil morphology and areas with different compositions, helping Gabriel decide where to carry out more detailed chemical analyses.

Uncovering clues with compositional techniques

Compositional techniques such as X-ray fluorescence (XRF) and Raman spectroscopy reveal what fossils are made of. XRF uses X-rays to excite atoms in the fossil which then emit X-rays that are characteristic of the chemical elements it contains. Raman spectroscopy uses a laser to interact with molecules in the fossil to identify minerals and organic compounds. Gabriel also uses a suite of palaeoenvironmental geochemistry techniques to examine the chemistry of fossils and surrounding rocks. This is often done by dissolving samples and analysing their chemical composition to uncover the ancient environments and conditions in which organisms lived and were preserved.

Electron microscopy produces highly detailed images of tiny fossil structures while accelerator techniques, such as synchrotron-based computed tomography (CT) scanning, use powerful radiation sources in large laboratories to create high-resolution three-dimensional images of the inside of fossils without causing damage. "Accelerator techniques have several advantages over conventional equipment, like higher sensitivity to detect small amounts of chemical elements and the possibility of measuring smaller, deeper regions in samples," explains Gabriel.

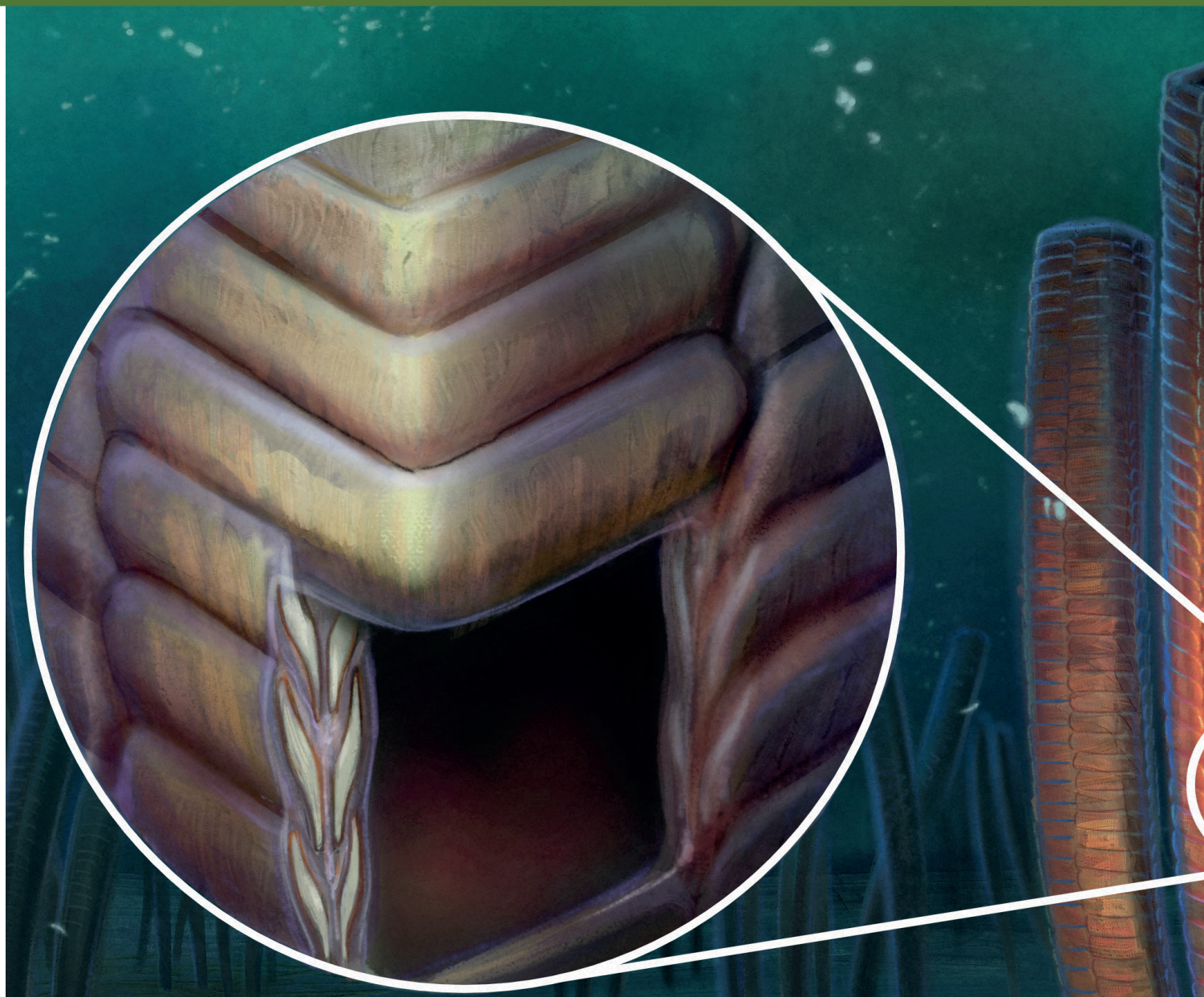
Corumbella and Cretaceous creatures

Gabriel has used a combination of these techniques to transform our understanding of the early biomineralising Ediacaran fossil *Corumbella*. CL and CT imaging provided new details of its skeleton, while electron microscopy and Raman spectroscopy detected mineral components and possible original organic material. "Our results challenge previous biological interpretations of *Corumbella*, allowing us to tentatively suggest a relationship with other organisms," says Gabriel.

Combining palaeontological techniques has also helped Gabriel to uncover how delicate tissues were preserved in Cretaceous (145-66 million years ago) insects and fish. "Electron microscopy showed soft tissues like eyes, muscles and digestive tracts," he says. "XRF, Raman spectroscopy and accelerator techniques provided elemental composition and organic matter identification. UVF highlighted mineral distribution in samples, and IL mapping enhanced fossil boundaries, identification of alteration spots and gave information on rock composition." As a result, Gabriel has been able to develop theories to explain how soft tissues of these insects and fish were preserved.

Digging deeper

Next, Gabriel aims to improve these imaging and compositional techniques so they can detect even smaller structural and chemical differences. Then he hopes to solve even more mysteries about incredible ancient organisms – how they evolved, how they lived and died, and how they were preserved to form the fossils we find today.



About *palaeontology*

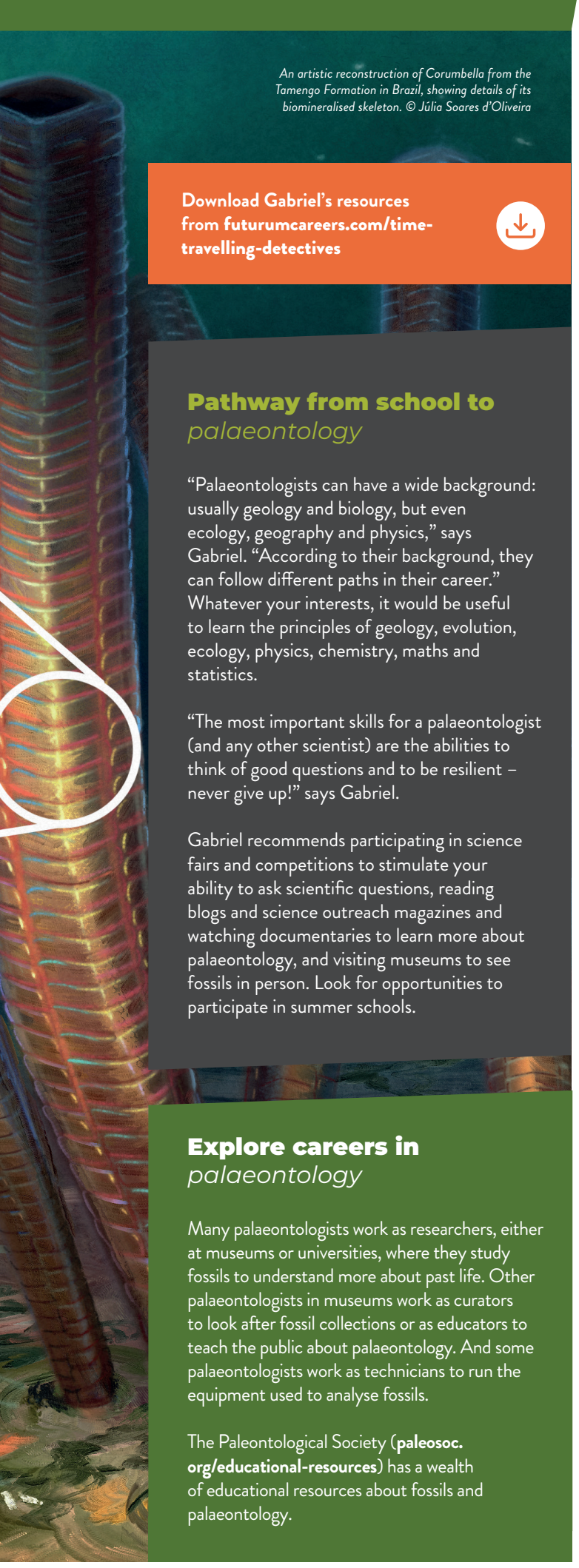
Palaeontology is the scientific study of ancient life. Palaeontologists combine knowledge from different fields to investigate extinct organisms and the environments in which they lived and evolved. "I work with a highly interdisciplinary team," says Gabriel. "There are palaeontologists, sedimentologists, geochemists and physicists."

How do palaeontologists find fossils?
For Gabriel, one of the most exiting parts of the job is searching for new fossils to study back in the lab. "Fieldwork is always a great adventure!" he says. "I have faced broken vehicles and dealt with poisonous snakes and scorpions! It is a great opportunity to meet new people, try exotic food, and gain a lot of experience in logistics, time management and geology." Careful planning and preparation are essential. Before a trip, Gabriel will study geological maps and scientific papers to find promising fossil sites, and then spend time organising transport, equipment and supplies. "In the field, the works is highly coordinated," he says. "People work in different roles according to their expertise – describing rocks, taking photos and collecting fossils."

Gabriel's fieldwork focuses on two fascinating fossil sites in Brazil. The Cretaceous Crato Formation contains exceptionally well-preserved insects, fish, pterosaurs and plants, while the Ediacaran Tamengo Formation houses some of the oldest fossils of biomineralising animals, like *Corumbella*.

Where else do palaeontologists work?
Not all palaeontology happens outside. "A lot of my work is conducted in scientific collections in museums," says Gabriel. "These collections allow palaeontologists to study well-documented specimens using tools not available in the field, like microscopes."

"Lab work is fun too," continues Gabriel. "Planning and running experiments in our lab and at accelerators can be challenging, but it is always exciting to test your ideas and share your findings with others."



An artistic reconstruction of Corumbella from the Tamengo Formation in Brazil, showing details of its biomineralised skeleton. © Júlia Soares d'Oliveira

Download Gabriel's resources from futurumcareers.com/time-travelling-detectives

Pathway from school to *palaeontology*

"Palaeontologists can have a wide background: usually geology and biology, but even ecology, geography and physics," says Gabriel. "According to their background, they can follow different paths in their career." Whatever your interests, it would be useful to learn the principles of geology, evolution, ecology, physics, chemistry, maths and statistics.

"The most important skills for a palaeontologist (and any other scientist) are the abilities to think of good questions and to be resilient – never give up!" says Gabriel.

Gabriel recommends participating in science fairs and competitions to stimulate your ability to ask scientific questions, reading blogs and science outreach magazines and watching documentaries to learn more about palaeontology, and visiting museums to see fossils in person. Look for opportunities to participate in summer schools.

Explore careers in *palaeontology*

Many palaeontologists work as researchers, either at museums or universities, where they study fossils to understand more about past life. Other palaeontologists in museums work as curators to look after fossil collections or as educators to teach the public about palaeontology. And some palaeontologists work as technicians to run the equipment used to analyse fossils.

The Paleontological Society (**paleosoc.org/educational-resources**) has a wealth of educational resources about fossils and palaeontology.



Meet *Gabriel*

As a teenager, I was interested in palaeontology and archaeology. I started with the most popular topics, but with time I discovered a whole new world of possibilities. I learnt that palaeontology can involve working with technology to get more information from samples, which opens new approaches and allows us to answer new questions and push forward the frontiers of knowledge.

I remember being extremely curious about geological cycles – how sedimentary rocks formed in ancient environments, what these environments looked like, how organisms evolved and how fossils formed. The beautiful mystery of the deepness of geological time and the vast information about past life that is recorded in rocks have always motivated me.

I was also inspired by my grandmother (who had a strong connection to nature), my father (a very curious biologist) and my mother (who, together with my father, took my brothers and me for visits to museums and parks). I used to dig for snail shells in my grandmother's garden, and once my classmates and I built a replica of the famous hominid Lucy for a school science fair!

Ediacaran (635-539 million years ago) and Cambrian (539-485 million years ago) fossils have always intrigued me – they provide information about a completely different world compared to modern ecosystems. I have always been amazed by fossils with preserved soft tissues, wondering how they formed and what biological information they bring. Through my work, I hope to uncover the environmental conditions for soft-tissue preservation in these periods.

When I'm not working, I really enjoy outdoor activities, like hiking and riding a bicycle. This helps me connect to nature, which is inspiring because my job is trying to understand it! I also enjoy watching TV shows and documentaries and reading books with mysterious and investigative storylines.

Gabriel's *top tips*

To pursue a career in palaeontology you need to be curious, work hard with consistency, work collaboratively with colleagues, develop creativity, and have courage to overcome troubles and never give up! Something that also helps is to imagine yourself in the future and think, "What will I be doing in the next 10 years or so? Will I be hunting fossils and making new discoveries?"

How are geologists supporting the energy industry?



Geologists play a vital role in the energy industry by locating the resources and minerals needed to power society, while also helping to reduce the negative impacts of our reliance on fossil fuels. **Professor Sherilyn Williams-Stroud** is a structural geologist at **Texas A&M University** in the US. Her research into how fractures impact the way fluids flow through rocks is supporting the energy industry and mitigating the effects of climate change.



Professor Sherilyn Williams-Stroud

Director, Berg-Hughes Center for Petroleum Geoscience and Sedimentary Studies, Department of Geology and Geophysics, Texas A&M University, USA

PROFILE

Fields of research
Structural geology; energy geology

Research project
Investigating the impacts of fluid storage in rocks, related to energy production and use and how fluids can be safely stored

Funders
US National Science Foundation (NSF); US Department of Energy (DOE); Berg-Hughes Center

doi: 10.33424/FUTURUM736

Talk like a ...

structural geologist

Brine – water containing dissolved salts

Carbon sequestration – a method to combat climate change by storing captured CO_2 in rocks or other materials

Fracture – a crack in a rock

Induced seismicity – earthquakes caused by human activity, such as injecting fluid into rock

Permeability – the ability of a rock to allow fluid to flow through it

Pore – space between grains in a rock

Porosity – a measure of how much pore space is in a rock

Sedimentary rock – a rock composed of deposited grains that have been weathered from older rock

The seemingly solid ground beneath your feet is actually full of fluids. Pores and fractures in rocks contain water, oil, natural gas or brine, which are valuable resources for society in the form of groundwater, fossil fuels and geothermal power.

The nature of the rock will impact how much fluid it contains and how easily it will flow, which in turn influences the region's potential for producing resources. "I'm interested in how fluids move through rocks, and how this movement is related to fractures," says Professor Sherilyn Williams-Stroud, a structural geologist at Texas A&M University.

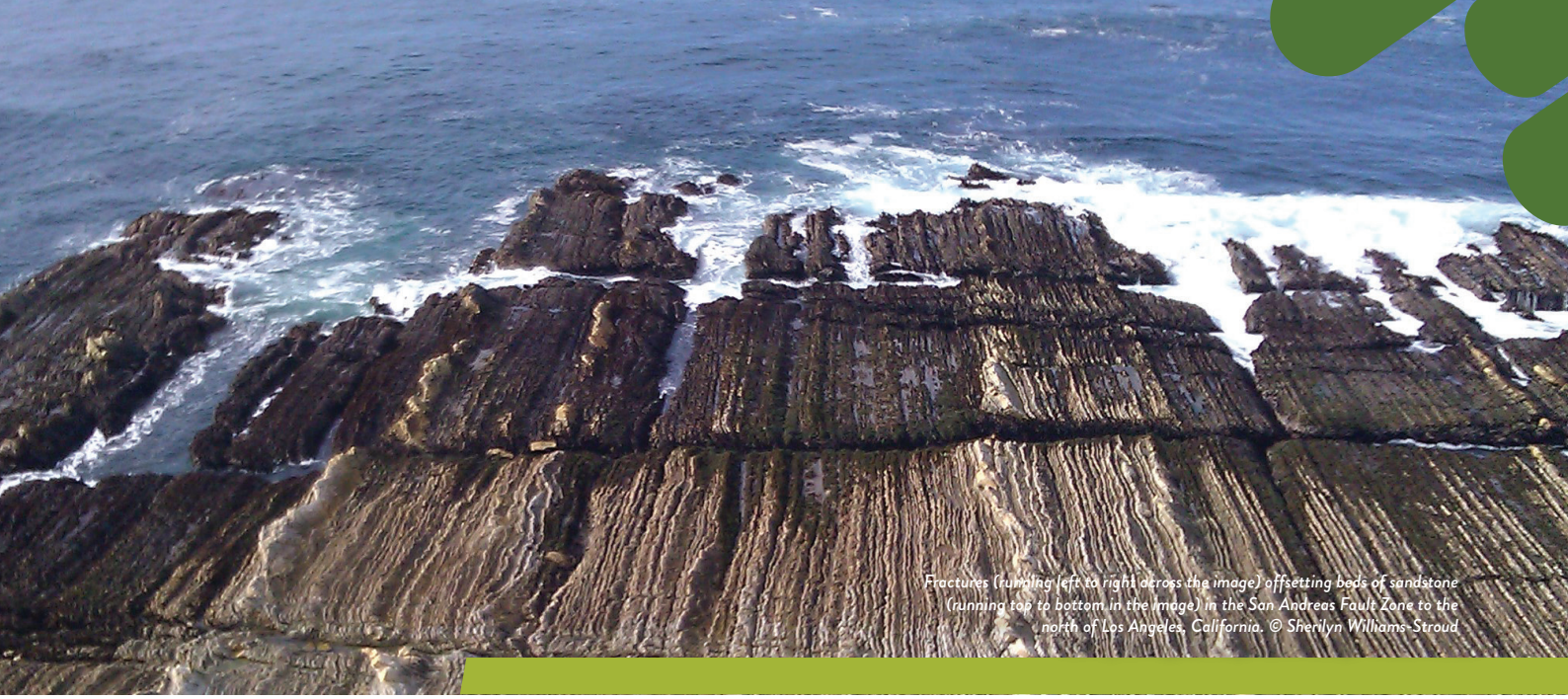
How do rock characteristics impact fluid flow?

Sedimentary rocks composed of small grains, such as sandstones, can have high porosity and permeability, allowing fluids to flow through the pores. In contrast, sedimentary rocks composed of tiny grains, such as shales, generally have low porosity and permeability and the tiny pores cannot hold much fluid.

"There are many theories about how fluids flow along fractures, and how fractures can develop into connected networks," says Sherilyn. "As we can't see how fractures are connected in the Earth, it isn't possible to know which pathways fluids will take through a fracture network. Chemical interactions also play an important role and there is still a lot to be learnt about how rock-fluid interactions work under different conditions."

How does fluid flow through rocks impact energy projects?

