futurum

Inspiring the next generation

ISSUE 23
November 2023

futurumcareers.com

RYAN HICKMAN

RYAN HICKMAN
The 14-year-old running a non-profit recycling business

NEW FUTURES NETWORK
Connecting employers with prison leavers

CRANFIELD UNIVERSITY
Flying high with careers in aviation

Be part of a STEM and SHAPE education community

Want more articles like these from researchers, students and associate organisations?

By signing up to **Futurum Careers**, you are subscribing to a community of academics, educators, employers, students – people like you – who want to show the world just how fascinating and rewarding a career in **STEM** and **SHAPE** can be.

What's in it for you?

As a member of Futurum Careers, you'll receive:

- The **latest articles** from academics and associate organisations
- **Teaching and classroom resources** relating to specific topics in STEM and SHAPE
- **Careers resources,** including PowerPoints, podcasts, animations and articles about inspirational role models
- A free, monthly **newsletter.**

Scan to sign up for free, or visit the website:
www.futurumcareers.com/sign-up

A note about your privacy

Your privacy is very important to us. We will not share, sell, reveal, publicise or market your details in any way, shape or form. Our full privacy policy can be found on the Futurum Careers website: **www.futurumcareers.com/privacy**

WELCOME

ISSUE 23
It's never too late!

At 14 years old, Ryan Hickman (p 04) is confident about the societal impact positive action can have. Running his own non-profit recycling business, he serves hundreds of customers and has recycled millions of cans and bottles. While he knows that many people find it hard to know where to begin when wanting to help the environment, he reassures us that "it's never too early or too late to make a difference".

Duncan O'Leary (p 46) shares the belief that a real difference can always be made. Duncan is CEO of the UK's New Futures Network, a specialist employment team in His Majesty's Prison and Probation Service (HMPPS). Connecting employers with prison leavers, New Futures Network is evidence that it is, indeed, never too late to enable change – giving someone a second chance can reap huge rewards for you, them and society as a whole.

The many researchers featured in this issue of Futurum would attest that success can be achieved, even if does not come easy or come first-time round. Ambition and commitment make anything possible: from sky-soaring careers in aviation (p 50) to innovative ideas in computer science (p 80), from musical therapy for mental health (p 38) to community action for environmental justice (p 08).

Ryan believes that big things can happen "if everyone does a little bit". It is never too late to make your mark, so follow Duncan's advice, and "don't be afraid to put yourself forward for something you haven't done before".

THE FUTURUM TEAM

Karen Lindsay
Director

Erica Morgan
Editor

Isla Foffa
Assistant Editor

Sophia Kerby
Senior Graphic Designer

Brett Langenberg
Director

Chris Dowell
Project Manager

OUR WRITERS

Jacob Ashton, MA

Joe Aslett, MSc

Kate Wilkinson, MA

PUBLISHED BY SCI-COMM CONSULTING

A limited company registered in England.
Company No: 10791252

CONTACT

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

POWERPOINTS
Our PowerPoints summarise the articles and include reflective 'Talking Points', making them a fantastic classroom resource:
futurumcareers.com/ppts

ANIMATIONS
As part of our free package of education resources, we include animations that bring many of the research stories to life:
futurumcareers.com/animations

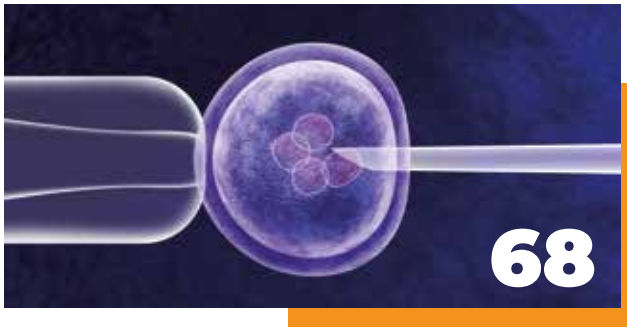
PODCASTS
Featuring researchers talking candidly about their personal experiences, our podcasts are accessible, engaging and inspiring:
futurumcareers.com/stem-shape-podcasts

SOCIALS

@FUTURUMCareers | @Futurumcareers | Futurum Careers | @futurumcareers | Futurum Careers

CONTENTS

Research articles



Research articles

INTERVIEWS

COVER STORY
Ryan Hickman

04

RYAN HICKMAN

© Ryan Hickman

“It’s never too early or too late to make a difference.”