Oil and natural gas are fossils fuels



Fractures (running left to right across the image) offsetting beds of sandstone (running top to bottom in the image) in the San Andreas Fault Zone to the north of Los Angeles, California. © Sherilyn Williams-Stroud

that have supported the current global state of industrialisation. Once these fluids have formed from buried organic material, they buoyantly rise through the rock, flowing through interconnected pores and fractures. When they reach an impermeable layer of rock, such as shale, they become trapped, forming a reservoir of oil and/or gas in the rock below. "When looking for oil and gas reserves, geologists search for formations consisting of an impermeable layer of rock above porous rock (known as 'traps')," explains Sherilyn. "They also create fractures in low-permeability rocks containing oil and gas by injecting water, to enable the fluids to flow out."

However, burning fossil fuels is contributing to climate change due to the carbon dioxide (CO_2) that is released into the atmosphere. "Geology offers solutions to help us manage those side effects, such as carbon sequestration," says Sherilyn. This involves taking CO_2 that has been removed from (or captured before it gets into) the atmosphere and injecting it into the Earth to store it within rocks. In rocks, CO_2 behaves in a similar way to oil and gas – it will buoyantly rise upwards until it becomes trapped by a layer of impermeable rock. So instead of trying to locate potential oil reserves, many geologists are using the same skills to identify potential locations for injecting and storing CO_2.

Geothermal power is produced by using hot fluids in rocks to turn turbines to generate electricity. This requires permeable rocks so fluids can circulate through the hydrothermal system. "In cases where there are impermeable hot rocks, engineers can inject water under high pressure to fracture the rock," explains Sherilyn. "This creates a permeable fracture network where water can be pushed through the hot rock to be heated up so that it can be used to produce geothermal power."

> **"When looking for oil and gas reserves, geologists search for formations consisting of an impermeable layer of rock above porous rock."**

How is Sherilyn studying fluid flow through rocks?

"I work on geological problems that help us understand how fluids move through the rock (whether pores or fractures) and how these fluids get trapped," says Sherilyn. To investigate this, she begins by characterising fracture orientations and sizes. "If most of the fractures in a rock are oriented in the same direction, they should enhance fluid flow in that direction," she explains.

However, uncovering the structures in the rock below our feet is no easy task, as Sherilyn is trying to study something inaccessible and buried below ground. Rock cores extracted from drilling wells provide detailed samples of rock features, but only in one-dimension and at a single location, while seismic data provide large-scale 3D imaging of subsurface features, but not at a high enough resolution to identify individual fractures.

As neither method can give the full picture of the complex 3D structures of subsurface fractures, Sherilyn combines these techniques with geological modelling of rock deformation and fluid flow. "This allows me to develop realistic models of the subsurface," she says. "This provides the information needed to make decisions about how to proceed with projects involving extraction or injection of fluids from or into rocks."

A key aspect of Sherilyn's work involves communicating with the communities impacted by energy projects, such as those near fluid extraction or injection sites. "It is important to engage directly with communities because they have a right to know how a project may impact them," she says.

What has Sherilyn discovered?

"Our research has shown that some injection projects have a greater impact on surrounding communities than others," says Sherilyn, as injecting fluids into rock causes small earthquakes (known as induced seismicity). "Induced seismicity can cause problems if the earthquakes are large enough to cause damage, so it is important to know if earthquakes are natural or caused by human activity," she continues. For example, Sherilyn supported carbon sequestration projects in Illinois, where seismicity was monitored for a year and a half before CO_2 injection began. "No earthquakes were detected during this time," she says. "Tiny earthquakes were then detected during injection, but they could not be felt by people."

In this way, Sherilyn is using her skills as a geologist to support the energy industry and help mitigate the impacts of climate change.

About *energy geology*

Geologists play a vital role in the energy industry. Without them, we wouldn't have oil and gas, nuclear fuel, geothermal power, hydroelectric dams or batteries. "Structural geologists map the structures of rocks on the Earth's surface and geophysicists use geophysical imaging to identify subsurface structures," explains Sherilyn. "This information is combined with analysis of how the rocks have been heated and deformed over time and with drilling to confirm the character of subsurface rocks." This allows geologists to locate reserves of fossils fuels and minerals essential for energy production, such as lithium for batteries, uranium for nuclear power, and the minerals needed to build solar panels and wind turbines.

"Geologists can use various prospecting techniques to infer high heat flow areas in the subsurface that have the potential for development of geothermal applications," continues Sherilyn. "They also identify risks to energy infrastructure from tectonic activity, landslides and flooding." This is important because the consequences of an earthquake damaging a nuclear power plant or hydroelectric dam could be catastrophic.

Geologists in the energy industry must be able to work in interdisciplinary teams, as once they have located energy resources, it is engineers who extract them. "As a structural geologist, I work with geochemists, geophysicists, petroleum engineers, civil engineers and materials scientists," says Sherilyn. "Geologists and geochemists characterise rock properties to understand rock-fluid interactions, while engineers model fluid flow through rocks and identify drilling techniques to extract resources."

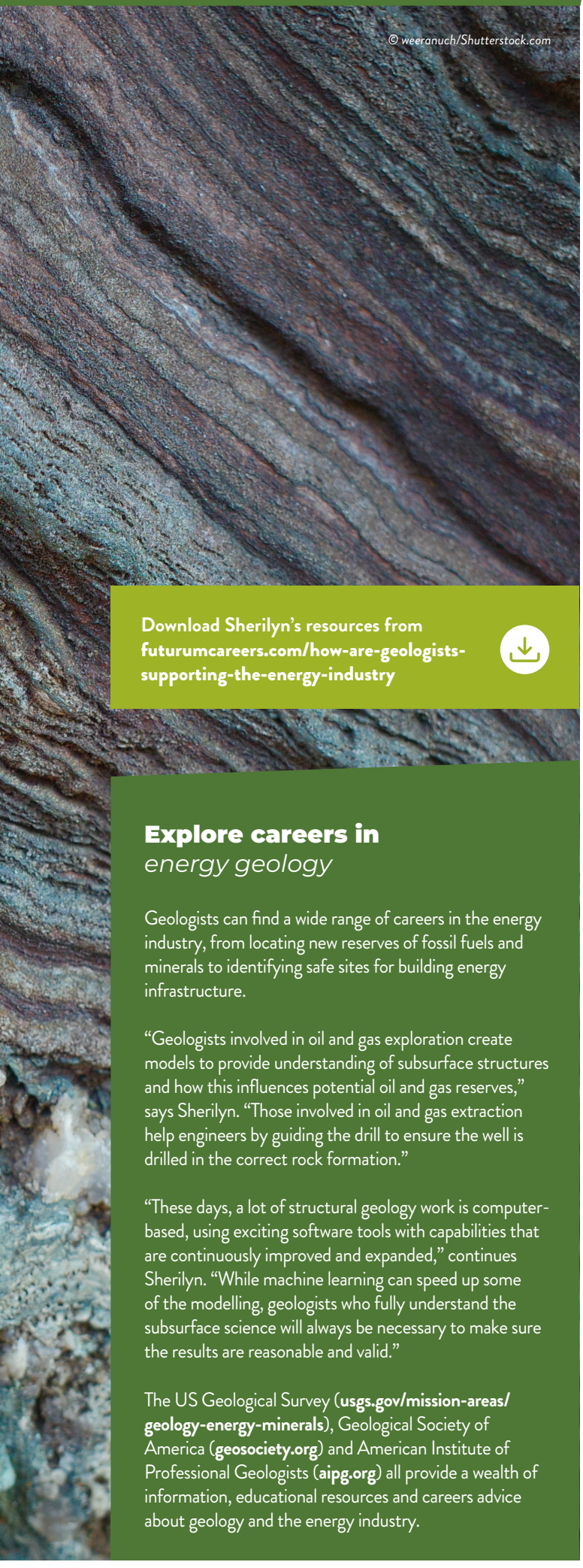
After geologists have identified energy resources and estimated how much is available, engineers then estimate how much of the resource can actually be extracted from the Earth. This allows the team to determine the economic value of the resource, and extraction will only begin if it is economically profitable.

Pathway from school to *energy geology*

At high school, study geography, mathematics, physics and chemistry to learn the knowledge and skills underlying geology and energy production. "A strong math foundation is important for structural geology, including trigonometry and linear algebra," advises Sherilyn. "Statistical skills are useful for analysing structural data."

At university, study a degree in geology, Earth science or geophysics, and take courses in structural geology, mineralogy and rock mechanics to learn how rocks and minerals deform. Students who want to work in the oil and gas industry should pursue a geology study programme that emphasises a strong foundation in interpreting the geologic subsurface.

Most geology programmes include practical field courses. "I highly recommended participating in field courses because they will help you understand the spatial relationships that are important for doing geology," says Sherilyn. "Knowing what the rocks look like in real life is critical to developing realistic interpretations of seismic and well data."



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Download Sherilyn's resources from futurumcareers.com/how-are-geologists-supporting-the-energy-industry

Explore careers in *energy geology*

Geologists can find a wide range of careers in the energy industry, from locating new reserves of fossil fuels and minerals to identifying safe sites for building energy infrastructure.

"Geologists involved in oil and gas exploration create models to provide understanding of subsurface structures and how this influences potential oil and gas reserves," says Sherilyn. "Those involved in oil and gas extraction help engineers by guiding the drill to ensure the well is drilled in the correct rock formation."

"These days, a lot of structural geology work is computer-based, using exciting software tools with capabilities that are continuously improved and expanded," continues Sherilyn. "While machine learning can speed up some of the modelling, geologists who fully understand the subsurface science will always be necessary to make sure the results are reasonable and valid."

The US Geological Survey (**usgs.gov/mission-areas/geology-energy-minerals**), Geological Society of America (**geosociety.org**) and American Institute of Professional Geologists (**aipg.org**) all provide a wealth of information, educational resources and careers advice about geology and the energy industry.



Meet *Sherilyn*

I had a wide range of hobbies as a teenager, from playing softball and riding my unicycle to tap dancing lessons and performing jazz ballet. I also loved music – I played the French horn in the school band and orchestra, and enjoyed I listening to all types of music, from classical to jazz to rock.

I 'fell' into geology from music. I enjoyed structural geology and stratigraphy (the study of layers of sedimentary rocks), and my graduate research combined these interests to investigate the deformation of sedimentary rocks at low temperatures.

My career as a research scientist began at the US Geological Survey working on projects related to oil and gas. I then helped to evaluate a site for nuclear waste disposal, which involved analysing fracture networks in the rock to determine if the site would be suitable. I measured fracture lengths, spacing and orientation, and did statistical analyses to predict how they would influence fluid flow. I really enjoyed the analysis, and that project set my career pathway towards studying rock fractures and fluid flow.

I have spent many years working as a geologist in industry and government. At the oil companies Texaco and Chevron, I created fracture models of subsurface reservoirs for oil exploration and production projects, and I analysed fracture geometries to assess the behaviour of fluids in the reservoirs. At the seismic monitoring company Microseismic Inc., I interpreted induced seismicity data from hydraulic fracturing projects. I carried this expertise to the Illinois State Geological Survey where I monitored induced seismicity from CO2 being injected into deep rocks for carbon sequestration.

I enjoy the controversies that exist in science. Conclusions are always based on incomplete data, and different researchers will interpret the data in different ways. Narrowing the gap between what we know and what we don't is a fun challenge.

Sherilyn's *top tips*

1. Be observant and open-minded.
2. Find people who support you and what you want to do. Sometimes the best supporters are not mentors who are assigned to you, but people you happen to meet. So take advantage of opportunities to meet and talk to experienced people in your field.
3. Don't be afraid to ask for help when you need it.

Uncovering the biotechnological potential of microalgae

Microalgae are tiny organisms with huge potential. As well as being found in food supplements and skincare products, they could provide us with new drugs and be a source of sustainable fuel. However, most commercially cultured microalgae species are not adapted to grow in the regions where biotechnology companies want to use them. Which is why, at **Agroscope** in Switzerland, **Dr Daniel Kurpan** is collecting native microalgae species and analysing them to determine how they could be used for biotechnological applications.



Dr Daniel Kurpan

Agroscope, Switzerland

PROFILE

Fields of research
Biotechnology; microbiology; phycology

Research paper
Isolation, characterization, and maintenance of native Swiss microalgae for biotechnological prospection. Kurpan et al. (2025) doi: **10.1038/s41598-025-10989-w**

Funders
Lidl Switzerland; Swiss Federation

doi: 10.33424/FUTURUM718

Talk like a ...

biotechnology researcher

Biofilm – a layer of microorganisms (e.g., slime that accumulates on a damp surface)

Biotechnology – the use of biological organisms to create products that benefit humans

Colorimetric method – a laboratory technique to measure the concentration of a compound based on its colour intensity

Culture – (noun) cells that have been grown in a laboratory; (verb) to grow cells in a laboratory

Lipid – an organic water-insoluble molecule (e.g., fats and oils)

Microalgae – a very diverse group of microscopic photosynthetic organisms (technically, they are not classified as plants)

Productivity – a measure of how much biomass can be produced per unit of volume per unit of time

Spectrophotometer – a device that measures how much light a sample absorbs and refracts

After a rainy day in the Swiss mountains, you might find Dr Daniel Kurpan poking around in puddles. He is on a mission to collect microalgae: microscopic photosynthetic organisms that are found in lakes, ponds, rivers, biofilms, oceans and –you guessed it – puddles!

"Microalgae are a group of very diverse organisms which can be used in various industrial sectors," says Daniel, a biologist at Agroscope. "However, the incredible diversity of microalgae remains largely unexplored in today's biotechnology sector." Around the world, only a few species are currently grown and used for commercial applications, meaning we are missing out on the huge potential benefits that microalgae could bring to society.

Why are microalgae useful?

Have you ever had a drink or smoothie containing spirulina? If so, you have consumed microalgae! Spirulina is commonly used as a dietary supplement due to its many health benefits, and scientists are looking to microalgae as a sustainable, plant-based way to feed the world's growing population. Many microalgae species are high in protein and vitamins, making them an ideal food source for humans and animals. Microalgae with a high lipid content can be used to produce biodiesel, providing a sustainable source of energy. And microalgae containing anti-inflammatory compounds and antioxidants are used in the pharmaceutical industry to develop new drugs and cosmetic products.

Why is Daniel collecting Swiss microalgae?

Most of the microalgae species that are currently used for biotechnological applications come from tropical regions. However, biotechnology companies in non-tropical parts of the world can benefit in two ways from using local microalgae instead. "First, native species are already adapted to local conditions," explains Daniel. "Second, they do not pose environmental risks associated with the introduction of exotic species."



The AlgoScope team is collecting microalgae from biofilms and puddles around Switzerland. © Daniel Kurpan

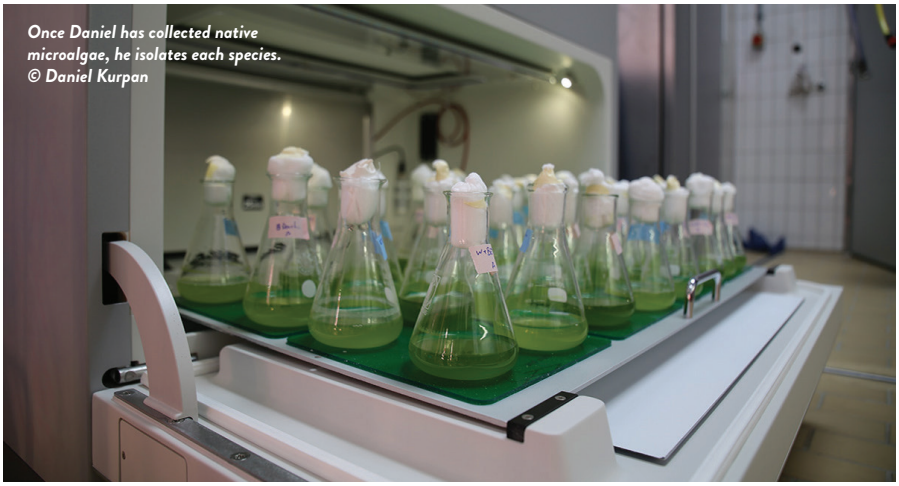
Daniel is part of the team that has been creating AlgoScope, the first public Swiss microalgae culture collection. "We conduct sampling campaigns throughout Switzerland to collect samples of native microalgae species," he explains. "Back in the laboratory, we isolate each species, characterise them to determine their properties, then maintain them as cultures so they will survive in the collection for extended periods." So far, AlgoScope contains over 120 Swiss microalgae species. "This culture collection provides new biological and genetic resources for study and exploitation," Daniel continues. Scientists can examine the collection to find microalgae species that could be used to improve the national biotechnology sector.

How is Daniel analysing native microalgae species?

Having built up the microalgae culture collection, Daniel is now analysing some of the species it contains to explore their biotechnological potential. Characteristics such as productivity and biochemical composition impact whether a microalgae species will be useful for commercial applications, so these are key properties that Daniel is investigating. "Market demand must be met in terms of both quantity and quality," he explains. "For example, if the goal is to create a protein source for food, the microalgae biomass must contain an adequate amount of high-quality proteins."

To be commercially useful, a species must have a high enough productivity that growing it is economically viable. To test the productivity of different species, Daniel measures the growth rate of samples that he cultures, using three different techniques to monitor cell growth. At regular intervals, he uses a microscope to count the number of microalgae cells in a sample, he dries and weighs a known volume of culture, and he uses a spectrophotometer to track changes in the colour of the culture as the cells grow.

The biochemical composition of a microalgae species will determine what applications it can be used for, with protein-rich species being useful for food supplements and lipid-rich species being useful for energy production. To analyse the composition of different species, Daniel uses colorimetric methods and physical separation methods. "Colorimetric methods involve a molecule that binds to the specific compound of interest, resulting in a colourful complex," he explains. "The intensity of the resulting colour is proportional to the concentration of the compound of interest and can be measured using a spectrophotometer." Physical separation methods, such as filtration, evaporation and distillation, physically separate the compound of interest out from the sample, where it can then be measured (e.g., by weighing or comparing with known standards).



Once Daniel has collected native microalgae, he isolates each species. © Daniel Kurpan

What has Daniel discovered?

"We have discovered that microalgae growth characteristics are extremely diverse and species-specific, which aligns with the huge physiological diversity of microalgae," Daniel says. "We have also discovered that, despite the great diversity among microalgae, the amino acid profiles of most species are very similar."

In a recent study, Daniel characterised the productivity and biochemical composition of seven native Swiss microalgae species from AlgoScope. He identified two species (*C. saccharophilum* and *T. brasiliensis*) that have great potential for being used as animal feed, as both have high productivity, protein levels and fatty acid content. "Based on our results, these species are good candidates for feed material," he says. "However, scale-up feasibility analysis and animal acceptance tests need to be conducted before actual implementation."

Through his research, Daniel is exposing the incredible potential of microalgae for solving some of the world's most pressing problems, such as how to sustainably feed and power an ever-growing population. These amazing organisms will have an exciting role in the biotechnology of the future!

Download Daniel's resources from futurumcareers.com/uncovering-the-biotechnological-potential-of-microalgae

How does forest composition affect pollination in nearby apple orchards?

Many apple orchards in the northeastern US rely on wild bees for pollination. Orchards that are surrounded by a larger amount of forest tend to be visited by a more abundant and diverse community of pollinators. But does the *type* of forest surrounding an orchard matter as well? At **Rutgers University**, **Joanna Greenwood** is studying this question to learn more about the relationship between pollinators, orchards and their surrounding forests.



Joanna Greenwood

PhD Student, Winfree Lab,
Rutgers University, USA

PROFILE

Field of research
Ecology

Research project
Studying the effects of forest composition on pollinators and yield in adjacent apple orchards and linking forest management and crop production

Funder
US Department of Agriculture (USDA) National Institute of Food and Agriculture, award number 2024-67011-42897

doi: 10.33424/FUTURUM725

Talk like an ...
ecologist

Coniferous forest – forest dominated by cone-bearing, evergreen trees such as pine, spruce and fir

Deciduous forest – forest dominated by broad-leaved trees such as oak, beech and maple that shed their leaves annually

Insect collection vacuum – a device used to suck up insects for further observation

Yield – the amount of a crop that is produced in an orchard or other crop field

Picture yourself sat in the dappled shade of an orchard. A gentle breeze wafts the sweet scent of apple blossom through the air and gently rustles the leaves above you. All around, bees buzz from tree to tree, filling the warm afternoon with a soft, soothing hum. Believe it or not, this idyllic scene is the site of Joanna Greenwood's field research.

Joanna, a PhD student at Rutgers University, is studying the relationship between forests, pollinators and apple orchards in the northeastern US. "Work by other researchers has shown that apple orchards that are closer to forest or surrounded by a larger amount of forest are visited by a more abundant and diverse community of pollinators," she says. "Apple flowers can't produce fruit unless they are visited by pollinators, which transfer pollen between flowers, so the higher abundance and diversity of pollinators near orchards results in more apples."

But apple growers don't only care about how many apples they produce; they also care about the quality of those apples – for example, how big and round they are. "Apples with more seeds tend to be larger and rounder, and each seed requires a grain of pollen to fertilise it," says Joanna. "That means that more pollinators depositing more pollen can improve the quality of the fruit."

Busy bees

Many kinds of insects visit apple flowers in the northeastern US, but bees are the most important apple pollinators because they deposit the most pollen on flowers. "Many apple growers rent managed honey bees to help with pollination," says Joanna. "However, honey bees are expensive, and some wild bees, such as mining bees, are more effective at pollinating apple flowers." If their orchards are surrounded by good habitat for wild bees, some apple growers decide not to rent honeybees and rely entirely on wild bees instead. For these growers, understanding the relationship between their orchards, the surrounding habitat and their wild pollinators is crucial.

A bee's favourite forest

While several studies have found that the amount of forest surrounding an orchard impacts the number of pollinators it receives, Joanna wanted to find out whether the *type* of forest also has an impact. "The northeastern US has both coniferous and deciduous forests," she says. "We know that bees prefer deciduous forests because they have more flowers, which bees need for food." So, Joanna suspected that high

surrounding forest cover wouldn't benefit apple pollination if it wasn't the type of forest that bees prefer.

"I designed a study to answer two questions," says Joanna. "Firstly, do apple orchards surrounded by different types of forest (deciduous vs. coniferous) differ in the abundance and diversity of wild bees visiting apple flowers? And secondly, if that is the case, does this translate to differences in apple yield and quality?" To answer these questions, Joanna found six orchards surrounded by coniferous forest and six orchards surrounded by deciduous forest and collected data on the pollinators and apple yield at those orchards.

The big bee count

"To understand how many pollinator visits apple flowers were receiving at each orchard, we conducted visual visitation observations," says Joanna. "This involved counting how many and what kind of insects visited a clump of flowers for a set period of time, then calculating how many visits each flower received per minute, on average." However, it is difficult to identify most species of bee without looking at them under a microscope, so Joanna and her field technician, Kirah, also caught samples with an insect collection vacuum and took them back to the lab to determine which species were present in the orchards.

"We also determined the percentage of flowers that turn into fruits by marking branches on apple trees, counting the flowers and returning later to count the fruits," says Joanna. "When the apples were ripe, we collected them and recorded their mass, whether they were approximately symmetrical, and how many seeds they had." Counting the number of fruit allowed Joanna to figure out how many of the flowers were pollinated, and the number of seeds in each apple told her how well each flower was pollinated.



An apple tree in bloom in an orchard surrounded by coniferous forest.

The results are in...

"Contrary to our expectations, we did not find a large difference in the diversity or visitation rate of wild bees in orchards surrounded by coniferous and deciduous forests," says Joanna. However, she did find that orchards with higher wild bee diversity and visitation rates had apples with more seeds. "These apples were larger and more symmetrical, making them more valuable," Joanna continues. "So, our results confirm that higher abundance and diversity of wild bees contributes to the production of higher-quality apples."

Joanna is unsure why she didn't find the results that she expected, so she will be doing more data analysis to dig a little deeper. "If we could repeat the study with more orchards, we may be able to better understand these relationships," she says. "It is also likely that other variables – such as the amount of pesticide used in the orchards – affected our results."

For the love of bees

"As crop pollinators, bees are critical for human wellbeing – but I find them fascinating in and of themselves; there are over 20,000 species of bees worldwide, and each one is unique and beautiful," says Joanna. "My favourite part of my job is spending time outdoors collecting data, but I also love talking to people about my research and about bees in general." Despite not finding the results that she expected, Joanna is excited to continue her investigation of the relationship between bees and orchards. When she's in an orchard surrounded by sweet apples and buzzing insects, there's really no place she'd rather *bee*.



Joanna records how many flowers are on a branch then returns to see how many turned into fruit.

Download Joanna's resources from futurumcareers.com/how-does-forest-composition-affect-pollination-in-nearby-apple-orchards

How can sustainable agriculture improve the hospitality industry?

The hospitality industry provides a vital service to society and the economy, but it also often relies on environmentally damaging resources and is responsible for significant food waste. At **New Mexico State University** in the US, **Professor Jean Hertzman** is ensuring the next generation of hospitality and culinary professionals have the knowledge and skills to reduce the environmental impact of the industry. To achieve this, she is developing lesson plans that connect hospitality and culinary arts with sustainable agricultural practices.



Professor Jean Hertzman

School of Hotel, Restaurant and Tourism Management, New Mexico State University, USA

PROFILE

Fields of research
Hospitality and culinary arts; sustainable agriculture; food safety

Research project
Training hospitality and culinary arts teachers so they can educate their students about the importance of sustainable agriculture

Funder
This work is supported by the US Department of Agriculture (USDA) National Institute of Food and Agriculture (NIFA) Agriculture and Food Research Initiative (AFRI) Agricultural Workforce Training Priority Area, award #2023-67037-39940

doi: 10.33424/FUTURUM737

Talk like a ...

hospitality manager

Agricultural literacy – an understanding of how agricultural systems connect with society

Agriculture – the industry that grows crops and raises livestock to produce food, fibre and other resources

Agritourism – agricultural-related tourism activities, such as farm tours, dinners and stays

Culinary professional – someone whose job is to prepare, cook and present food

Food service – the sector of the hospitality industry that provides food outside of private homes

Hospitality industry – the sector of the service industry that provides food, accommodation and entertainment to guests

Supply chain – the network that an item passes through from its initial raw components to its final consumption by an end-user

Sustainable agriculture – agricultural practices that promote environmental health while supporting farmers' livelihoods

"The hospitality industry would not exist without agriculture," says Professor Jean Hertzman, Director of the School of Hotel, Restaurant and Tourism Management at New Mexico State University. "All of our foods and most of our supplies start with agriculture."

Jean is on a mission to educate the next generation of hospitality managers and culinary professionals about the connections between agricultural systems and the hospitality industry. Most importantly, she wants the industry to become more environmentally friendly by supporting sustainable agricultural practices.

What environmental problems exist in hospitality supply chains?

Agricultural resources produced by traditional farming methods often have a negative environmental impact. For example, livestock such as cows (raised for meat and milk) release methane into the atmosphere, while fertilisers and pesticides (spread on fields to improve crop growth) wash into rivers and lakes which harms aquatic ecosystems and reduces water quality.

Agricultural goods must then be transported to restaurants, hotels and other hospitality

venues which, if done by truck or plane, releases carbon dioxide into the atmosphere. And at the end of the supply chain, food waste is a huge environmental problem, with 29% of all US food being thrown away. While a third of this wasted food is from households, 24% is wasted on farms and 18% is wasted by the food service industry – a key component of the hospitality industry. "Reducing food waste is a concern that hospitality operations can directly address," says Jean.

How can sustainable agriculture reduce these problems?

"Sustainable agricultural practices provide products for the hospitality industry that have been produced and transported responsibly," says Jean. Sustainable agriculture is defined as an integrated system of plant and animal production practices that satisfy human food and fibre needs while also enhancing environmental quality, sustaining the economic viability of farm operations, and improving the quality of life for farmers and society. "While most people think about sustainability in relation to the environment, sustainable agriculture also emphasises sustaining people, society and the economy," explains Jean.

When hospitality operations (such as hotels and restaurants) source their products from sustainable agricultural systems, they are contributing to a fairer and more environmentally friendly society. For example, organic products must be grown without the use of fertilisers and pesticides which improves water quality and biodiversity, and locally sourced products are not transported long distances which reduces greenhouse gas emissions.

Why is it important to learn about agriculture?

"Many people don't connect the fact that the food they get from a food service operation starts in a field, forest, river or ocean," says Jean. "The same goes for items in hospitality operations, such as the cotton to make sheets and towels in hotels." Other examples include trees grown to make paper and bamboo grown to produce disposable bowls and cutlery. "Students need to understand where these products come from and the challenges that producers face in ensuring their continued availability, as these students will be the next generation of hospitality and culinary managers,"



continues Jean. Future hospitality workers will improve the industry by using resources responsibly and supporting sustainable farming, fishing and other agricultural operations.

"Everyone, but especially hospitality and culinary professionals, will benefit from having agricultural literacy – a basic understanding of where their food and fibre come from," says Jean. Hospitality and culinary professionals need to understand the supply chain of how products go from an agricultural operation, through manufacturing and packaging processes and distributors, to food service and hospitality operations, before finally reaching the consumer (such as a restaurant or hotel guest).

How is Jean supporting the next generation of hospitality and culinary professionals?

Jean hopes to address the current disconnect between the agricultural systems that produce food and resources and the hospitality and food service operations that use them by equipping the next generation of hospitality and culinary professionals with knowledge of sustainable agricultural systems. To achieve this, she is educating and training high school hospitality and culinary arts teachers, so they can share this knowledge with their students. Together with her graduate assistants, Sierra Chopito and Hunter Lindsey, Jean is working with hospitality and culinary arts teachers to develop a series of lesson plans that can be used to introduce sustainable agriculture into the curriculum. These cover topics such as the connections between agriculture and culinary arts, purchasing and supply chain management, reducing waste in restaurants and hotels, and agritourism. Students are encouraged to visit local farms and food distribution warehouses, plan and cook meals using local and seasonal ingredients, develop recipes that use 'scrap' products, and perform carbon footprint audits of how foods get from a farm to a restaurant.

"The ultimate goal of my project is to train the next generation of culinary professionals and hospitality managers with the skills needed to ensure the effective and socially responsible use of resources from the producer to the end-user," says Jean. "By gaining agricultural literacy and becoming advocates for sustainable practices in the workplace, you can contribute to reducing the effects of climate change, reducing food waste and providing demand for products created through better agricultural processes." In this way, Jean and her team are ensuring that the hospitality industry will play a key role in making the planet healthier for all of us.



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About *hospitality*

Hospitality is a dynamic industry with a huge range of exciting career opportunities. "The careers in hospitality and culinary arts are endless because there are so many types of operations," explains Jean. Food service operations range from food trucks, fast-food chains and independent cafés to hotel restaurants, entertainment venues and independent fine-dining establishments, along with catering for schools and hospitals. "Food service jobs include chefs, servers, bartenders and managers, while hotel careers include front-of-house operations, catering, housekeeping and sales," says Jean.

This range of opportunities means that whatever your interests, you are sure to find a role in hospitality that allows you to fulfil your goals. "With the variety of jobs available, there is room for everyone," says Jean. "Hospitality management and culinary arts are careers that will always be in demand. Everyone eats, and even if the percentage of people eating out fluctuates, the industry will always adapt."

Jean's first job was at an ice cream and sandwich shop. "It was a long time ago, so my pay was $2.85 per hour plus all the ice cream I could eat!" She then worked as an executive chef at an independent restaurant and as a restaurant manager at a hotel. As executive chef, she was responsible for overseeing all food preparation, developing menus, cooking, and ordering food and kitchen supplies. "As I worked at an independent restaurant, I enjoyed the creativity I had to adapt the menu and I loved watching people enjoy the meals we cooked," she says. As restaurant manager, she was responsible for the 'front of house' operations, supervising servers and bartenders, checking reservations, greeting guests and dealing with any problems. "I enjoyed sharing my passion for hospitality with both the guests and employees," she says. "No two days are ever the same in a restaurant, so I never got bored with the job!"

Pathway from school to *hospitality*

At school, take any hospitality and culinary classes that are offered. "You will learn key skills which will help you secure entry-level jobs and get ahead in your career," says Jean.

"Math is also important," advises Jean. "It is essential to know how to convert recipes to make different amounts and to know how to determine the cost of a dish and price it accordingly."

You can earn hospitality and culinary certificates and qualifications from community college, trade school or university. Most courses will include practical internships to give you hands-on experience, and Jean also recommends finding part-time work in the industry, even if it is just washing dishes to begin with. "There is no substitute for practising your skills on a daily basis and progressing through different job levels to gain the experience needed to succeed," she says. "You could also plan a party for your family, school or community centre, or help serve food at a food bank or community kitchen."

"To work with food, it is essential to study food safety and gain basic food preparation and cooking skills," says Jean. "If a class in meats and butchery is offered, take it! These skills are in demand and pay high wages."

Download the team's resources from futurumcareers.com/how-can-sustainable-agriculture-improve-the-hospitality-industry

Explore careers in *hospitality*

In addition to the huge variety of roles in food service and hospitality venues mentioned above, there are also opportunities to teach culinary arts and hospitality in high schools, trade schools, colleges and universities. "I wanted to teach because I recognised the tremendous need for training in the industry," says Jean.

The National Restaurant Association (**chooserestaurants.org/restaurantswork/career-pathways**) and The Hotel Industry (**thehotelindustry.com/career-pathways**) provide information about career pathways in restaurants and hotels, along with the skills, experience and qualifications you need to follow different paths.



Meet *Sierra*

Sierra Chopito is the culinary business and product development manager at Stampede Culinary Partners

I have been cooking since a very young age, and I've always enjoyed exploring flavour combinations. I took culinary classes throughout high school and went to university to study culinary arts. One day, I witnessed chefs from different food chain companies come together and cook. The sight of their collaboration inspired me to become one of those chefs.

I took an introductory class in food science and was intrigued – I love working with food and it was exciting to understand the science behind food and how this relates to cooking in a kitchen. I also completed an internship in a five-star restaurant at a luxury ski hotel, where I learned discipline in the kitchen and built my strong mentality, which shaped my style as a chef today.

> **"It is exciting to see food products that I made in the test kitchen on the shelf at a grocery store."**

As product development manager at Stampede Culinary Partners, I manage our test kitchen where we develop new food products. Developing new food products involves working in the kitchen to create prototypes to ensure a successful transition from the kitchen to commercialisation. My inspiration for creating new products can come from current trends in restaurants and health, my friends, a vacation, a movie… anywhere!

I enjoy being able to create new things and try everything I make. I also love being able to collaborate with chefs and learn from their experiences and knowledge, because I believe you can learn new things from anybody. It is exciting to see food products that I made in the test kitchen on the shelf at a grocery store or on the menu in a restaurant and to know that millions of people are eating my food!



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Meet *Hunter*

Hunter Lindsey is studying for a master's in agricultural extension and education

Throughout my childhood, I raised my own flock of sheep at home in Arizona and showed them at livestock shows. But throughout high school, I didn't have a clue where my future would take me. I knew I wanted to work with animals and considered everything from marine biology to wildlife rehabilitation. In the end, I studied animal science with minors in agricultural business, ranch management and horse management, along with an internship in a reproductive physiology research barn. Studying so many different areas helped me realise just how broad agriculture is.

I'm now studying agricultural extension, which focuses on how we communicate agricultural information to farmers and the public. Animal science helped me understand the 'why' behind agriculture, and now my favourite part is learning how to share this knowledge with others.

I'm helping to develop agricultural lessons for culinary and hospitality educators. This involves connecting agriculture to topics students are learning about, such as where food comes from. For example, I've created resources covering the beef supply chain and sustainable beef production.

It's important to know that you don't have to come from a 'traditional' agricultural background to find a place in the industry. There are so many careers in agriculture – it's not just farming and ranching. There are also opportunities in animal science, education, business and food production.

My advice to students is to stay open-minded, take advantage of opportunities that come your way and try to gain as much hands-on experience as possible. My journey has been shaped by being willing to explore different opportunities, even when I wasn't sure where they would lead.

How did a high school science project uncover a potential new treatment for Alzheimer's disease?

It was an 8th Grade biology lesson that inspired **Claire Su**, a high school student at **BASIS Ahwatukee** in the US, to conduct her own scientific research project. After learning about the gene that causes people to perceive the taste of brussels sprouts differently, she decided to investigate the links between this gene and Alzheimer's disease. Mentored by scientists at **Arizona State University**, Claire not only discovered that supertasters have a lower risk of Alzheimer's, but she also found that a drug currently used to treat diabetes could be repurposed to prevent cognitive decline.



Claire Su

BASIS Ahwatukee, Phoenix, Arizona, USA

Field of research
Computational neuroscience

Research project
Investigating the links between the TAS2R38 taste gene and Alzheimer's disease

Research paper
TAS2R38 taster variants-linked MGAM expression in Alzheimer's disease: a novel target for precision drug repurposing. Su et al. (2026) **doi: 10.3389/fnagi.2026.1768436**

doi: 10.33424/FUTURUM719

PROFILE

Talk like a ...

computational neuroscientist

Allele – a variation in a gene

Alternative allele – an allele that is different to the reference allele in the human reference genome

Alzheimer's disease – a progressive brain disorder that causes cognitive decline

Cognitive decline – the loss of cognitive abilities such as thinking and memory

Genotype – the alleles that a person has for a particular gene (e.g., the taster genotype defines which TAS2R38 alleles a person has, categorising them as a supertaster, nontaster or heterozygote)

Heterozygote – a person whose TAS2R38 gene contains both the reference allele and the alternative allele

MGAM – the gene that produces an enzyme to digest starch

TAS2R38 – the gene that influences a person's ability to taste certain bitter compounds, such as those found in brussels sprouts

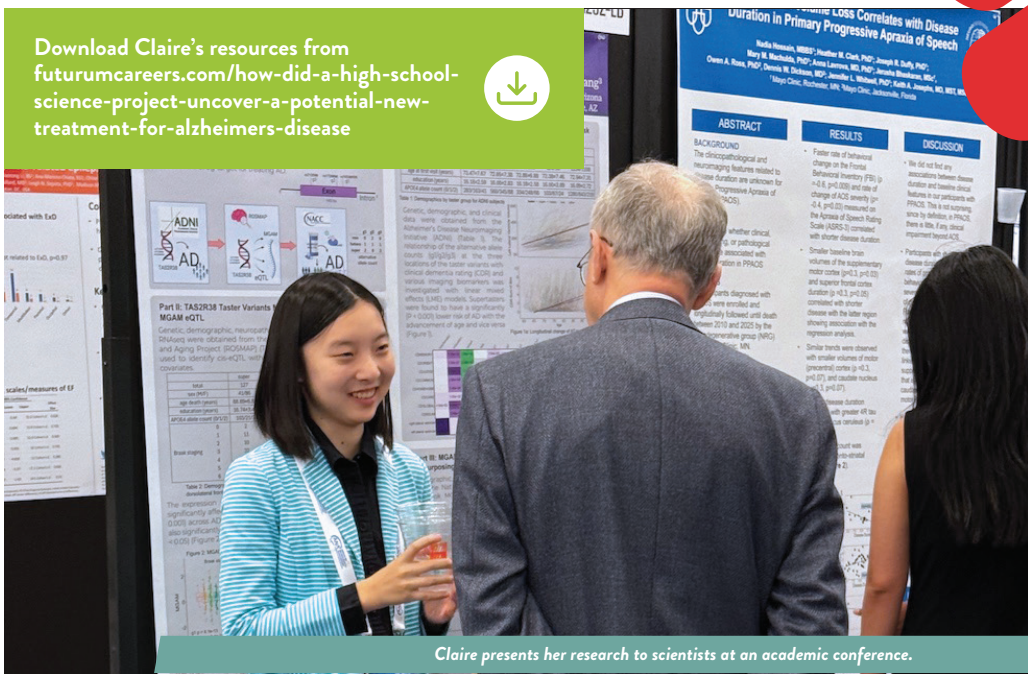
Do you like brussels sprouts? These vegetables famously divide opinion over whether they are delicious or disgusting. If you can't stand brussels sprouts, you aren't being a fussy eater – you probably have a genetic disposition to find the taste unpleasant.