Ryan Hickman is 14 years old and already has a non-profit recycling business under his belt. He has also appeared on talk shows, met celebrities and travelled in a submarine in the Mediterranean Sea. But, as Ryan explains, nothing compares to the impact he has made from recycling, and helping others to recycle, millions of cans and bottles.

What ignited your passion for recycling?

When I was three years old, my dad and I took a few small bags to the local recycling centre. I just loved seeing all the cans and bottles being sorted and crushed up. As I got a bit older, I had an idea to ask all our neighbours to start recycling with me, too.

How does Ryan’s Recycling work?

Ryan’s Recycling started with people calling or emailing my dad and leaving their cans and bottles for me to collect, rather than throwing them away. We pick up the items on weekends, and then I sort them and take them to be recycled. Most people I recycle with have been my customers for a long time, so they’ve seen me grow up over the past 11 years. I collect every week and have hundreds of customers. The money I make from the recycling redemption fees goes towards my college fund.

Two years ago, we started a residential programme called Recycle From Home, a pilot programme launched with the State of California to get more people recycling. We have a fleet of vans and a team of drivers who collect cans and bottles from customers in select cities. We pay our customers for their cans and bottles.

Ryan on the Ellen DeGeneres Show in the US © Ryan Hickman

Collecting cans and bottles at five years old
© Ryan Hickman

What is Project3R?

So many people were asking me how they could help support my efforts, so my dad and I created Project3R. It's a non-profit organisation that leads community clean up events and classroom teaching sessions for elementary schools in my local area. We have an amazing team of people who help run Project3R.

When did you start public speaking?

My first public speaking event was at my school when I was in 1st grade. I spoke to all the kids about recycling. After that, I spoke at stadiums and arenas full of people, so I quickly got used to it.

Where do you get the confidence to talk in front of thousands of people?

I don't really get nervous in front of crowds, so I guess I'm lucky that way. I once spoke at an event in Vancouver, Canada, in front of 23,000 kids. I think that's the biggest event I've ever spoken at.

When you give presentations at schools, what is the most frequently asked question?

A lot of kids ask me how they can get started doing what I do. I tell them to start by recycling a little bit each day. Picking up a piece of trash from the ground might save an animal's life, and recycling what you can each day makes a difference. You don't have to be crazy about recycling like me because if everyone does a little bit, it adds up to a big difference.

I also get asked about some of the celebrities I've met, the television shows I've been on and places I've been to.

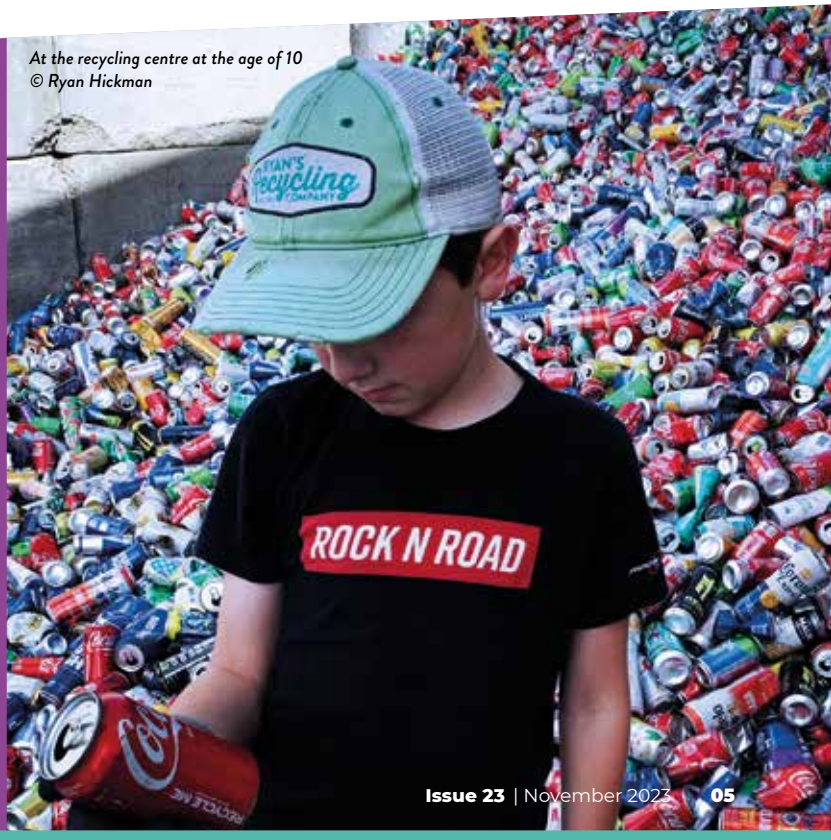
How did you manage to get invited to clean up rubbish from the riverbanks of the Rhine River in Mainz, Germany?

I went to Germany with my friends at GotBag. They make travel bags out of ocean-bound recycled plastic. There was a huge turnout of people to help clean up trash along the riverbanks.

One thing I noticed was that there weren't any plastic water bottle caps like we have in the US. There were a lot of metal water bottle caps, though. We picked up a lot of trash, but it was a great event.

I loved going to Mainz. Some people recognised me when I was walking around there, which was pretty cool!

> **"Most people want to do the right thing and help the environment but aren't clear on how they can make a difference."**



At the recycling centre at the age of 10
© Ryan Hickman

Recycle From Home has a fleet of vans. Ryan stands next to one of these vans © Ryan Hickman

> ***You don't have to be crazy about recycling like me because if everyone does a little bit, it adds up to a big difference.***

Is this your most exciting experience so far?

It's definitely one of my favourites. I've been in a submarine with OceanX* in the Mediterranean Sea where I picked up a glass bottle from the bottom of the ocean and had it recycled. I've also been to Bogota, Colombia, speaking to thousands of kids. But it's also super exciting when hundreds of people show up to help me clean up a beach, wherever that may be.

You have recycled over 1,838,800 cans and bottles to date. How do you keep count?

We count everything we recycle, and we've done this since the very first time we went to the recycling centre. Everything is weighed so we're able to divide the total weight by the weight of an aluminium can or plastic bottle. I'm hoping to reach 2 million by the end of 2023.

How do you find the time to run a business, give presentations and go to school?

I'm pretty busy, but it's fun. My first priority is school, and my parents line up events for me and set my calendar. I usually recycle a little bit each night, and we do beach clean ups on Sunday nights. My dad helps me handle a lot of the business stuff, too.

Do you think anyone at any age can start a project like yours?

Definitely! I was only three years old when I started. It's never too early or too late to make a difference. I've had older people tell me that they recycle now that they've seen me do it, and I get fan mail from all over the world from people who have been inspired to recycle. I think that's super cool.

What are your hopes for the future?

I'm going to keep doing what I do and maybe, someday, I'll get to 10 million recycled items. I hope that our Recycle From Home business gets into hundreds or thousands of cities. I think if we make recycling easy to understand and accessible, more people will take part. Most people want to do the right thing and help the environment but aren't clear on how they can make a difference.

Ryan started recycling when he was three years old © Ryan Hickman

Connect with Ryan

Follow Ryan on social media and tell him how you're changing the world! "I love hearing from kids around the world," he says.

- **@ryansrecycling**
- **@ryans_recycling**
- **@ryans_recycling**
- **RyanHickmanRecycling**
- **ryansrecycling.com**

** OceanX is a global community of explorers, scientists and storytellers dedicated to inspiring and educating people to protect the oceans.*

Combining science and community action to combat environmental injustice

The Salton Sea, a polluted lake in southern California, USA, is rapidly drying up as a result of changes in climate and water usage. As the muddy lakebed becomes exposed, toxic dust is blown into surrounding communities, where residents have high rates of asthma. Scientists from the **University of Southern California** are working with community partners at **Comite Civico del Valle** to investigate how this air pollution is impacting children's respiratory health and to empower affected communities to advocate for change and fight for environmental justice.