"The TAS2R38 gene is a taste receptor that affects people's sensitivity to bitter compounds, such as those in brussels sprouts," says Claire Su, a high school student at BASIS Ahwatukee in the US. "If someone has the supertaster variant of the gene, they can perceive bitter taste compounds and so may have an aversion to foods containing these." People with the nontaster variant are unable to taste the bitter compounds in brussels sprouts, and heterozygotes' taste perceptions lie between supertasters and nontasters.

What inspired Claire to research taste genes?

Claire first learnt about supertaster genes in her 8th Grade biology class. "I was curious whether perceptions of taste might connect with memory, since I had heard that taste and smell are often connected with cognitive abilities," she says. "I wanted to study if there was a connection between TAS2R38 and Alzheimer's disease." And so, in 9th Grade, Claire joined a science fair club where she was mentored by scientists from Arizona State University who supported her as she conducted her own scientific research project.

Download Claire's resources from futurumcareers.com/how-did-a-high-school-science-project-uncover-a-potential-new-treatment-for-alzheimers-disease



Claire presents her research to scientists at an academic conference.

How did Claire investigate links between taste genes and Alzheimer's?

Claire analysed data from over 2,000 people who had taken part in the Alzheimer's Disease Neuroimaging Initiative (ADNI). First, she examined their genetic data to determine their taster genotype (whether they were a supertaster, nontaster or heterozygote) by examining the alleles in three locations on the TAS2R38 gene. Supertasters have two copies of the alternative allele in the first and third location, while nontasters have two copies of the alternative allele in the second location, and heterozygotes have one alternative allele and one reference allele.

Claire then compared these people's taster genotypes with their Alzheimer's biomarkers. This included numerical scale ratings, such as their Clinical Dementia Rating, as well as imaging data collected from brain scans, such as the presence of amyloid and tau proteins that build up in the brain during cognitive decline.

"I found that alternative first and second TAS2R38 alleles are positively correlated with biomarkers for cognitive decline, while an alternative third allele is negatively correlated with cognitive decline," Claire says. "As supertasters have alternative first and third alleles, the positive and negative effects counteract each other, resulting in a slower rate of cognitive decline compared to nontasters, who only have alternative second alleles. Thus, my results showed that TAS2R38 supertasters displayed a lower risk of Alzheimer's."

Next, Claire analysed genotype data from over 900 people who had taken part in the Religious Orders Study and Memory and Aging Project (ROSMAP). "I connected genotype data to the expression of nearby genes in the genome to find a potential molecular mechanism behind the association," she explains. She discovered that the TAS2R38 gene variants themselves do not directly impact the risk of Alzheimer's. Instead, Claire found that they act as expression quantitative trait loci, meaning they mediate the expression of nearby genes, and she identified the MGAM gene (which produces an enzyme to digest starch) as being affected. "I found that the supertaster variants are associated with a lower expression of MGAM in the Alzheimer's-affected brain regions, and vice versa," she says, indicating that a higher expression of MGAM is linked to cognitive decline.

> ***"My results showed that TAS2R38 supertasters displayed a lower risk of Alzheimer's."***

Finally, Claire analysed data from the National Alzheimer's Coordinating Center (NACC) to investigate whether MGAM-inhibiting drugs could reduce the risk of Alzheimer's. "MGAM is a target for diabetes treatment and drugs inhibiting its expression have already been developed, which allowed me to investigate how the drug could affect the susceptibility to Alzheimer's," she explains. Claire found that people taking MGAM-inhibiting drugs do indeed have slower rates of cognitive decline, suggesting that these diabetes drugs could be repurposed for treating Alzheimer's. Claire's mentors are now exploring her findings further through animal model testing, with the aim of evaluating their potential for translation into clinical practice.

What next for Claire?

Since completing her science fair project, Claire has written up her findings and, with the support of her mentors, published them in an academic journal so that scientists and doctors around the world can learn from her work. But this wasn't always an easy journey. "The research experience was hard at first because I knew very little about coding and data analysis when I began, but I have now become fluent in these skills," Claire says. "There were always setbacks, such as when results weren't statistically significant or when my code disappeared and I had to redo whole portions of the project." However, the joys have greatly outweighed the challenges. "The moments when I got significant results really excited me!" says Claire. "During the gene expression analysis, it was fascinating to learn about lots of genes that I'd never heard of before."

Now in 12th Grade, Claire is looking forward to going to college to study cognitive science. "I'm drawn to understanding human thought and how people see the world differently," she says. "I want to continue doing research as I'm constantly reminded about what a big and unexplored world the human body really is and how research can help improve diagnosis and treatment of diseases."

Claire's story highlights how curiosity born from a science lesson can lead to remarkable new scientific discoveries, as what began as a high school science project has resulted in a potential new treatment for a devastating disease.

How can people with haemophilia reduce the risk of long-term joint damage?

Haemophilia is a genetic disorder that prevents blood from clotting properly. It can cause prolonged bleeding from minor cuts and scrapes, internal bleeding into joints and muscles, and spontaneous bleeding that occurs without any obvious injury. **Dr Jesus Ardila** collaborated with adult and paediatric haematologists who care for patients across Colombia to study haemophilic arthropathy, a form of joint damage that occurs as a result of long-term bleeding into joints. This research initiative, supported by **Roche**, aims to translate clinical findings into better care strategies and a higher quality of life for affected patients.



Dr Jesus Ardila

Scientific Director, Hemo&Onco, Colombia

Field of research
Haematology

Research project
Investigating the factors that cause haemophilic arthropathy

Research paper
Factors contributing to the development of hemophilic arthropathy: A real-world study. Ardila et al (2026) doi: 10.1007/s00277-026-06866-9

Funder
Roche

Websites
roche.com.co; hemoonco.com

doi: 10.33424/FUTURUM734

PROFILE

Talk like a ...

haematologist

Clotting factors – specialised proteins that stop bleeding by forming blood clots

Haemophilia – a genetic disorder that prevents blood from clotting properly

Haemophilic arthropathy – a progressive, disabling joint condition caused by repeated bleeding inside joints

Prophylaxis – a medical treatment used to prevent a condition from occurring, rather than treating it after it starts

If you've ever fallen over and scraped your knee, you'll know that your body acts quickly to stop the bleeding. The injured blood vessels constrict to slow the bleed, tiny cells called platelets clump together to block the leak, and proteins in the blood called clotting factors create a blood clot to protect the wound as it heals.

However, for people with haemophilia, small scrapes and scratches present a much bigger problem. Haemophilia is a rare, inherited disorder that prevents blood from clotting properly due to a lack of clotting factors. This poses a serious risk, not just from external wounds but also from internal bleeding, which can go unnoticed and lead to long-term, debilitating joint damage known as haemophilic arthropathy.

Dr Jesus Ardila is part of a team of Colombian haematologists and orthopaedists who care for paediatric and adult patients and who are studying the factors that lead to the development of haemophilic arthropathy. They are also educating patients, families and clinicians about how to avoid it. "What drives me every day is a promise I made to myself years ago while examining a boy who was no longer able to extend his arm: not one more preventable bleed," says Jesus. "Prevention begins with education and becomes a reality through training professionals; that is what this research is for."

What causes haemophilic arthropathy?

When bleeding happens inside a joint, it causes irritation and the joint becomes inflamed. The repeated cycle of bleeding and inflammation slowly destroys cartilage and bone, and over time the joint becomes painful, stiff and hard to move.

"No quantity of blood inside a joint is harmless; that is something I try to make clear to my patients and their families," says Jesus. "The damage begins with the very first bleed." Preventing bleeding from the earliest possible age and catching joint change before it becomes irreversible will determine whether a child grows up with physical freedom or not.

How does haemophilic arthropathy affect patients?

"Haemophilic arthropathy reaches far beyond the joint itself," says Jesus.

"As the damage progresses, everyday activities – climbing stairs, playing sports and even holding a spoon – can become exhausting challenges." And the condition can cause psychological and emotional damage too. For example, the fear of triggering a bleed makes people reluctant to move and exercise. This creates a vicious cycle: less activity makes joints more vulnerable to bleeding, which increases the reluctance to be active. Limited mobility affects school attendance, social participation, self-confidence and mental well-being. "The emotional burden of haemophilic arthropathy should never be underestimated," says Jesus. "Protecting joint health is not just about preventing physical damage; it is about preserving a person's autonomy, dignity and right to live a full life."

How does Jesus study haemophilic arthropathy?

"Haemophilic arthropathy is not caused by a single factor," says Jesus. "It develops through an intricate interaction of biology, treatment decisions, lifestyle choices and healthcare access, so no single source of data could tell the complete story." To investigate this complex interplay of factors, Jesus and his research team used three types of evidence.

First, they reviewed scientific literature to identify everything that previous research had already suggested as a factor in haemophilic arthropathy. They then gathered real-world data from 90 Colombian patients with haemophilic arthropathy, collected from patient diaries completed by their doctors. Finally, the team interviewed nine experienced haematologists, allowing them to interpret their findings through the lens of people who care for these patients every day.

> ***"The clearest message across every part of our study was 'start prophylaxis early and prevent bleeding'."***

What did the team discover?

"The clearest message across every part of our study was 'start prophylaxis early and prevent bleeding'," says Jesus. Prophylaxis is a preventative treatment given to reduce the risk of bleeds. "Patients who started prophylaxis in early childhood before any joint damage had occurred were significantly less likely to have haemophilic arthropathy compared to those who started later or were treated only once bleeding had occurred," continues Jesus. "And patients who experienced at least one bleed per year were approximately six times more likely to develop haemophilic arthropathy compared with those who had no bleeds."



Dr Jesus Ardila performs an ultrasound scan on the joint of a patient with haemophilic arthropathy.

Crucially, the study emphasised that monitoring joint health must extend beyond simply counting bleeding episodes. Physicians need to proactively evaluate for haemophilic arthropathy using validated clinical scoring scales, alongside appropriate imaging like ultrasound. The team's research revealed real-world gaps in how frequently these objective assessments are performed in routine care.

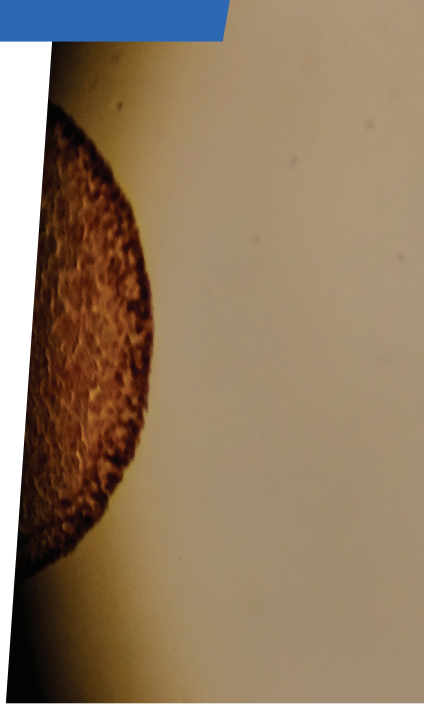
The team also found that physical activity was a major protective factor. Patients who remained physically active were less likely to develop joint damage and arthropathy than sedentary patients. This does not mean that exercise is risk-free for someone with haemophilia. "The type and intensity of activity must always be individualised," says Jesus. "But it does confirm that encouraging safe, appropriate physical activity is an important part of joint protection."

How can patients avoid haemophilic arthropathy?

Patients with haemophilia should stick to their prescribed prophylaxis regimen, maintain regular follow-ups and communicate any new symptoms straightaway. "Staying physically active is equally important," says Jesus. "Rather than avoiding exercise because of haemophilia, to preserve mobility patients should work with their healthcare team to choose safe, rewarding activities that strengthen the muscles that support the joints."

However, protecting joint health should not be the patient's responsibility alone. Healthcare professionals, medical researchers and clinicians all have a role to play in improving the quality of care for patients with haemophilia. And maybe you do too. "To any young person reading this who is considering a career in medicine: this work is hard, and the problems are real, but they are solvable," says Jesus. "The science to prevent haemophilic arthropathy already exists; what we need now are committed physicians, nurses and educators to bring that science to the communities that need it most."

Download Jesus's resources from futurumcareers.com/how-can-people-with-haemophilia-reduce-the-risk-of-long-term-joint-damage



What role does folate play in pregnancy and autism spectrum disorder?

Within the first few weeks of pregnancy, mothers begin passing an essential nutrient called folate to their developing baby. However, in some pregnancies, the baby doesn't receive enough folate, which can lead to developmental disorders. At **Santa Barbara City College** in the US, neuroscientist **Dr George Ayoub** is investigating how a lack of folate during pregnancy can lead to neurodevelopmental conditions such as spina bifida and possibly autism spectrum disorder (ASD).



Dr George Ayoub

Department of Psychology, Santa Barbara City College, USA

PROFILE

Fields of research
Neuroscience; neurodevelopment

Research project
Investigating the links between folate and autism spectrum disorder

Funder
Self-funded

doi: 10.33424/FUTURUM727

Talk like a ...

neuroscientist

Folate — an essential vitamin that is important for cell growth

Folate receptor alpha — a protein that transports folate across the placenta into the developing baby's brain

Folate receptor alpha autoantibodies — an immune malfunction that prevents folate receptor alpha from doing its job

Folic acid — a synthetic version of folate

Neural tube — a narrow channel that develops into the brain and spinal cord

Placenta — a temporary organ that connects the baby to the mother during pregnancy and provides nutrients

Reduced folate carrier — a protein that transports specific forms of folate across the placenta

Folate, also known as vitamin B9, is an essential nutrient that helps us create new DNA, supports cell growth and division, and plays an important role in a baby's development during pregnancy. In our day-to-day lives, we consume folate by eating foods such as leafy vegetables, eggs, citrus fruits and legumes. Since folate is so important for a baby's development, pregnant women and those trying to conceive are also advised to take folic acid, a synthetic form of the same vitamin.

"Folate is especially critical for closing the neural tube (which becomes the brain and spinal cord) in the first weeks of pregnancy," explains Dr George Ayoub, a neuroscientist at Santa Barbara City College. "Too little folate raises the risk of neural tube defects and can affect broader brain development, potentially leading to autism spectrum disorder (ASD)." Although ASD develops from a complex mix of many different factors, folate seems to play a key role in many cases.

How does folate reach the baby?

During most pregnancies, a protein called folate receptor alpha transports folate across the placenta, from the mother's blood into the baby's blood to reach its developing brain. While this is often a smooth process, some mothers' immune systems make folate receptor alpha autoantibodies (FRAAs) that attack the folate transport proteins. In one study, 17% of women planning for pregnancy tested positive for FRAAs.

"When FRAAs block or bind to folate receptor alpha, they can stop the transport of folate across the placenta," explains George. "This means that insufficient folate reaches the baby's brain, even if the mother is taking folic acid supplements and has plenty of folate in her blood." The lack



of folate reaching the baby increases the risk of developmental disorders.

What is the link between folate and ASD?

George is investigating how insufficient folate caused by FRAAs is linked to ASD – a neurodevelopmental condition that affects how people communicate and interact with the world. The latest figures from the US Centers for Disease Control and Prevention show that 3.2% of all pregnancies in the US produce an ASD child. "However, in a recent study, 60% of FRAA positive pregnancies produced an ASD child, despite the mothers taking folic acid during pregnancy," says George.

For expectant mothers with FRAAs, taking folic acid supplements may be insufficient. "Research shows that unmetabolised folic acid builds up in the blood, and this could worsen inflammation or immune activity," says George. "Telling every pregnant woman to take the same dose of folic acid ignores the fact that a significant subgroup of these women cannot transport it across the placenta, putting both them and their developing child at risk." George is investigating how a different form of folate called leucovorin might be a better option for mothers with FRAAs.

What is leucovorin?

"Leucovorin is a natural folate, similar to what you get from food," explains George. "That means it is in the form your body can use, unlike folic acid which must be metabolised first." Importantly, this means that leucovorin can enter the developing brain not just through folate receptor alpha but also through a different transport protein called the reduced folate carrier. This allows it to cross the placenta even if the mother has FRAAs.

Imagine that the developing brain is a construction site and folate molecules are the construction workers. The folate workers normally travel from the mother to the baby through folate receptor alpha, a wide highway built to give them an easy route on to the site. However, some mothers have FRAAs which act like road blocks, preventing folate from travelling down the main road. Reduced folate carrier is like a country road that bypasses the FRAA roadblocks, and leucovorin is able to travel down this route to reach the construction site.

When folate travels through folate receptor alpha, it concentrates in the placenta at three times the level found in the mother's blood. However, reduced folate carrier can only transport enough folate into the placenta to match the mother's folate level. This means that when leucovorin is used as a folate supplement, it needs to be taken at higher doses than folic acid.

How can leucovorin help?

Although less folate can pass through reduced folate carrier than folate receptor alpha, recent evidence suggests that leucovorin can have a positive impact on early brain development. In a randomised control trial, FRAA-positive pregnant women were given either leucovorin or folic acid supplements. "The results showed that leucovorin supplementation was linked to markedly lower autism incidence and reduced ASD symptom severity in children," says George. "60% of the folic acid pregnancies resulted in ASD children, compared to just 10% of the leucovorin pregnancies."

Leucovorin can also improve symptoms for ASD children with FRAA. "In this group, leucovorin treatment has been shown to meaningfully improve symptoms related to social communication," says George. "However, while leucovorin can help some ASD children with folate-pathway issues, it is not a 'cure', and it isn't universally effective, helping about half the ASD children in the trials."

What are the next steps in George's research?

Although recent studies have had encouraging results, more research into the effects of leucovorin is needed. "We still don't know who might respond to leucovorin, and there is a need for larger randomised controlled trials, both to identify if leucovorin is optimal for all FRAA-positive pregnancies, and also for FRAA-positive autism cases," explains George.

It is an exciting time to be in this field of work, with leucovorin being approved by the US Food and Drug Administration in early 2026 to treat a genetic form of folate deficiency. "There is also research on developing non-invasive tests that can screen for FRAA-related risks in pregnancy and infancy," says George. "These tests are important because we know that early provision of the needed folate can reduce developmental risks before symptoms even emerge."