PROFILE

Assessing Imperial Valley Respiratory Health and the Environment (AIRE)

Fields of research
Environmental justice, environmental epidemiology

Research project
A community-driven research project to assess the impact of air pollutants on children's respiratory health around the Salton Sea

Funder
US National Institutes of Health (NIH); grant number NIEHS R01 ES029598

Talk like an ...

environmental justice researcher

Agricultural run-off — water that drains off agricultural land

Asthma — a respiratory disease that causes breathing difficulties

Environmental justice — the right for all people to have access to a healthy environment

Heavy metals — high-density metallic elements that are commonly toxic

Particulate matter (PM) — tiny particles in the air (such as dust) that are harmful to human health

Playa dust — particulate matter formed when a muddy playa (beach) dries out

Respiratory — related to breathing and the breathing system (lungs and airways)

Environmental mismanagement disproportionately affects poor and marginalised communities. Finding solutions to such problems and achieving justice for communities can be challenging, highlighting the need for collaborations between community advocacy efforts and scientific research.

The Assessing Imperial Valley Respiratory Health and the Environment (AIRE) study is a community-driven collaboration between the Comite Civico del Valle (CCV; which is a community organisation focused on environmental justice in Imperial Valley), local schools and scientists at the University of Southern California (USC). The study aims to determine the effects of the shrinking Salton Sea on children's health.

The Salton Sea

The Salton Sea is located in the Imperial Valley of Southern California, a rural region containing predominantly Mexican-American communities facing high levels of poverty and unemployment. In 1905, a canal diverting water from the Colorado River failed, causing water to flow into the Salton Basin. This engineering failure led to the creation of the Salton Sea – a large, shallow lake in one of the hottest and driest parts of California. For decades, the lake was sustained by agricultural run-off from surrounding fields, with evaporation from the lake's surface balanced by an input of water contaminated with pesticides, synthetic fertilisers and industrial chemicals.

However, in recent years, the lake has started to dry up. Reallocation of water resources means less run-off is entering the lake, and a hotter climate is increasing evaporation. As the Salton Sea shrinks, the lakebed is becoming exposed, forming wide beaches (playas) of mud contaminated by heavy metals and toxic chemicals. As the exposed mud dries in the hot sun, it turns to dust. This toxic playa dust is now blowing into surrounding communities and being breathed in by residents. The case of the Salton Sea is a prime example of how poor land use decisions (in this case, mismanagement of water resources and agricultural pollution) can damage the health of entire communities.

Health impacts of the shrinking Salton Sea

"Around the Salton Sea, one in every five residents has asthma," says Luis Olmedo, Executive Director

© Felix Lipov/Shutterstock.com

of CCV. "Children in Imperial Valley suffer from some of the highest rates of asthma in the country, which is a significant concern for communities." As Dr Shohreh Farzan, an environmental epidemiologist at USC, explains, "Children are particularly susceptible to the impacts of air pollution as their lungs and immune systems are still developing."

The AIRE study is monitoring the health of 700 children in the region and linking these data to local measurements of air quality to examine correlations. As a collaboration between scientists, community partners and local families, the project's aim is to scientifically evaluate whether the increase in air pollution caused by the shrinking Salton Sea is contributing to the high levels of respiratory diseases affecting communities.

A community approach to air quality monitoring

"CCV has a community air monitoring network that measures levels of particulate matter (PM) at over 25 schools across Imperial Valley," explains Christian Torres, one of the project's air monitoring technicians. These monitors provide near-real-time measurements of air quality at the neighbourhood level, alerting residents to increases in air pollution and allowing them to react accordingly. For example, CCV and local schools established an innovative scheme in which schools use the monitoring network to determine the air quality each day, then they communicate this to the neighbourhood by raising a colour-coded flag. A green flag indicates good air quality, while orange and red flags indicate more hazardous levels. Schools and families can then use this information to make informed decisions, such as when to allow children to play outdoors. The AIRE study makes use of CCV's air quality monitoring network to scientifically investigate local sources of air pollution and community exposure to this pollution.

The importance of community engagement

"Our research is built upon the ongoing work around air quality and asthma led by CCV in schools and the wider community," says Dr Jill Johnston, an environmental justice researcher at USC. CCV had been raising awareness of air pollution and helping families manage their children's asthma long before Jill and Shohreh arrived. Community-driven research must begin with the needs of the community, and working with established community partners is essential for a project's success. "We have partnered with CCV from the very beginning of the AIRE study and this partnership has been foundational to the entire project," says Shohreh. "CCV, school officials, parents and community members have shaped the questions that led to this work."

A scientific approach to air pollution analysis

In addition to analysing data provided by CCV's real-time air quality monitoring network, the AIRE team is also collecting PM samples for analysis. "Our set-up consists of a large pump that pulls air through a filter to collect any airborne particles," explains Edgar Ruiz, an air monitoring technician at CCV. "These PM samples are analysed in the lab to determine their size and composition, which gives an indication of their source." Air pollution in Imperial Valley comes from several sources in addition to dust from the Salton Sea, including the burning of organic matter and diesel exhaust fumes. By combining all these data on air quality, the team can build a high-resolution picture of the amount and type of air pollution experienced by different neighbourhoods.

Investigating respiratory health

The other key information for the investigation consists of data on children's respiratory health. Since 2017, the AIRE team has partnered with schools in Imperial Valley to enrol children in the study. "We send questionnaires to the children's families asking about each child's respiratory health history since birth, including any medication use, hospitalisations and diagnosis of asthma," says Esther Bejarano, a community health worker at CCV. "We also ask about the child's lifestyle, home environment and day-to-day activities."

Each child then completes a lung function test, which provides information about their lung size and capacity. "This helps us learn more about each child's lung health, which we can link to air pollution information," explains Dayane Duenas Barahona, the AIRE research coordinator. "In addition, we collect data on where each child currently lives and has lived in the past which, when combined with the air quality data, allows us to understand how much PM each child has been exposed to throughout their life."

Working together to find solutions

By examining the links between children's respiratory health, local air quality and the shrinking Salton Sea, the AIRE study is providing communities with the scientific evidence needed to understand and address the challenges they are facing. "Our research is ongoing, but it is clear that as air quality worsens, children experience poorer respiratory health, with symptoms such as wheezing and coughing," says Shohreh. The team has also observed that children living closest to the Salton Sea suffer the greatest impacts.

Residents of Imperial Valley are understandably desperate for solutions to this ongoing environmental health crisis. "Such strategies could include limiting the amount of dust that is blown into communities by creating wetlands around the lakeshore and planting native grasses to stabilise the exposed lakebed, or erecting barriers to prevent dust from blowing," suggests Jill. "Air quality could be improved by reducing PM emissions from other sources, such as by limiting the use of diesel machinery and preventing agricultural burning."

To fight environmental injustices such as the Salton Sea crisis, affected communities must have a say in the decision-making process. It is vital that residents of Imperial Valley can participate in conversations about how to address these challenges, and the AIRE study is helping them to do so.

About *environmental justice*

Environmental justice is a social movement to address the fact that poor and marginalised communities are disproportionately harmed by environmental hazards. "The idea of environmental justice means that everyone has the right to live, work and play in communities that are safe, healthy and free of dangerous conditions," says Luis. "The reality is that poorer people, Indigenous people and people of colour bear greater environmental burdens, such as poor air and water quality." These communities can lack the resources to combat the issues they face, such as stopping the source of pollution or taking the perpetrators to court, and so they are especially vulnerable.

The environmental justice movement gives power and agency to the communities affected by unjust environmental practices. "Environmental justice becomes possible when all communities have access to the information they need and can act as decision-makers to take action and create positive change for themselves," explains Dayane. Engaging with local communities and supporting them to make their own decisions is, therefore, essential for effective environmental justice work.

"When facing environmental hazards, community organisations often gather their own data in the face of government inaction or industrial denial about hazardous exposure," explains Jill. Placing this burden on communities is not fair but is usually what occurs. It should be the responsibility of those creating pollutants or damaging the environment to ensure their actions do not adversely affect others. Unfortunately, this rarely happens. "The burden of providing scientific proof that environmental harm is occurring falls on affected communities," says Shohreh. "Collaboration with scientists, such as through the AIRE project, can help increase environmental health literacy, raise awareness, inform policy makers and contribute to decisions that improve public health. Working to address the unequal distribution of environmental burdens is critical to fostering a healthier, more sustainable future."

Pathway from school to *environmental justice*

- At school and post-16, STEM subjects (including chemistry, physics, biology, physical geography, environmental science and mathematics) will teach you the scientific foundations that will be useful for promoting environmental justice. Social science and humanities subjects (including human geography, psychology, history and languages) will help you understand and communicate with communities impacted by environmental issues.
- Many university degrees can be applied to environmental justice. With a degree in public health, you will understand how public policies impact communities' health. Chemistry will help you understand the reactions of polluting chemicals, while biology will teach you about the effects of these pollutants on the body. With a degree in engineering, you could develop infrastructure to eliminate toxic chemicals, while a law degree will enable you to provide affected communities with legal support. Biostatistics will teach you how to analyse data, and geography will teach you how to document communities' stories and map environmental hazards.
- Whatever you choose to study, Jill recommends taking courses that specifically focus on the foundations and history of the environmental justice movement.