About *neuroscience*

Neuroscience is an interdisciplinary field that combines physics, biology, psychology and philosophy to investigate the brain and the nervous system. "I like neuroscience for a number of reasons; the foremost being that the questions we study are fascinating because they are about who we are as people," says George. Neuroscientists might study neurodevelopmental conditions to understand how they begin, explore and come up with treatments for neurodegenerative diseases such as dementia, look into the underlying principles of our nervous systems, or investigate the processes behind our thoughts, feelings and actions.

"Neuroscience allows me to explore topics from philosophy using tools from the physical sciences," explains George. "For example, I use cellular or molecular tools and clinical studies to help me think about why things are the way they are, what changes when things develop differently, and how we might rectify that."Neuroscience is an exciting and ever-changing field. "The ways we can do experiments are always changing, which often creates new questions, new ways of seeing things and new answers, too," says George.

A day in the life of a neuroscientist can be quite varied. "How I spend my time changes over the course of the year," says George. "My typical day during the semester includes teaching classes, interacting with students, communicating with scientific colleagues, writing research papers and reading."



Pathway from school to *neuroscience*

During high school, take classes in biology, chemistry and physics. If you're able to, take a psychology or philosophy course as well.

"During college, I majored in physics and minored in philosophy," says George. "When I took a neuroscience course, I loved seeing how these two areas combined, and it showed me that my knowledge of physics could be used to improve people's health."

At university, consider a bachelor's degree in neuroscience, psychology or biology. "If you are interested in the sciences, take a range of science courses," says George. "Each will have value for you and help you learn how to think from different perspectives."

After your bachelor's degree, you will need to complete a PhD if you want to work in research.

Explore careers in *neuroscience*

"Try to read some research papers and summaries of current research," suggests George. "Use PubMed Central (**pmc.ncbi.nlm.nih.gov**) to find papers that interest you – these may introduce you to new ideas."

"When reading about science research, try to avoid click-bait articles and instead choose articles that explain things well," says George. "You will quickly learn to spot the difference and you'll be able to learn so much more!"

This Stanford Report article (**news.stanford.edu/stories/2019/07/like-experimental-neuroscientist**) contains interviews from neuroscience students, PhD candidates and the chair of the department on what they enjoy about their research.

The Franklin Institute has produced a suite of resources as part of their Neuroscience and Society Curriculum: **fi.edu/en/neuroscience-society-curriculum**



© Natalia Deriabina/Shutterstock.com

Download George's resources from **futurumcareers.com/what-role-does-folate-play-in-pregnancy-and-autism-spectrum-disorder**



Meet *George*

As a teenager, I spent my time reading, playing hockey and soccer, and figuring out how things worked. I would fix things by taking them apart and puzzling through what wasn't working to find a solution. I also enjoyed sciences, especially physics.

I love the challenge of explaining complex information in a way that my students understand – especially when they see how it impacts them. I like to think of answers to 'why' questions, and that applies to my teaching and to my research. I've learned that to be a good teacher I need to know something well, to be able to see it from many vantage points and continually ask 'why'.

I enjoy working in neuroscience because it is central to who we are, so understanding how and why each aspect works is exciting. Secondly, I always focus on nutrition and health in my research, not only because I am curious, but also because I may be able to help others with health issues.

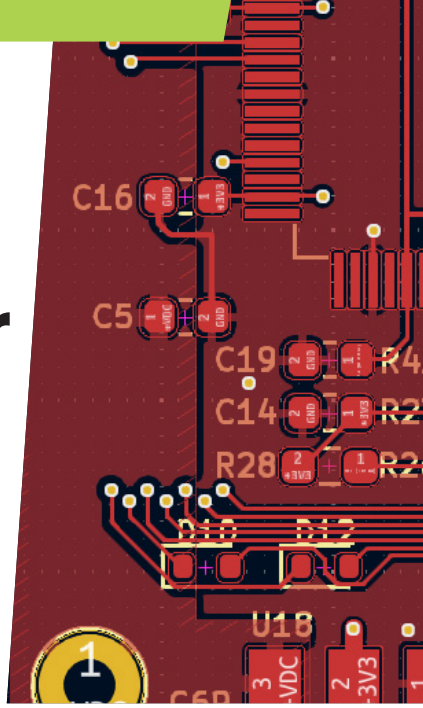
Always being curious has helped me lead a successful career. I never rush to conclusions, I remain sceptical about new theories until there is overwhelming evidence to support them, and I'm open to different ways of looking at things – recognising that how I see something is only one view. When we can hear from a wide variety of views, we can be more successful in coming up with ideas that may prove useful.

Outside of my work, I make time to exercise – which is when I usually have time to think through things that I'm reading or writing. It is a sort of prayer/meditation time for me. Preparing meals also keeps me grounded, and I love to explore nature and volunteer with charities. Although the charities change over time, it is always rewarding to see my efforts help others.

George's *top tips*

1. Stay curious. There is always a push to conform to how 'everyone else' is viewing things, but if you stay curious you are much more likely to find a new perspective.
2. Keep reading. I read science articles from a wide variety of fields in my down time. This helps me find new ways of looking at things.
3. Choose the right teacher. When you like someone's teaching style, take their classes or work with their research. We always gain more when we resonate with the person. And the opposite is true as well. If a teacher is difficult for you, even if they may be famous, that's not a good fit. Try to work with people you feel connected to.

Semiconductors in space: how can we protect computer chips from radiation?



Computer chips are found all over our modern world in devices ranging from laptops and smartphones to motorbikes and washing machines. But what happens when you send a computer chip into outer space? **Professor Li Chen** from the **University of Saskatchewan** in Canada runs the STARR-Lab where his team investigates the effects of radiation on semiconductors and designs new chips that work reliably in the harsh conditions of space.



Professor Li Chen

Department of Electrical and Computer Engineering, University of Saskatchewan, Canada

PROFILE

Fields of research
Electrical engineering; computer engineering

Research project
Testing and designing radiation-resistant computer chips in the STARR-Lab

doi: 10.33424/FUTURUM731

Talk like an ...

electrical engineer

Complementary metal-oxide-semiconductor technology (CMOS) — the standard process used to build computer chips, allowing billions of transistors to be packed onto each chip

Microcontroller — a tiny, self-contained computer on a single chip

Open-source — when the original design or source code for a digital resource is publicly accessible

Semiconductor — a material that can act as a conductor and an insulator, often used to make transistors

Transistor — a device used to switch electrical signals on or off, serving as a core component of computer chips

Have you ever heard of complementary metal-oxide-semiconductor technology? If the answer is no, don't worry – most people haven't either. Despite its complicated name and relative obscurity, you probably use this technology every day.

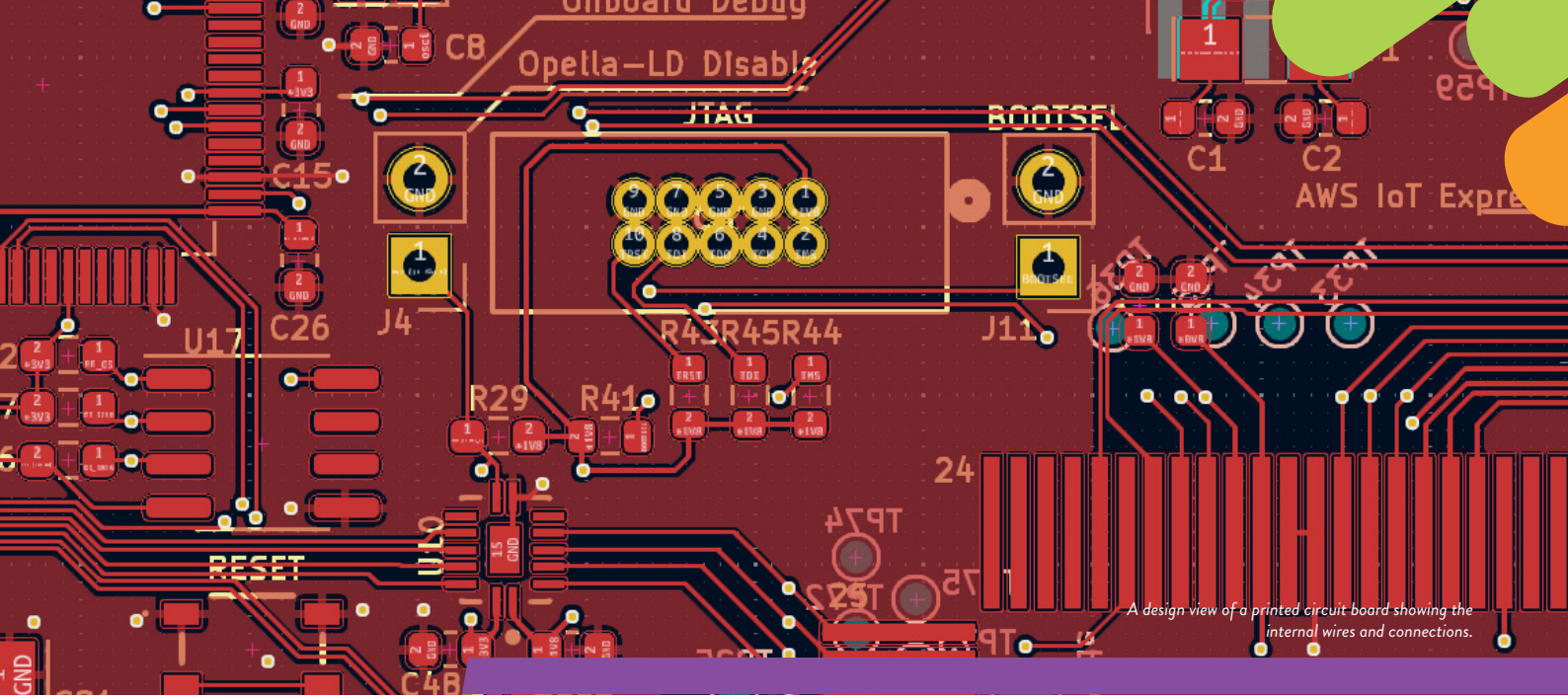
"Complementary metal-oxide-semiconductor technology, usually shortened to CMOS, is the foundation of almost every modern computer chip," says Professor Li Chen from the University of Saskatchewan. "This is the technology that allows us to have enormous computing power in a device that is as small as our fingernails."

CMOS computer chips contain billions of microscopic switches called transistors that are used to represent information in binary code, a series of 1s and 0s. Digital circuits use voltage levels to represent 1s and 0s and a network of transistors to manipulate and store those values. "By themselves, these transistors aren't particularly useful," says Li. "But if you connect billions of them together in carefully designed patterns and configurations, they can perform calculations, store information, process images and even run artificial intelligence."

CMOS is used to build the computer chips found in electronic devices that you probably use every day, from your mobile phone to your microwave. But the technology is also used in more complicated devices such as X-ray machines, particle colliders and even satellites.

CMOS in satellites

Like many other devices that we rely on, satellites are packed full of computer chips. "These chips control power, communications, navigation, scientific instruments and autonomous decision-making," explains Li. "You can think of



A design view of a printed circuit board showing the internal wires and connections.

them as the satellite's brain and central nervous system – without them, satellites would just be useless hunks of metal floating around our planet."

However, electronics that work perfectly on Earth can behave very differently when they are launched out of the safety of our atmosphere. "Space is an extremely unforgiving environment," says Li. "Temperatures can change dramatically, there is no air and it's difficult to send people up to repair a broken component." But Li's research group is particularly interested in one particular extra-terrestrial issue: radiation. "Spacecraft are constantly exposed to radiation from the Sun and from energetic particles travelling through the universe," says Li. "Just as excessive radiation can damage the cells in our bodies, it can also damage the tiny electronic structures inside a computer chip."

The problem with radiation

As a radioactive particle passes through a chip, it leaves behind a trail of electrical charge which can interfere with the chip's transistors, pressing switches that weren't meant to be pressed. "Radiation can instantly change stored data, corrupt a calculation, interrupt a program or cause a sudden surge of power," says Li. "It can also produce gradual damage over time, causing a chip to become slower, consume more power or stop working altogether."

For a spacecraft that is hundreds or even millions of miles from Earth, a tiny electronic error can have serious consequences. Understanding how radiation affects computer chips is therefore essential for building spacecraft that can operate reliably for years without repair.

The STARR-Lab

In the STARR-Lab, Li and his team recreate space-like environments in controlled laboratories. "We take computer chips – sometimes commercially available devices and sometimes custom chips we have designed ourselves – and we operate them while exposing them to radiation," he explains. "We use particle accelerators to bombard the chips with radiation while our equipment checks whether the chip is calculating correctly, storing the right information and consuming the expected amount of power."

Once they have identified the chips' most sensitive and failure-prone areas, Li's researchers design new chips that are better able to withstand radiation. "People often assume that radiation-hardened electronics must be made from exotic materials or wrapped in thick shielding," says Li. "However, radiation can still pass through substantial shielding, and every extra kilogram is expensive to launch into space."

Instead, Li's team makes the circuits themselves more resilient. "We use many of the same manufacturing processes as commercial semiconductor companies, but we arrange and connect the transistors in clever ways," explains Li. "Sensitive transistors can be separated or duplicated so that one particle is less likely to disrupt them all at once and information can be stored in circuits that check one another, allowing an error to be detected and corrected almost immediately."

Li compares this process to designing buildings in earthquake-prone areas. "We cannot prevent the earthquake from happening, but we can design the structure in clever ways so that it doesn't collapse," he says.

The StarRISC programme

StarRISC is the latest computer chip to be developed by the STARR-Lab. "It is a microcontroller (essentially a small but complete computer on a single chip) designed to be capable, energy-efficient and highly resistant to radiation," explains Li. "It combines years of radiation-hardening research from our laboratory with an open-source processor design from the OpenHW Foundation." If it is successful, StarRISC could be the first fully Canadian-designed computer chip of its kind to operate in space.

"Our next goal is to keep building upon the success of StarRISC," says Li. "We know how to make the processor reliable, so now we want to give it much more computing power." Modern spacecraft are expected to process large amounts of information by themselves, rather than sending every piece of data back to Earth. "A satellite might need to identify a wildfire in an image, navigate autonomously or make decisions when communication with Earth is delayed," explains Li. "These tasks increasingly involve artificial intelligence, which demands lots of computing power." With the second generation of StarRISC currently being developed, Li and his team at the STARR-Lab will be supporting the future of space exploration.

About *electrical engineering*

"Almost everyone interacts with the work of electrical engineers from the moment they wake up," says Li. "They help generate the power in our homes, build communication networks, design smartphones and computers, develop medical equipment, create the electronics used in cars, aircraft and spacecraft, and so much more!"

What makes the field especially exciting is its enormous range of scale. "An electrical engineer might work on a power station large enough to supply a city or on a transistor so small that its most important features are only a few atoms across," explains Li. "Our modern world depends on the work of electrical engineers, and the next generation will be able to push the boundaries even further in areas such as artificial intelligence, renewable energy, robotics, quantum computing and space exploration."

"One of the most rewarding parts of electrical engineering is seeing an idea become something real," continues Li. "A project may begin as just a drawing on a board, a computer simulation or a few lines of code, but eventually you may be able to hold the finished device in your hand and watch it work. That is such a rewarding feeling."

As an electrical engineer, you will have to solve complex problems. "There may be ten different ways to solve the same problem, each with different costs, risks and advantages," says Li. "The challenge is not simply finding one answer, but deciding which answer works best in the real world. That uncertainty can be difficult, but it is also what makes engineering so interesting and creative."

You can prepare for these challenges by developing your critical-thinking, problem-solving and communication skills. "You should also become comfortable with trying an idea, discovering that it doesn't work and improving it," advises Li. "In engineering, failure is often not the end of an experiment – it is the information that leads to the next one."

Pathway from school to *electrical engineering*

"Mathematics and physics provide an important foundation because they are necessary to understand how electricity, forces and energy behave," advises Li. "Computing and programming are also increasingly valuable, as modern electrical systems usually combine hardware and software."

Practical experience is just as important as learning technical information. "You can learn a great deal from a textbook, but building something teaches you in a way that a book alone cannot provide," says Li.

Join robotics clubs, electronics projects, coding groups or other industrial-arts courses. "Even a simple project, such as using a sensor to switch on a light, can introduce you to the same process of designing, testing and improving that professional engineers use," says Li.

Explore careers in *electrical engineering*

"An electrical engineer might design power lines that stretch across many miles, antennas that communicate with satellites, autonomous machines that explore mines or transistors that are far too small to see with the human eye," says Li. "The kinds of careers that are possible are too long to list!"

Other potential careers include working with computer simulations, medical devices, renewable energy, robotics, nanomaterials or spacecraft systems. "There is something for anyone who enjoys technology, especially those interested in using it to solve problems and improve people's lives," enthuses Li.

Explore the websites of the Institute of Electrical and Electronics Engineers (**ieee.org**) and the Institution of Engineering and Technology (**theiet.org**) to learn more about careers in this field.

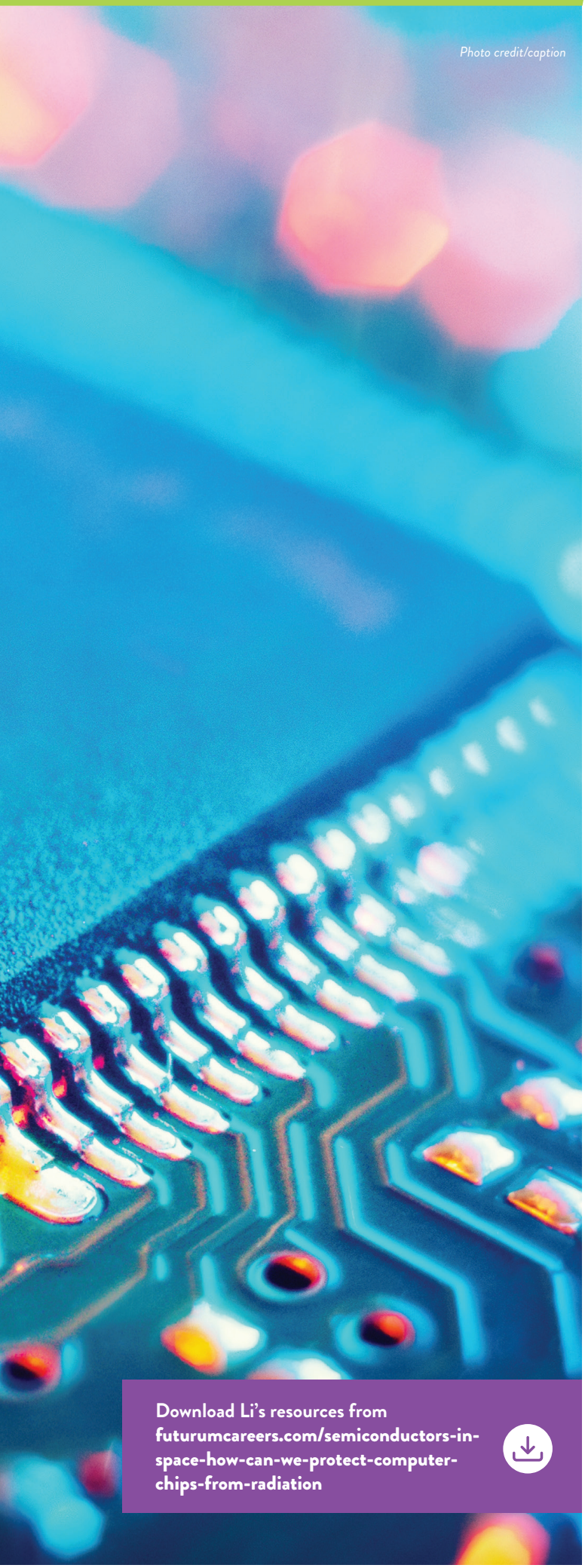


Photo credit/caption

Download Li's resources from **futurumcareers.com/semiconductors-in-space-how-can-we-protect-computer-chips-from-radiation**



Meet *Li*

When I was younger, I was interested in electronics and small science projects. For example, I made small steam boats (by filling empty eggs with water and burning a candle underneath them), a simple prototype of a stealth periscope and a magnetic coil for weight lifting. These simple scientific projects were guided by my dad's magazines and books, which inspired my curiosity in science and engineering.