Explore careers in *environmental justice*

- If you are passionate about improving the well-being of communities, there is a wealth of career opportunities related to environmental justice. These include careers in public health (to improve the health of communities disproportionately affected by environmental issues), policy making (to ensure policies address the needs of communities and the environment), urban planning (to design communities that work with the environment), law and advocacy (to fight for communities impacted by environmental mismanagement), environmental education (to raise awareness of environmental concerns within communities) and research (to scientifically study the environmental hazards that are harming communities).
- Anyone of any age can get involved in the fight for environmental justice for all. Find a local, national or global organisation that promotes community and environmental health and well-being, and join their campaign to support their cause.

Meet *the team*

Dr Jill Johnston

Keck School of Medicine,
University of Southern California

Environmental justice is a social movement that works to create healthier places where we live, work and play. To transform the systems that have harmed communities for generations requires building power within communities. I used to work as a community organiser with an environmental and economic justice organisation, and this experience highlighted the need for community-based science.

I was motivated to develop a research project focused on children's health after listening to the concerns of community members and leaders in Imperial Valley. Through the AIRE project, I hope we can collectively produce actionable information to address environmental pollution and public health challenges.

The conversations with our young participants have been a highlight of this project. They are curious, knowledgeable and excited to engage in science. My advice for young people is to think about how you can use science to develop solutions that benefit communities and support environmental justice.

Studying environmental sciences and engineering helped me develop the skills needed to measure pollutants in the environment and understand how chemicals travel through the environment. I then studied epidemiology, which examines patterns of health in communities. When combined, this background provides me with the scientific foundation to help design research projects that address community health concerns.

Children in Imperial Valley suffer from some of the highest rates of asthma in the US © Ground Picture/Shutterstock.com

Dr Shohreh Farzan

Keck School of Medicine,
University of Southern California

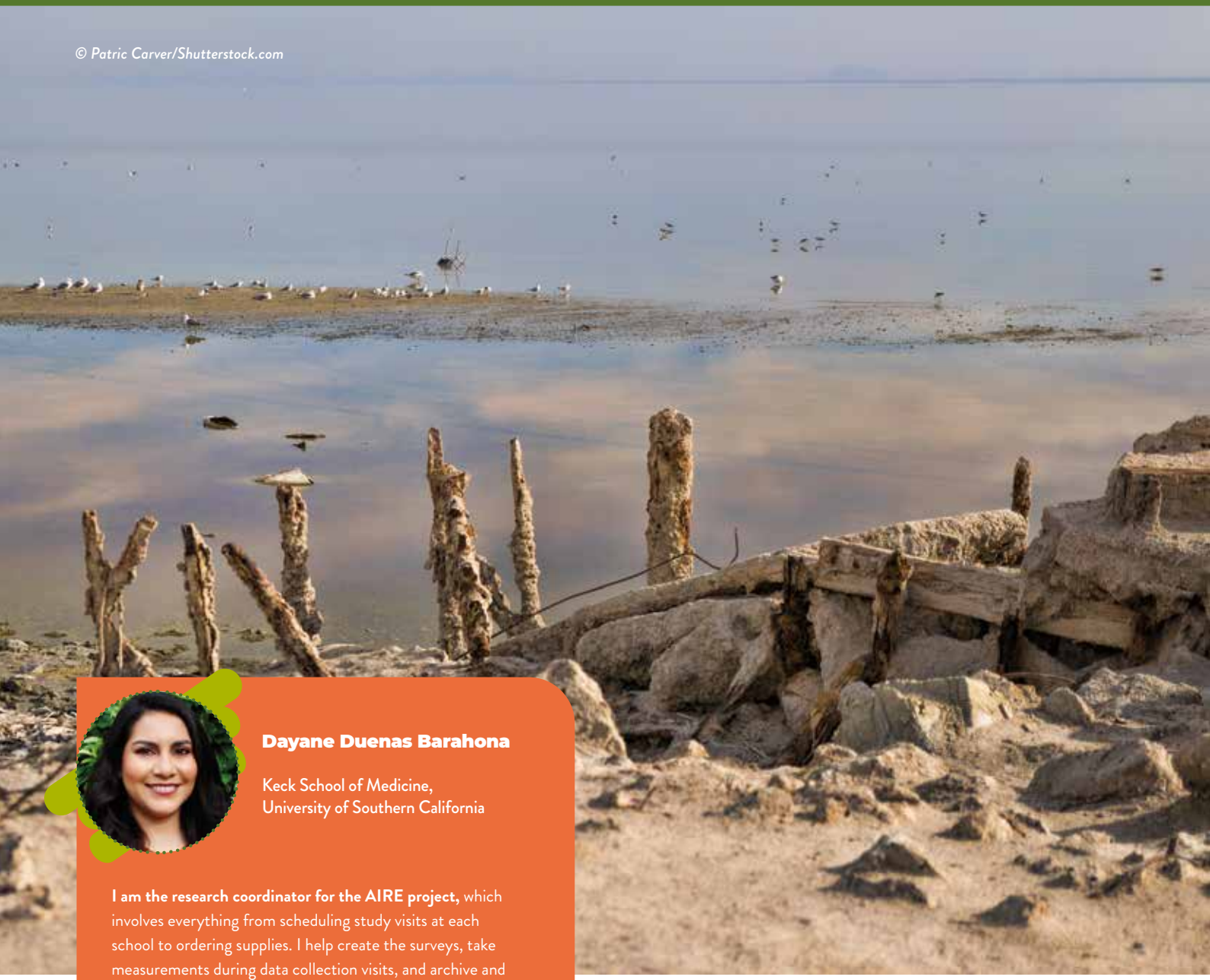
When I moved to California, I didn't know much about the Salton Sea. After visiting the area and listening to the concerns of the community, it became clear that many people were worried about how the shrinking lake would affect their health. Parents often spoke about how many children in the communities suffered from asthma and other respiratory issues. However, they felt that most conversations about the impacts of the drying lake were focused on the health of the ecosystem rather than the health of communities. This inspired the AIRE project, which aims to understand respiratory health in Imperial Valley and shift the conversation to one about public health.

This project was one of my first opportunities to conduct community-engaged research. It's been highly rewarding to conduct research that is aligned with the needs and concerns of community members. It is also rewarding to help inform the next steps needed to protect children's health.

My PhD research was in pharmacology and toxicology. I spent most of my days in the lab, working with cultured cells and fruit flies. While I really enjoyed being able to answer clearly defined questions about protein interactions, I wanted my life's work to have a broader public health impact, so I shifted my focus to environmental epidemiology. I still consider biological pathways, but now I study how they are disrupted by exposure to harmful substances, such as air pollution, and how this leads to disease, such as asthma.

As a young adult, I thought that science was all about lab work. I had no idea what environmental epidemiology was and could never have dreamt of doing what I am doing now. My advice to young people is to be open to opportunities that expose you to the huge range of scientific research. Reach out to people working on topics that interest you to see if you can get involved. I love it when students come to me because they are excited about my research.

There is an urgent need to create a fairer, healthier, more sustainable world for everyone. This should be regardless of someone's background or where they live. Addressing environmental justice is not only about improving the environment and reducing pollutants, but also about promoting social equity and well-being. To me, these ideas are foundational for the creation of a more just society.



Dayane Duenas Barahona

Keck School of Medicine,
University of Southern California

I am the research coordinator for the AIRE project, which involves everything from scheduling study visits at each school to ordering supplies. I help create the surveys, take measurements during data collection visits, and archive and share our results.

Previously, I was part of a research study investigating children's exposure to their environment. I joined the AIRE project because it was a great opportunity to apply what I had learnt in a new setting, and I wanted to expand my knowledge of air pollution. I was excited to lead a project based in a rural community that I had not experienced before; it is rewarding to be part of the solution to the struggles faced by communities.

I love working with the children who are participating in our study. It has been great to watch them grow over the years and see their continued interest in the project. A highlight was their reaction to our mobile clinic at the start of the study – they thought it was the coolest thing!