I love working with and training students. Taking part in our research can help them achieve their career goals.

I am driven by curiosity and a desire to understand how complex electronic systems behave under challenging conditions, particularly in radiation environments. This motivation led me to specialise in semiconductor reliability in space.

Perseverance has been critical to my career. Research in electrical engineering often involves long-term projects, experimental setbacks and difficult technical problems. The ability to remain focused and continuously seek solutions has been important throughout my career.

I have benefited from interdisciplinary collaboration. Research into the effects of radiation requires expertise in device physics, circuit design, semiconductor technology, computer engineering and reliability analysis. Working with researchers from different backgrounds has broadened my perspective and enabled more impactful research outcomes.

I usually unwind by spending time with my family, taking walks and playing badminton. These activities help me disconnect from daily research challenges, maintain balance and return to work with renewed energy and a fresh perspective.

Li's *top tip*

Curiosity and persistence are often more valuable for an engineer than already knowing the answer.

How are vampire stories a metaphor for adolescence?



Adolescence is a time of transition, as young people grow from childhood into adulthood. The physical and psychological changes that accompany adolescence can lead to identity crises, as young people struggle to find their place in the adult world. At **Doshisha University** in Japan, **Dr Sayaka Oki** is studying how vampire narratives express these challenges and how stories can be used to explore questions about identity.



Dr Sayaka Oki

Associate Professor, Faculty of Global and Regional Studies, Doshisha University, Japan

Currently a visiting researcher at LMU Munich, Germany

Field of research
Literature

Research project
Exploring how vampire narratives are a metaphor for adolescence

Research paper
Adolescence in vampire narratives: symbolic motifs from the fairy tale *Little Red Riding Hood* in E.T.A. Hoffmann's *Vampyrismus* (1821) and Moira Buffini's *A Vampire Story* (2008). Oki, S. 2026, doi: 10.1080/23311983.2026.2661497

Funder
Doshisha University

doi: 10.33424/FUTURUM738

PROFILE

Talk like a ...

literature researcher

Comparative close reading – a method to compare different literary works by searching for recurring themes

***Femme fatale* –** a mysterious and attractive woman who causes danger (a 'fatal woman')

***Femme fragile* –** a vulnerable and emotionally delicate woman (a 'fragile woman')

Gothic literature – a genre associated with the supernatural, mystery and horror

Liminal – an 'in-between' state at a boundary or transition

Motif – a recurring pattern, symbol or idea that helps to develop a theme

Prohibition – the act of forbidding something

Psychoanalytical – relating to psychoanalysis, the psychological idea of how unconscious thoughts influence conscious behaviour

Subjectivity – being shaped primarily by one's own beliefs and feelings, even though external influences also play a role

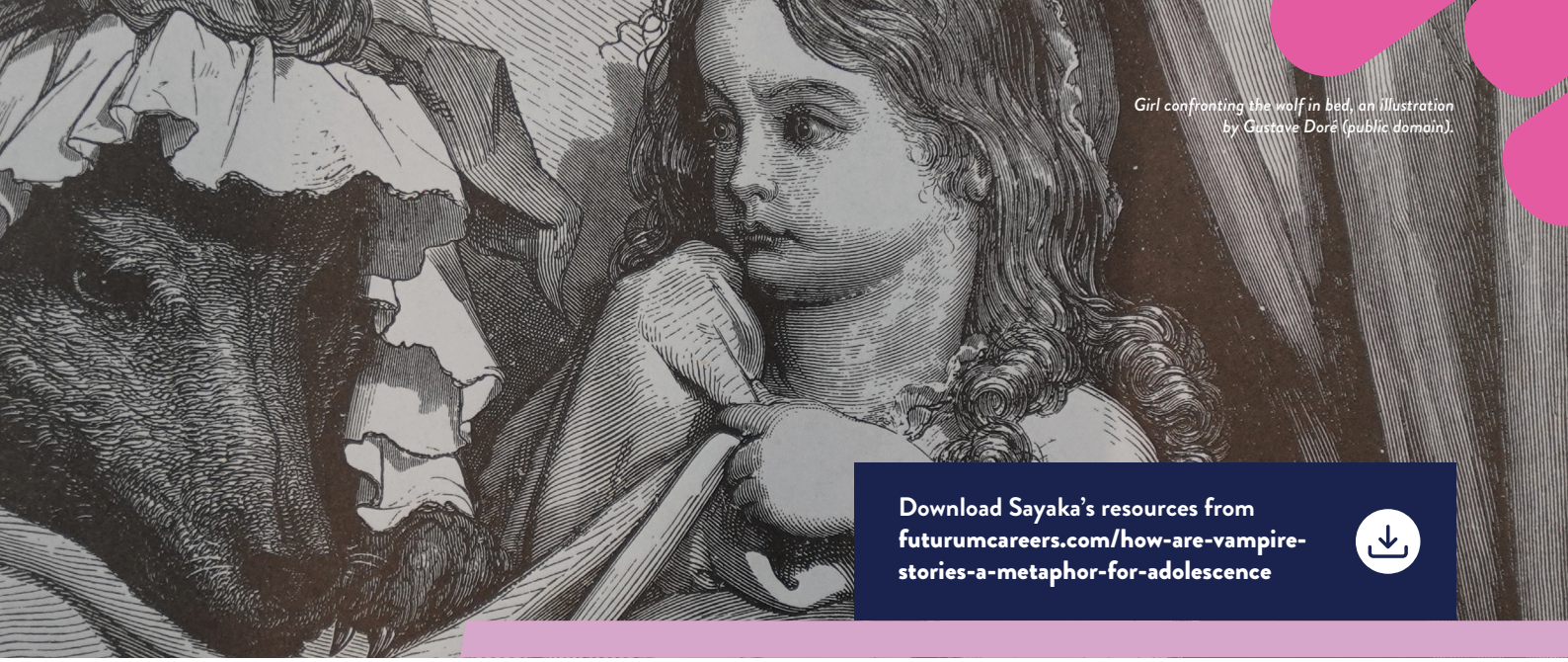
Once upon a time, a young girl in a red hood walked through the woods to bring cake and wine to her grandmother. But on the way, she met a wolf who persuaded her to pick some flowers as a gift for her grandmother, disobeying her mother's instructions to go straight to her grandmother's house. By the time the girl arrived, the wolf had eaten her grandmother, disguised himself in her grandmother's clothes and was waiting to swallow the girl.

You are probably familiar with the classic folktale of *Little Red Riding Hood*. But have you ever wondered about the deeper meanings behind the story?

"A key motif from *Little Red Riding Hood* is the conflict between desire and prohibition, which often appears in stories about adolescents," says Dr Sayaka Oki, a literature researcher at Doshisha University in Japan, who is studying how adolescence is portrayed in vampire stories. While there are no vampires in *Little Red Riding Hood*, the story shares many features with vampire narratives. "In older versions of the tale, Little Red Riding Hood unknowingly consumes her grandmother's flesh and blood, a detail which intensifies the connection with vampire stories," says Sayaka.

How does Sayaka study vampire narratives?

Sayaka is exploring how symbolic motifs



Girl confronting the wolf in bed, an illustration by Gustave Doré (public domain).

Download Sayaka's resources from futurumcareers.com/how-are-vampire-stories-a-metaphor-for-adolescence

from *Little Red Riding Hood* appear in vampire narratives using a method called comparative close reading. "This involves examining details (such as words, imagery or symbols) in different narratives and comparing how they appear across stories to analyse recurring themes," she explains. "I use comparative close reading to study fairy tales, modern literature and films, which allows me to notice shared ideas and patterns."

Vampire stories have a long tradition, from classical tales to modern fiction, meaning that studying them can uncover how ideas have changed through history and across cultures. Through her comparative close reading, Sayaka noticed that psychoanalytical symbols appear in many of the stories she was studying.

What psychoanalytical symbols exist in vampire stories?

"An Oedipal structure (named after the ancient Greek character, Oedipus) describes how young people form identity," explains Sayaka. "In adolescence, a young person may feel close to the opposite sex parent and compete with the same sex parent." This psychoanalytical idea appears in *Little Red Riding Hood* when she disobeys her mother's instructions and instead follows her curiosity then meets the wolf, who symbolises temptation, danger or a forbidden realm.

"In the Gothic narratives I analyse, vampire transformation symbolises cultural fears about women's bodies," explains Sayaka. "Such transformations often reveal what society cannot say openly, turning inner conflict into the fantastic." For example, in Hoffman's *Vampyrismus* (1821), the 16-year-old vampire Aurelie occupies a liminal position as she is neither an adult nor a child, and her supernatural change places her outside social structures. The conflict between desire and prohibition appears in Aurelie's rebellion against her mother's pressure to marry. "In this sense, vampirism functions as a metaphor, revealing unstable identities in the transitional phase of adolescence."

In 19th century Gothic literature, female vampires were portrayed as *femmes fatales*, but this idea is subverted in Buffini's A *Vampire Story* (2008; adapted into the film *Byzantium*, Jordan 2012). The 16-year-old vampire Eleanor is a *femme fragile* character who rebels against her *femme fatale* mother, highlighting her conflict between desire and prohibition and her struggle over her identity. "Buffini challenges traditional views of female vampires by showing Eleanor's emotional and creative perspective," explains Sayaka. "Eleanor's act of writing a story symbolises the search for her own voice, and in *Byzantium*, her gaze expresses her emerging subjectivity."

"Across these works, the tension between danger, desire and identity persists," continues Sayaka. "Each literary work offers a different view of adolescence and individuality, which reflects changing cultural values."

How does vampirism act as a metaphor for adolescence?

From reading, analysing and comparing different vampire narratives, Sayaka argues that vampirism is used as a metaphor for an identity crisis during adolescence. "An adolescent's identity crisis not only involves physical changes, but also emotional conflict as the young person attempts to establish who they are," she explains. "Vampirism works as a metaphor because the supernatural transformation reveals the hidden fears and pressures that exist in society. Vampire narratives depict diverse ways in which adolescents negotiate their individuality."

How can literature be used to explore ideas about identity?

"Literature allows readers to explore questions about identity and social pressure in a safe and imaginative way," explains Sayaka. "Stories help young people to reflect on their own experiences during the emotionally sensitive period of adolescence." By reading and discussing stories, you can observe how characters grow emotionally as a plot progresses, notice the hidden conflicts they face and learn how they overcome these challenges.

Vampire stories in particular are useful for thinking about identity and societal expectations. "They are a rich genre for studying symbolic motifs because they show the border between human and non-human, predator and prey, dominance and submissiveness, and even ideas of justice," says Sayaka. "I loved Gothic fiction as a teenager, and vampire stories were the ones I found most frightening. Vampires are 'in-between' beings that destabilise binary categories, making them well-suited for exploring deeper questions about adolescence."

Sayaka's work highlights how the supernatural transformations in vampire stories represent the psychological challenges of adolescence. Little Red Riding Hood, Aurelie and Eleanor all face conflicts and fear the fact that they rebel against their mothers – a tension central to Gothic fiction. In doing so, they form their own individual identities and emerge as young women.

How can the writings of a 17th century nun help us explore our sense of self?

Who am I? Humans have been asking themselves this question for thousands of years – but the answer isn't as simple as you might think. **Dr Judith Sribnai** from the **University of Montreal**, **Stéphanie Guité-Verret** from **Limoilou College** and **Dr Nathalie Freidel** from **Wilfrid Laurier University** in Canada are exploring this question through the writings of Marie de l'Incarnation, a 17th century nun. Although she lived and died around 400 years ago, her ideas about identity and the sense of self are still relevant today.



Dr Judith Sribnai

Associate Professor, Department of French-Language Literatures, Faculty of Arts and Sciences, University of Montreal, Canada



Stéphanie Guité-Verret

Literature teacher, Limoilou College, Quebec, Canada



Dr Nathalie Freidel

Professor, Faculty of Arts, Wilfrid Laurier University, Canada

Field of research
French literature

Research project
Investigating the 'self' through the writings of Marie de l'incarnation

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

doi: 10.33424/FUTURUM735

PROFILES

Talk like a ...

literature researcher

Colonisation – a system in which one country takes control of another region and its people, often imposing its own political, economic and cultural systems

Convent – a community of religious women who live, work and pray together

Indigenous peoples – the original peoples of a particular region, with their own cultures, languages, histories and communities

Mystic – a person who seeks direct, profound experiences of the divine or spiritual reality

New France – a large region of North America, including parts of Canada, colonised by the French between 1534 and 1763

Subjectivity – the way an individual experiences and understands the world from their own perspective

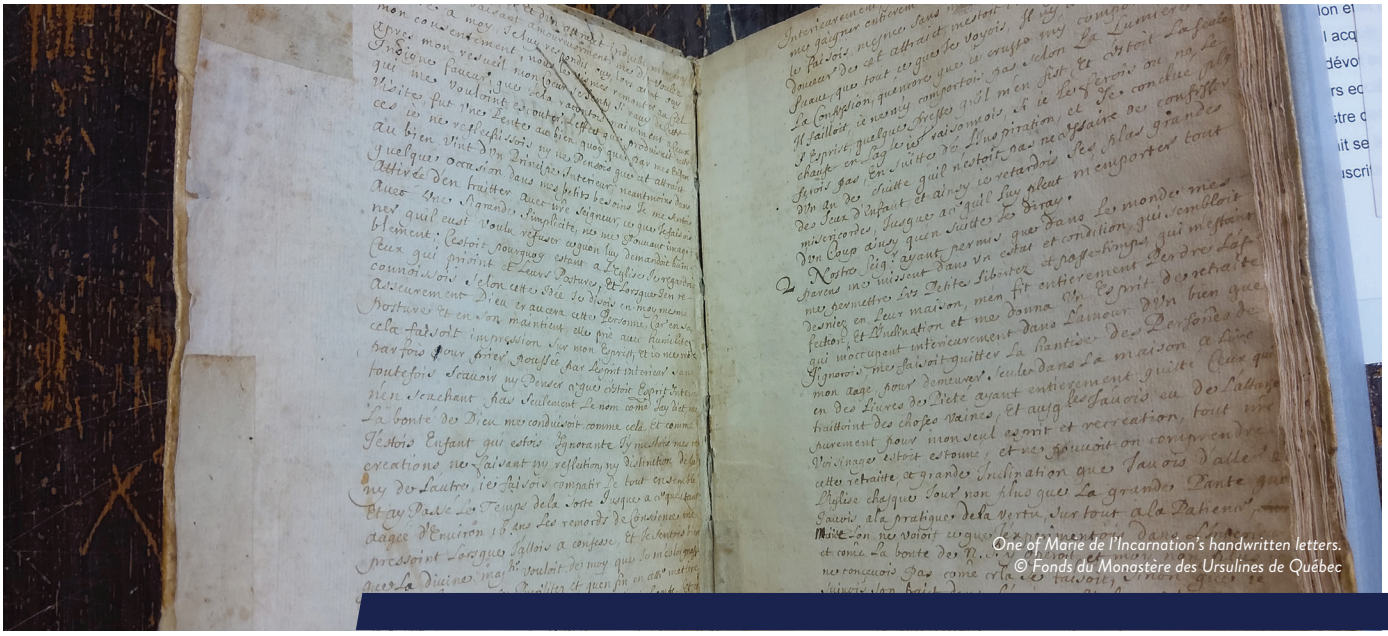
When you use the word "I", what are you referring to? The collection of cells that make up your body? The past experiences that have shaped who you are? The thoughts, feelings and opinions that make up your inner life? The more you try to define your 'self', the more you might find it slipping away from you.

"In a sense, one can never tell the exact truth about oneself," says Judith Sribnai from the University of Montreal. "We have many different expressions of our 'self', and they are often inseparable from one another."

Along with her colleagues Stéphanie Guité-Verret and Dr Nathalie Freidel, Judith is exploring the concept of the self through the writings of a 17th century nun called Marie de l'Incarnation.

Who was Marie de l'Incarnation?

"A nun, mystic, traveller, single mother and tireless writer, Marie de l'Incarnation was a remarkable woman," says Judith. "We know about her life through the few writings that remain to us – her letters and two autobiographical texts – but also through the accounts written later by her son."



One of Marie de l'Incarnation's handwritten letters.
© Fonds du Monastère des Ursulines de Québec

Marie Guyart was born in France in 1599 and was drawn to religion from a very young age. "God appeared to her from the age of seven, but she hid her devotion from those close to her," says Stephanie. "She married at 19, had a son and managed her husband's business for more than 10 years." Against her family's wishes, Marie became a nun in 1631, taking Marie de l'Incarnation as her religious name and entrusting her son to the care of his aunt before moving to 'New France', the vast French-colonised territory covering parts of present-day Canada and the United States. She founded a new convent in Quebec and remained there until her death in 1672.

Marie de l'Incarnation's writings

"Marie de l'Incarnation was a remarkable writer," says Nathalie. "She was an important figure in the development of spiritual and personal writing, which allowed many women to tell their own stories and share their experiences." As a result, her writings have attracted considerable interest from historians, scholars of religious studies and psychoanalysts.

Surprisingly, Marie de l'Incarnation often said she did not want to write, and only did so because she felt her son, her spiritual directors and, above all, God asked it of her. She also felt that her experiences of God were impossible to express in ordinary words. "Because of this, she practised a fascinating style of writing – one of detour and approximation," explains Judith. "She invented multiple strategies for 'saying while not saying', for telling the story of her life while evading the gaze of her readers."

Who is the 'I' and who is the 'Other'?

When we refer to ourselves, who are we really talking about? Marie de l'Incarnation's writings suggest that the answer is not simple. "Her writings dramatise the difficulty of living and reconciling all our different stories," says Stephanie. "She was a mother who abandoned her son, a nun in constant dialogue with God, a woman discovering life in New France, a participant in colonisation and a businesswoman in charge of a convent."

Each of these expressions of her 'self' were intertwined, and each existed in close relation to an 'other'. The mother sent letters to her son, the nun conversed with a God who spoke through her, and the participant in colonisation grew to know the Indigenous peoples who she tried to convert, and who profoundly changed her perspectives. "In this way, the sense of self often conceals other voices," says Nathalie.

"It is the way all these 'I's intertwine, respond to one another and sometimes contradict each other that we are studying," explains Judith. "Marie de l'Incarnation's writings invite us to reflect on how we can tell our stories and make others understand who we are, and the other voices and stories that inhabit us."

Marie de l'Incarnation's relationship with Indigenous peoples

Marie de l'Incarnation's writings document the often-violent process of how French colonisation affected Indigenous lives in North America. Initially, her writings reflected European views of Indigenous people as 'savage', but eventually she began to question this position.

"She never lost her faith or her desire to share it, but she began asking questions such as, 'Is it truly necessary to force Indigenous peoples into European customs and logic?' and 'What is the cost of forcing other people to change?'" says Stephanie. "She increasingly expressed her admiration for Indigenous people, particularly women, and for the richness of their way of life."

Are Marie de l'Incarnation's writings still relevant today?

The colonial context of Marie de l'Incarnation's writings and her life as a 17th century nun who travelled to convert people she initially viewed as 'savage' is important. "We cannot understand systemic racism today without grasping the discourses through which it was constructed and sustained," explains Judith. "We cannot heal today's wounds and misunderstandings without considering what gave rise to them."

Marie de l'Incarnation's writings are also relevant because they raise questions about our identities and how we express them. Like Marie de l'Incarnation, we often feel obliged to tell our own stories or to put ourselves on display. "We feel as though it's important to be seen and to have a presence on social media, and we want to know the secrets of celebrities and compete with our friends," says Judith. "By exploring the writings of a woman who worked her whole life to shed her individuality and to renounce herself, we can release ourselves from the cult of individualism and learn to soften our egos."



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About *literature*

"Literature is a unique space where we experience all different kinds of emotion," says Judith. "Some texts please us and others irritate us, some console us and others reveal questions that had been haunting us for a long time but that we could not yet put into words. Studying and working in the field of literature is a way of understanding what draws us to stories, the way we tell them, why certain narratives touch us more than others, and why certain characters have endured through time. For me, the most rewarding part of working in the field of literature is discovering new texts and different worldviews."

Researchers studying literature use a variety of methods to learn more about the texts they are interested in. They may start with historical research to place the text in context or biographical research to understand more about the person who produced the work. Often, researchers will seek to learn about the physical history of the text by studying different manuscripts and editions, as well as the people who read the text and how it was received. As with the writings of Marie de l'Incarnation, researchers will often study the works through the lens of political, social or cultural issues such as feminism or post-colonialism.

"There isn't really a typical day in my job, and that's part of the pleasure of it," says Judith. "Every day is different!" Some days may be devoted to research: reading texts, visiting archives or studying others researchers' work. Other times are set aside for sharing research findings with colleagues, writing articles or books, and attending conferences.

"Although we may not cure disease or solve climate change, taking an interest in what others have said and thought, what they wanted to share, and the questions they asked themselves is a rare quality," says Judith. "Understanding how ideas are passed down, hearing the questions previous generations asked – questions that are often still the ones that concern us today – and being able to formulate one's own, are important acts."

Download the team's resources from futurumcareers.com/how-can-the-writings-of-a-17th-century-nun-help-us-explore-our-sense-of self

Pathway from school to *literature*

At school, study literature, philosophy, art, history, and modern and ancient languages. These subjects can help you engage with literature from different perspectives.

"Many different things can enrich our reading and understanding of texts, so it's important to engage with things that might not interest you at first glance," says Judith. "The key is to remain curious and open-minded; if you're interested in contemporary literature, you should read older texts too, and vice versa."

"Studying abroad is a truly enriching experience – you meet other people, other ways of asking questions and other habits of thought," continues Judith. "It keeps your mind open and alert."

Explore careers in *literature*

Studying literature could lead to a range of directly-related careers including writing, teaching, editing, working as a librarian or archivist, or working in academia, like Judith, Stéphanie and Nathalie. The skills you gain by studying literature could open up paths into careers as diverse as law, marketing, communications and human resources.

Explore professional bodies such as the Modern Language Association (**mla.org**), the International Society for the Study of Women of the Ancien Régime (**ancien.siefar.org**) and Early Modern France (**earlymodernfrance.org**).

"Loving to read, being curious and not being afraid to step outside your comfort zone are important qualities that will help you succeed in – and most importantly, enjoy working in – this field," says Judith.



Meet *Judith*

What I love about literature is the space it makes for emotions, uncertainties and contradictions – you can't extract a single truth or system from it.

Reading was never separate from the rest of my life, and it allowed me to get through difficult times, as it still does today.

I was drawn to Marie de l'Incarnation by the beauty and power of her writing. I don't have much in common with this woman from another era, of a faith I don't share, who carried within her a colonial violence whose devastating effects we still perceive every day. But her resistance to telling her own story and her way of tirelessly trying to renounce herself to make room for something greater still speaks to me.

I believe that it is important to take pleasure in what we do. It is easy to get swept up in obligations, tasks and deadlines. Coming back to what we love, what drives us and what keeps us creative and alive is essential.

Judith's *top tip*

The world around us is changing very quickly. Being able to understand it and maintain a critical mind toward all the discourses circulating today are vital qualities.



Meet *Stéphanie*

I always had an inclination towards everything related to language, history, philosophy and the arts. Literature presented itself as an inexhaustible space that brings these different interests together in a way that is lively and original, and allows me to explore them with sensitivity.

I teach literature to young people who are required to take my course. Making them want to read, moving them with a poem, unsettling them with a character's troubles or drawing them into a fictional story are everyday challenges. But when I see indifference turn into curiosity in a student's eyes, when another tells me they started reading for pleasure, or when I catch students passionately debating a book – these are extremely rewarding moments!

The story of Marie de l'Incarnation never ceases to amaze me with the strength of character it reveals in this woman who managed to overcome many obstacles to pursue her spiritual quest. There is something transcendent that emerges from her texts, even for those who do not share her faith.

Stéphanie's *top tips*

Read a lot, and read a bit of everything. The more you read, the better you are able to grasp the influence works have had on one another.



Meet *Nathalie*

As a teenager, books were as important as friends and stories were as formative as 'real life'. Teaching was an obvious choice, since it was a way to share and pass on this love of reading, storytelling and travelling through texts.

I've taught in France, Tunisia and Canada, and to different age groups. Each time, I've had to relearn and reinvent myself, try new things and make mistakes. It's very stimulating to face a demanding audience whose expectations and needs are constantly evolving.

In the 17th century, women were excluded from literary institutions, and largely denied the education given to boys. Letter-writing provided some women with a way into writing. I believe it's important for younger generations to understand that feminist struggles have a history.

Nathalie's *top tip*

In the age of AI, there is a risk that reading and writing skills will become the privilege of an elite. Those who choose a literary career today are therefore making a choice that is vital for our societies, which will have an urgent and essential need for literacy, free thought and creative energy.

A taxonomy of discrimination: how can a new framework help protect our human rights?



Every human on Earth has the right to equal treatment regardless of race, gender, religion or any other protected characteristic. Despite this human right, discrimination is widespread and causes serious harm to people all around the world. At **Newcastle University** in the UK, PhD candidate **Bernardo de Mello** has developed a taxonomy of discrimination to help human rights courts make more informed rulings in cases of discrimination.



Bernardo de Mello

PhD candidate, Newcastle Law School, Newcastle University, UK

PROFILE

Field of research
Human rights law

Research project
Developing a new taxonomy of discrimination

doi: 10.33424/FUTURUM729

Talk like a ...

human rights law researcher

Cultural violence — ideas, beliefs, symbols and narratives that make direct or structural violence appear normal, acceptable or unavoidable

Direct violence — physical attacks, killings, threats and other harms with an identifiable actor and victim

Discrimination — the unfair treatment of a person or group based on traits such as race, gender or age

Intersectionality — a concept describing how social identities overlap to create unique combinations of discrimination

Structural violence — when an institution systematically prevents a group of people from accessing their basic needs and rights

Taxonomy — a system for organising different types of something

Everyone is entitled to human rights. They apply to all of us, no matter who we are or where we come from. Unfortunately, these rights are violated more often than we realise.

Discrimination directly violates the right to fair and equal treatment. "Discrimination is not limited to one person deliberately treating another badly," says Bernardo de Mello from Newcastle University. "It may be built into institutional practices, public policies and cultural attitudes." For example, a history of exclusion can make it harder for certain groups to benefit from rights that belong to everyone.

When discrimination happens on a large scale, such as when it is perpetrated by governments, cases can be brought to an international court of human rights. Bernardo has developed a new taxonomy of discrimination to help these courts navigate complex cases. "Discrimination is often far more complex than the legal categories used to describe it," says Bernardo. "My taxonomy can help judges decide what evidence to consider and whether the legal categories being used capture the complete harm."

A taxonomy of discrimination

To develop his taxonomy, Bernardo studied how human rights courts around the world deal with discrimination cases. His taxonomy organises the different ways in which courts can understand discrimination. "It is not intended to place people's experiences into rigid boxes, as real lives are messier than legal categories," says Bernardo. "Instead, it works more like a map, helping judges, lawyers and researchers decide which type of analysis best captures what has happened to a person or group. The challenge is to make the law precise without simplifying a person's experience so much that an important part of the discrimination disappears."



Human rights law commonly examines discrimination based on a single characteristic, such as race, sex, disability or religion. "These categories are important, but people do not experience their identities separately," says Bernardo. "Instead, a person may simultaneously be affected by racism, sexism and poverty, and these factors can interact to produce disadvantage that cannot be properly understood by examining only one of them."

This idea is known as intersectionality, a concept that describes how systems such as racism, sexism, ableism, class inequality, colonialism and homophobia operate together. "Intersectionality is central to my taxonomy," says Bernardo. "It is a powerful way of understanding society, but judges need practical guidance about how to recognise intersectionality in evidence, legal arguments and remedies." Bernado also draws on conceptual engineering, which treats legal concepts as tools that can be revised when they no longer adequately capture the experiences they are supposed to describe. "I am not just applying intersectionality to discrimination law; I am deliberately re-engineering discrimination as a legal concept," he says.

Bernardo's taxonomy contains nine categories, moving from simple approaches that examine one characteristic at a time to more complex approaches that recognise how several forms of disadvantage can interact. "A judge can begin with the simplest category and move through the taxonomy until they find the category that best captures the experience of the person being discriminated against," says Bernardo. "Importantly, judges do not have to begin with legal labels. Instead, they can begin with the person's complete experience by asking 'What happened to this person?' and then identify which categories best describe it."

Forms of violence

The taxonomy also asks whether the discrimination is direct, cultural or structural, mirroring Johan Galtung's theory of violence. "Galtung, a Norwegian sociologist, distinguished between three interconnected forms of violence: direct violence, structural violence and cultural violence," says Bernardo. "The murder of George Floyd provides a powerful illustration of how these forms can interact."

In the summer of 2020, George Floyd, a 46-year-old Black man, was murdered by a police officer in Minneapolis. "The physical force used against Floyd was an act of direct violence," says Bernardo. "However, the event did not occur in a social vacuum." Instead, it took place within a broader history of racial inequality in policing and the criminal justice system.

"Black communities in the US have faced disproportionate surveillance, arrest, imprisonment and police violence," explains Bernardo. "These patterns are examples of structural violence because they are connected to the operation of institutions rather than an individual." Cultural violence embedded in American life made this direct and structural violence possible. "It can be seen in racist stereotypes that portray Black men as threatening or dangerous," says Bernardo. "Such stereotypes can influence how police officers, members of the public and institutions interpret behaviour, and they may also be used to excuse excessive force or to treat violence against Black people as less serious."

In many cases, these three forms of violence reinforce each other. Cultural stereotypes help legitimise unequal systems, and those structures place certain communities at greater risk of direct violence. "Galtung's theory supports my taxonomy because discrimination has a similar structure," says Bernardo. "Some discrimination is direct and visible, such as a person being refused a job because of their race. Other forms are embedded in institutions, such as recruitment systems that repeatedly exclude certain communities. And cultural attitudes may be used to explain or justify that exclusion."

By drawing on Galtung's theory, Bernardo's taxonomy prompts judges to ask not only who acted and what happened, but also what structures made the harm more likely and what ideas made it appear acceptable. "A judge who decides not to recognise an intersectional or structural dimension of discrimination should at least explain why," says Bernardo. "Ultimately, I want the taxonomy to make it harder for legally inconvenient parts of a person's experience to disappear."

About *human rights law*

"Human rights law deals with some of the most important questions a society can ask," says Bernardo. "How should power be limited? What does every person need to live with dignity? How should societies respond when their laws or institutions exclude certain people?" To answer these questions, researchers and lawyers draw on information from a wide range of fields including philosophy, sociology, political theory, peace studies, history, feminist theory, critical race theory and decolonial thought.

"This is an exciting field because it connects abstract principles with people's everyday lives," says Bernardo. "A debate about equality may affect whether someone can attend school, form a family, access healthcare, participate in politics or remain safely in their home." Progress is often slow, and research cannot transform society on its own, but advancing on a career in this field gives you the opportunity to play your part in the struggle for justice.

Looking to the future, human rights law research will have a major role to play in some of modern society's most pressing issues. Artificial intelligence will raise questions about surveillance, privacy and algorithmic discrimination, climate change will create challenges involving displacement, access to food and water, and the rights of future generations, and researchers will continue to examine migration, war, authoritarianism, economic inequality, racism, gender-based violence, Indigenous rights and the criminalisation of LGBTQ+ people.

"Young researchers should not assume that every important question has already been answered," says Bernardo. "Some of the most valuable work begins by noticing that the existing question has been framed incorrectly."



Pathway from school to *human rights law*

Many subjects can help prepare you for work in human rights law. "Begin broadly," says Bernardo. "Learn about history, politics and society as well as law." Other subjects can also be useful such as philosophy, literature, geography, economics and languages.

"At university, studying law, politics, international relations, sociology, anthropology, philosophy, history, development studies or criminology can lead to human rights law," says Bernardo. "Scientific and technical subjects are also increasingly relevant to human rights questions involving health, climate change and technology."

Seek practical experience by joining debating clubs, taking part in a Model United Nations or volunteering with local charities, community organisations and legal clinics.

Explore careers in *human rights law*

Careers in this field include legal practice, academic research, teaching, diplomacy, journalism and humanitarian work. "Human rights knowledge is relevant in areas such as healthcare, technology, environmental protection, and equality and diversity," says Bernardo. "A person does not need the job title 'human rights lawyer' to contribute to human rights."

University human rights centres, the Oxford Human Rights Hub (**ohrh.law.ox.ac.uk**), legal blogs (e.g. **law.ac.uk/resources/blog/**) and recorded public lectures (e.g. **youtube.com/watch?v=Ik4jQokLP_I**) can introduce you to current debates.

"Start with local issues," says Bernardo. "Human rights are present in schools, workplaces, neighbourhoods and local government. A small, responsible role in a community project can teach more than an impressive title with no meaningful work behind it."

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Download Bernardo's resources from **futurumcareers.com/a-taxonomy-of-discrimination-how-can-a-new-framework-help-protect-our-human-rights**



Meet *Bernardo*

As a teenager, I was always drawn to history, politics and questions about why societies develop in the way they do. I wanted to understand how past events continue to shape the present, especially in relation to inequality, power and the treatment of different groups. That interest led me to study history before I studied law, which taught me to look beyond individual events and think about the wider social, political and cultural forces behind them. It also showed me that many injustices do not appear suddenly; they are often connected to patterns that have developed over a long period of time.

My perspective as a Brazilian lawyer and a researcher from the Global South has shaped this project. Feminist, queer, decolonial and critical race scholarship taught me to question legal concepts presented as neutral or universal. These perspectives encourage us to ask whose experiences shaped a legal category, whose experiences are excluded and how the category might be improved.

The most rewarding part of my work is turning a highly theoretical argument into a practical tool. The taxonomy is not intended only to describe a problem. It is meant to help people reason about discrimination more carefully.

I am motivated by the fact that injustice can become invisible when the concepts used to describe it are inadequate. Courts may genuinely intend to protect human rights while still relying on categories that exclude important experiences. Improving those categories is therefore not a purely academic exercise. It affects whose suffering is recognised, whose evidence is believed and which changes an institution is required to make.

Curiosity is essential. Ask why a rule exists, who benefits from it and whose experience might be missing. Persistence is also important. Research involves rejected arguments, extensive revisions and periods when the solution is unclear. Progress often comes from returning to a problem several times rather than immediately finding the answer.

I also draw on empathy, independence and attention to language. A small difference in terminology can determine whether a person's experience becomes legally visible. Feminist, queer and decolonial approaches have taught me to examine how knowledge is produced and whose perspectives are treated as authoritative.

Bernardo's *top tips*

1. Practise explaining complicated ideas in ordinary language. Clear communication is one of the most valuable skills in human rights work.
2. Listen to affected communities. Human rights work should not be based on the assumption that researchers or lawyers always know what other people need.
3. Learn from criticism. Having an argument questioned is not the same as failing. It is part of making the argument stronger.
4. Rest is part of doing good research. Taking time away from a problem often makes it easier to see the solution when you return to it.



How can community colleges support innovative research while training the next generation of STEM students?

Community colleges in the US train millions of students every year, but their capacity for engaging in research is often overlooked. At **Metropolitan Community College, Kansas City** in the US, **Professor Antwan Daniels** and **Dr Tammie May** are hoping to change this. Using funding from the EPIIC grant, they are building the college's capacity to manage externally funded research, grow industry partnerships and connect students with STEM professionals and entrepreneurs.



Professor Antwan Daniels

Professor of Chemistry and Education; Principal Investigator



Dr Tammie May

Vice President of Instruction and Student Services; Co-Principal Investigator

Metropolitan Community College, Kansas City, USA

Field of research
STEM education

Funder
US National Science Foundation (NSF)
EPIIC grant

doi: 10.33424/FUTURUM739

PROFILES

Talk like a ...

STEM educator

Asset mapping – a highly structured, strategic method used to help an institution identify and catalogue their strengths and resources

Community college – a two-year public institution of education that offers affordable undergraduate education and workforce training

STEM – science, technology, engineering and mathematics

In the US, more than 8.5 million students attend community colleges each year – that's about 40% of all undergraduate students in the country. These colleges provide affordable, local education and help students gain the skills and experiences they need to find jobs or move on to university.

While studying at community college or university, students can take part in scientific research. While universities tend to focus their efforts on producing this research, community colleges prioritise student learning and development. Unfortunately, this framing means that their research capabilities are often overlooked.

At Metropolitan Community College, Kansas City (MCC), Professor Antwan Daniels and Dr Tammie May have secured funding to improve the institution's ability to produce innovative research, collaborate with industry partners and provide its students with hands-on learning experiences. "The grant we received has a big focus on emerging research institutions," says Antwan.

"Community colleges need to be seen for the value we have in this respect – we need to be seen and valued for our work."

The EPIIC grant

In partnership with Lawrence Technical University and the University of Puerto Rico – Bayamon, MCC has won funding from the US National Science Foundation's EPIIC grant. This award is designed to help higher education institutions build research capacity and collaborate with industry partners. The three institutions will work together to create new opportunities for staff, students and industry partners to conduct research that benefits local communities and solves real-world challenges.



"Science is collaborative and exists within a world that also includes politics, industry, community, and so many other players," says Antwan. "We can't function if we stay in our own silos; we have to collaborate with others if we want our work to have an impact." The EPIIC grant will help MCC build partnerships that allow staff and their students to pursue research that will make a real difference to local communities and national industries.

"I'm a sociologist by training, and we often talk about human communities as an organism," says Dr Tammie May, Vice President of Instruction and Student Services at MCC. "This idea holds true for the STEM community as well. We are part of an organism and the whole system has to be communicating and supporting itself in order to work." Like all organisms, the STEM community is complex and multi-faceted. The first step towards effective collaboration is understanding what all the constituent parts can offer, and how they can combine and support each other.

Asset mapping

Asset mapping is a highly structured, strategic method that an institution can use to shift its mindset from "What do we lack?" to "What do we have to offer?" With this mindset, MCC can form partnerships with other institutions from a position of strength. "The asset mapping process brings people together to think about their place in the wider STEM ecosystem," explains Antwan.

Using this method, the team at MCC are identifying and cataloguing the strengths within the college. This could be researchers and teachers with niche skills, industry experience or connections to community groups, or physical assets like chemistry labs or event spaces that could be used by local groups and businesses.

At the same time, the team is looking outside of the college to find potential collaborators. These could be local businesses in the STEM sector, community groups looking for research support or entrepreneurs that are using innovative science to solve problems. Creating these partnerships will transform MCC from an isolated educational institution into an active player in the regional economic ecosystem. "The asset mapping process has really allowed us to build relationships at different levels and better understand how we fit into the bigger picture," says Tammie.

STEMinars

Another way in which the MCC team connect their teaching and research to the outside world is through STEMinars. These interactive events bring students face-to-face with scientists and entrepreneurs from outside of their own institution as they learn about and discuss STEM topics. For example, at a STEMinar in April 2026, Dr Brittany Hufft-Martinez from the University of Kansas Medical Center shared her research on cleft palate formation, while other researchers discussed Lyme disease and tuberculosis.

"Through the STEMinars, we can reach out to external partners and bring new people in to allow our students to explore topics and viewpoints from outside the regular curriculum," explains Antwan. "I'm a chemist, so I talk about chemistry, but other contributors can talk about issues like cleft palates, Lyme disease and agentic artificial intelligence from different lenses, showing us the different parts of our STEM community."

For example, Dr Ladrian Brown, a professor of biology, and Joel Shaw, a computer science instructor, take part in the STEMinars and provide students with different ways of thinking about problems. Exposing students to diverse scientific perspectives and cutting-edge research helps them cultivate a true scientific mindset that embraces interdisciplinary collaboration.

The STEM ecosystem

Innovative research doesn't just rely on collaboration between different scientific disciplines, but also between people with many different skillsets and expertise. "For example, we have an accountant, and we couldn't do our work without him," says Antwan. "If we're out of line with the budget, that could ultimately lead to our funding being cut."

"I think it's easy to get caught up in science and think about creating the magic pill or winning the Nobel Prize," Antwan continues. "But there are a million smaller prizes to be won before the Nobel Prize; a million smaller things need to take place to get to the 'finish line'." Behind every scientific breakthrough and every prestigious award is a vast ecosystem of people playing their part. Finding your place within this ecosystem – whether you become a researcher, an entrepreneur or an accountant – will allow you to contribute to innovative research that could change lives.



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About *STEM*

Pursuing a career in STEM will bring you opportunities to explore your interests, solve meaningful problems and work with incredible people. Being able to collaborate with researchers from different fields, entrepreneurs from industry partners and members of the wider STEM community is key to success.

"You have to be able to operate in multiple worlds," says Antwan. "And that means making the effort to understand them and to be a good listener." This desire to learn and understand others is an important part of scientific curiosity. "You have to have that child-like desire to question things and say 'I don't understand this yet, but I want to know more'," continues Antwan. "That willingness to learn new things should never stop."

Tammie emphasises that it's not just important to understand other researchers and their scientific disciplines, but also to understand how the scientific community works as a whole. "The science community is very complex, and there are many external factors that can affect funding opportunities, from local politics to the global economy," she says. "These limiting factors exist, but that shouldn't stop you from dreaming – you just have to learn how to navigate the system and find support for your projects and ideas."

Getting to grips with this complexity at the start of your career will set you up well to navigate any challenges that you might face. Taking part in events such as STEMinars and getting hands-on experience in research groups is a great place to start. "Experiences like these have changed the trajectory for so many of our students," says Tammie. "It's all about building relationships that might lead you into future experiences that you haven't even thought of yet!"

Pathway from school to *STEM*

Build a solid foundation in biology, chemistry, physics and mathematics. Spot the topics that excite you and follow your curiosity wherever it leads.

Seek out hands-on opportunities to get experience with research. Join a science club or get in touch with a local research lab.

Look for points of connection between the STEM topics that you study. Science is becoming increasingly interdisciplinary, so being able to bridge the gap between subjects will help you see things from different perspectives.

Take part in one of MCC's College for Kids programmes, designed to give 8-to-15-year-olds new experiences and teach them important skills: **mcckc.edu/continuing-education/college-4-kids.aspx**

Download Antwan and Tammie's resources from futurumcareers.com/how-can-community-colleges-support-innovative-research-while-training-the-next-generation-of-stem-students

Explore careers in *STEM*

Read some other Futurum Careers resources to see the incredible variety of possible STEM careers: **futurumcareers.com/articles**

Explore the range of STEM courses available at MCC: **mcckc.edu/pathways/science-technology-engineering-mathematics.aspx**

Use the CareerXplorer platform to find out more about different careers in STEM and the pathways that can lead you to them: **careerxplorer.labxchange.org**



Meet *Antwan*

In the early stages of becoming a medicinal chemist, I tried to make a molecule that would reduce a person's addiction to cocaine. Later, I tried to kill tuberculosis! When you have big dreams, they don't always work out – but having that passion drives you forward.

I love bringing people together from different mindsets so they can think together, dream together and make great things happen. The only thing I love more than chemistry is people, so I want to bring people together.

As scientists, we don't go through it, we grow through it. The things that challenge us help us grow and come back stronger. You've just got to keep picking yourself back up and getting back in the lab.



Meet *Tammie*

I enjoy creating opportunities not just for students and staff, but also for our communities.

The key is being persistent. Some people will celebrate you and support your work, but others won't. Sometimes that is powerful because they push you harder. If this is truly the passion of your heart, you'll dig deeper and learn more deeply.



Meet *Joel Shaw*

Computer Science Instructor

I wanted to take part in the EPIIC grant because of the opportunity to gain different perspectives from colleagues I admire in different fields, and to share perspectives on my own field.

I love working with students, overcoming challenges and thinking about future possibilities.

If you want to work in STEM, give yourself grace and time, and learn to be resilient during your educational journey.

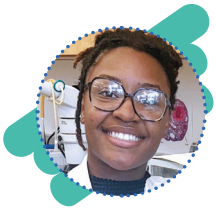


Meet *Dr Ladrian Brown*

Professor of Biology

One of the most rewarding aspects of teaching is the moment when students connect the concepts they're learning in the classroom and their own lived experiences. It is gratifying to watch learners develop the knowledge and skills they need to become successful.

It can be difficult to determine which STEM career is the best fit for you. Getting early exposure to a range of different fields is key. When making your decision, try not to limit yourself to traditional fields. Instead, explore other exciting roles that will allow for life-long learning.



Meet *Corinthian Evrin*

Pupil at MCC

I took part in a summer research initiative at Kansas University Medical Center exploring questions around female fertility and reproduction. I wanted to understand more about the science behind reproductive health rather than only learning about it from a classroom perspective.

I got to see biology in a way that I had never experienced in a classroom. You can learn about cells from a textbook, but seeing them through a microscope makes everything feel more real.

I started to understand that research is curiosity in action. Instead of simply being given a problem with a known answer, I had to think through what I was seeing, consider different possibilities and figure out what questions needed to be asked next.



How can fiction increase students' understanding of science?

"The division between literary studies and STEM is such that they may as well be two different star systems," says **Dr Rhona Trauvitch**, a Teaching Professor of English at **Florida International University** in the US. Yet she believes that connections between these fields can hugely benefit all learners, which is why she is using analogies from fiction to help illustrate concepts in science.



Dr Rhona Trauvitch

Science & Fiction Lab,
Florida International University, USA

Fields of research
Narratology; interdisciplinary analogical reasoning; STEM education

Research project
Leveraging the rhetorical power of fiction to make STEM more accessible

Funders
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scienceandfiction.fiu.edu

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PROFILE

What do the Muppets have to do with quantum physics? More than meets the eye, according to Dr Rhona Trauvitch, founding director of the Science & Fiction Lab at Florida International University (FIU). She is encouraging STEM educators to use analogies from fiction to explain concepts in science, and her favourite example is how the Muppets can be used to illuminate quantum superposition.

This counterintuitive physics phenomenon describes the condition of a quantum particle that is simultaneously in incompatible states. A rather perplexing concept for students to wrap their heads around! But the shape of this concept manifests in the Muppets, and Rhona believes students might have a much easier time conceptualising the phenomenon once they add the perspective of fiction into the mix.

We all know that the Muppets are fictional TV characters. Despite this, they also exist in the non-fictional real world – they are interviewed on talk shows, appear at award ceremonies, author magazine articles and host their own Instagram accounts. Which means that, analogous to quantum particles, the Muppets are in a superposition of states – in this case, simultaneously fictional and not fictional.

The importance of analogies

"According to Douglas Hofstadter and Emmanuel Sander, whenever we come across something new, we automatically compare it to something we already know that is similar in some way," says Rhona. "In other words, we approach new ideas by making analogies." This allows us to make sense of the new information by relating it to ideas we already understand. As such, analogies are a powerful pedagogical tool for explaining new concepts to students.

Using analogies from fiction to explain science

The challenge with finding science analogies is that certain science phenomena are so complex that we have nothing to compare them to. "By definition, a concept that is counterintuitive cannot be linked to anything we would recognise from our embodied experience of the world" [2], writes Rhona in her book, *Fi-Sci: Avatars of Science in Fiction*. She elaborates, "Objects in our everyday observed reality do not behave like quantum particles, so it is difficult to come up with something that is *like* superposition. Instead, we may need to consider objects that are not bound by reality and ideas that do not correspond to our embodied experiences." Which is why Rhona turns to fiction.

We can find analogies for complex science phenomena in the realm of fiction because the very nature of fiction asks us to imagine the non-actual and even the impossible. "When we experience fiction – in a book, movie or video game – we shed the assumptions we make when



encountering non-fiction narratives and accept the fantastical or counterintuitive ideas presented," explains Rhona. "We add these accepted ideas to our mental repertoire of concepts, which now includes notions that may indeed be comparable to complex or counterintuitive science."

How fi-sci differs from sci-fi

Rhona calls the process of identifying a phenomenon in fiction that is analogous to a phenomenon in science 'fiction-to-science (fi-sci) pattern mapping'. A key aspect of fi-sci is that it does not depend on fiction that features science, such as science fiction (sci-fi). "Fi-sci describes a different relationship between fiction and science," says Rhona. "Its analogies may be located in fiction that has no obvious connection to science."

While sci-fi contains literal manifestations of science phenomena (e.g., a plot about time travel), fi-sci searches for figurative manifestations of the phenomena. The aim of fi-sci is not to find the science itself within the fiction, but to find "the *pattern* of the science phenomenon... mirrored in some aspect of the fictive discourse" [4], writes Rhona. "Manifestations can arise in a narrative's structure or plot; in the reading or viewing experience; in the story's setup; via literary devices" [33].

For example, the film *Interstellar* does not provide an analogy for wormholes and spacetime curvature – these are literally manifested in the plot. Instead, Rhona searches fiction for figurative manifestations – avatars of the science in the fiction. "Both a wormhole and the metalepsis [a jump across narrative levels] in Julio Cortázar's story "Continuidad de los parques" ["Continuity of Parks"] connect two entities that effectively should not be able to meet," she writes. "It is not that a character in "Continuidad de los parques" enters a wormhole; the story has nothing to do with literal spacetime curvature. Rather, a character therein experiences a process that is *like* what happens when spacetime curves: The character intersects with something (another character) that intuitively should be in a different reality – in other words, out of reach" [32-33].

The benefits of interdisciplinary learning

Rhona teaches a course called 'Quantum Narratology and Other Curiosities: Intersections of Science and Storytelling' to students at FIU, where she introduces the concept of fi-sci pattern mapping and tasks students with developing their own fi-sci analogies. "This is an elective course taken by students from various degree programmes, including STEM, humanities and social sciences, which means the already interdisciplinary course is given an extra boost by the perspectives of students with experience across different disciplines," she explains.

Fi-sci does not only show STEM students a novel way to view and communicate the science they're learning – the interdisciplinary thinking it promotes is equally important for everyone. "Whether studying humanities or STEM, students who map fi-sci analogies gain cross-disciplinary proficiency and the ability to convey complex processes to a non-specialist audience," says Rhona. "Recognising the pattern of a science phenomenon in a field as far removed as literature encourages creativity, critical thinking and a more holistic understanding of both science and fiction."

Further examples of fi-sci analogies

Another of Rhona's favourite analogies was created by one of her students, a philosophy major, who noticed the similarities between dark matter and aspects of *Jacob's Room* by Virginia Woolf. Readers never directly observe Jacob, they only know about him from descriptions given by other characters. Analogously, scientists have never directly observed dark matter, they only know about it from the way it impacts its surroundings.

80 Days is an interactive video game in which players choose their own route through the game, thereby impacting the story's plot and narrative outcomes. This compares with the scientific process of genetic engineering, in which scientists reorganise genes to produce a different outcome in an organism. "Choose-your-own adventure stories and genetic engineering both involve the rearrangement of elemental units, highlighting the concept of permutative agency," explains Rhona.

Finding such connections between science and fiction can, Rhona believes, help enhance the learning of students from all disciplines. "One measure of success after university is a graduate's ability to translate knowledge and competencies gained in school to the world beyond academia," she says. "Yet prevailing structures of higher education are not necessarily conducive to this. The fi-sci project aims to break down disciplinary silos and better equip students for the world beyond the campus, using the instrument of fictionality."

Testing *the impact of fi-sci*

Having developed her fi-sci pattern mapping framework, Rhona is now leading a research project to explore the effectiveness of fi-sci as a teaching method, along with her colleagues Dr Tiberio Garza, Dr Bryan Dewsbury and Nicole Chlebek. FIU faculty participating in the project were paired across disciplines, each duo comprising one member who teaches fiction (including faculty in English, philosophy, history and law) and one who teaches STEM.

In each pair, the faculty shared the curricula of the courses they teach then looked for topics that are analogous across the disciplines. "The magic happened in these conversations," enthuses Rhona. "As one person described a topic, the other thought about the topics they teach and considered whether they might have a similar form. These discussions always led to a moment when something clicked – the sign of an elegant interdisciplinary analogy."

The pair then developed lesson plans for a 'jigsaw module' that linked their specialisations by way of fi-sci analogies.

> ***"We hypothesise that [fi-sci will lead to] improvement in terms of interdisciplinary perspective, critical thinking and subject matter communication."***

The first lesson introduces students to the analogy while the second shows them how it was generated through the fi-sci pattern mapping process.

Evaluating the effects of fi-sci on student learning

Rhona and her colleagues will now assess the impact of the fi-sci jigsaw modules by testing control and experimental groups of students before and after they take part in the fi-sci intervention. To do so, the participating faculty will begin by teaching a topic to all their students (without using fi-sci analogies). Students will then complete an assignment to introduce that topic to a friend who is not studying the course and to a fifth grader, and to make an analogy between any concept in STEM and any concept in fiction.

All students will then participate in a lesson giving an overview of analogies as thinking and learning tools. The experimental group of students will then participate in the two fi-sci pattern mapping lessons, learning the fi-sci analogy that links the topic they learnt in the initial lesson to a topic taught in their professor's partner's course, followed by learning how the analogy was generated. All students will then complete the same assignment again but in reverse order, making an analogy between any concept in STEM and any concept in fiction, then explaining the same topic to a friend who is not studying the course and to a fifth grader.

"We will evaluate whether learning about the power of analogies leads both groups to perform better in the second assignment and whether learning about fi-sci analogies and pattern mapping in particular increases the improvement of the experimental group," explains Rhona. "We hypothesise that the experimental group's improvement will surpass the control group's improvement in terms of interdisciplinary perspective, critical thinking and subject matter communication."

The jigsaw module library

The jigsaw modules developed during this project will be collated in a digital library for any FIU faculty to use and adapt for their own courses. "In the future, we plan to expand access to the library so the teaching materials are freely available to staff and students at any university," says Rhona. "Any educator would be able to browse the digital catalogue to find a module built around an analogy that involves a topic they're teaching, then they could use it in their own course, while adapting it to match their curriculum."



Rhona and her colleagues with some of the 2026 FIU Fi-Sci faculty.

Advice *for educators*

Common challenges for implementing fi-sci teaching

"The biggest hurdle I face when introducing the concept of fi-sci analogies is the confusion between the literal and the figurative," says Rhona. "Initially, students come up with cases of fiction that feature science, such as genetic engineering or time dilation." But these include the science itself, rather than narrative elements or manoeuvres that are analogous to the science concepts. The difference between literal and figurative manifestations of science within fiction is a key message to convey to your students.

One common challenge educators encounter when trying to incorporate fiction analogies in their STEM classes is simply a lack of time to fit fi-sci into an already-packed curriculum. "You might find it difficult to set aside time to show your students how a concept they have just covered is analogous to a concept in a different field," says Rhona, who has three suggestions for how to overcome this. "If possible, you could shorten other lessons to create room for a fi-sci intervention. You could adopt a more condensed version of the fi-sci jigsaw model. Or you could move some of the instructional material online so it takes up less class time."

While many students enjoy learning about how the subject they are studying manifests in a completely different discipline, another challenge you might face is students who do not see the value in making interdisciplinary connections. "Some STEM students may not recognise the relevance of fiction and will make comments like 'I didn't take a science course to read and discuss literature'," says Rhona. If you encounter this, Rhona recommends emphasising the benefits of interdisciplinary fluency and demonstrating how a fi-sci approach can help students communicate their expertise to a non-specialist audience.

The benefits of fi-sci teaching and learning

"Through fi-sci pattern mapping, students gain exposure to concepts and methods they would have otherwise not encountered in the typical compartmentalised university structure," says Rhona. "In doing so, they see their own subject in a new light, observe how it intersects with other fields and use it to increase their understanding of other subjects. This enables them to discover novel applications for their skills, which can translate into innovative job opportunities."

And it is not only students who benefit from fi-sci teaching. "The process of developing fi-sci analogies has been greatly beneficial to the participating faculty," says Rhona. "Several have told us how much they've enjoyed working with colleagues in other disciplines who they may never have met were it not for the fi-sci initiative." Several faculty have also commented on the excitement of including such a creative approach in their classes.

Download Rhona's resources from futurumcareers.com/how-can-fiction-increase-students-understanding-of-science



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October 26

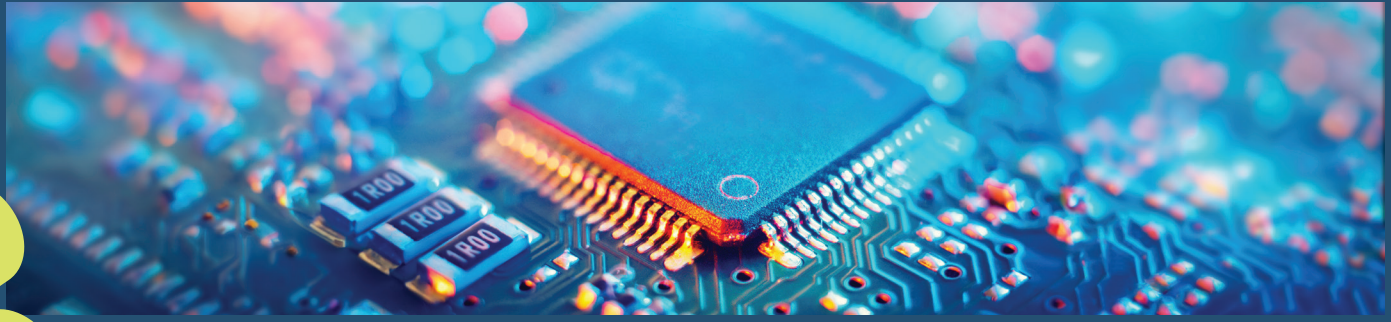
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