I studied public health at university, which taught me about research studies, the ethical considerations of working with vulnerable populations (such as children), how to see the big picture in data, and how data can influence policies which can then lead to systemic changes. Most importantly, I learnt how to work in a team, which is a valuable skill for anyone involved in research.

Luis Olmedo

Comite Civico del Valle

Communities in Imperial Valley suffer from some of the highest rates of asthma in the US. I joined the AIRE project to help our community find answers to critical questions around pollution and childhood asthma. I hope to produce interventions that can reduce asthma prevalence and influence policy changes related to the sources of pollution that lead to asthma.

As the executive director of CCV, I am a co-investigator for the AIRE project, and I advise the research team. It is important for CCV to partner with trusted scientists who have experience in community engagement and ethical research principles.

I have answered a call to service, driven by my quest for equity and justice. I believe we must pass down a better world than the one we inherited. The next generation needs to be given the draft 'operational manuals' so they can improve them for themselves and future generations.

Esther Bejarano

Comite Civico del Valle

As the AIRE programme manager for CCV, I lead outreach and education efforts, assist with the coordination of events and develop relationships with local schools. I also provide feedback to the project team on the infographics and presentations we deliver to the communities.

I joined the AIRE project because I want to address the health needs of local communities. I enjoy fostering relationships with schools and families, finding ways to support them and working with them in different capacities to combat the challenges of poor air quality.

I am also a community health worker, where I work with families who are impacted in their daily lives by issues such as air quality and access to healthcare. Most of the families I work with are from underserved populations, so I am determined to find ways to help them prosper and become advocates for change, raising awareness in their own communities. This role has opened my eyes to the issues facing our community.

Being a community health worker requires passion. It is a very rewarding career where you can make a difference and see true change occurring.

I am passionate about environmental justice because we suffer from environmental injustice. The Salton Sea crisis is a personal issue for me as both my kids suffer from asthma. I became an asthma educator because I wanted to be informed and help others. This is my home, and I want the best for my children and my community.

Edgar Ruiz

Comite Civico del Valle

I am an air monitoring technician for the CCV's community air monitoring network. My responsibilities include maintaining the equipment and checking that everything is working properly. For the AIRE project, I am also in charge of receiving, preparing and installing the air filters at their respective sites.

It is very rewarding to participate in a research study that is generating understanding of the negative impacts of the air pollution we are exposed to. I also enjoy learning about new monitoring equipment and techniques, such as new methods for obtaining air samples. This has helped me gain practical experience and learn more about my work.

I studied energy engineering at university. While this was not focused on air monitoring, I learnt a lot that helps me in my role as a technician. I can follow established procedures, adapt to different work situations and solve problems that arise.

We should all have the same right to have access to a dignified and healthy environment where we can grow and perform at our best. There are many situations in which communities are at a disadvantage, and that is what motivates me in my work. I want to influence change and educate the next generation about improving air quality.

Christian Torres

Comite Civico del Valle

I'm passionate about environmental justice because I grew up in a community affected by environmental issues. I saw similar communities benefitting from environmental justice work, and it felt like an injustice not to bring such opportunities back home.

I studied biology at university, which gave me a basic understanding of the issues I now deal with, including public health, the environment and the effects of pollution on the body. It also gave me critical thinking skills, which help me now as I often need to think outside the box and have a 'plan B' ready.

I always dreamt of being a field scientist who was involved in community work for the public benefit. My current role, as an air monitoring technician for the CCV's community air monitoring network, allows me to fulfil this goal as I collect air filters from schools that are used to assess air quality in local communities.

I enjoy working with the team on the AIRE project. I also enjoy applying what I learnt during my university studies to contribute to the research, and I like learning new things about monitoring equipment and the technical aspects of the project.

The Salton Sea in California is rapidly drying up
© Zack Frank/Shutterstock.com

The AIRE team's *top tips*

- Respect Mother Earth.
- Honour, respect and learn from elders and leaders in your community.
- If you want to help communities, it is important to listen to their needs, learn from what community members have to share and build trusting relationships with people.
- Don't give up, even if what you are currently doing doesn't seem to make sense. At some point in life, you will understand its importance.
- Work hard at what you do, but also remember to relax.
- Look for opportunities to get involved with research projects as this will give you practical experience and help you build connections for future work. Be open to different opportunities (such as collecting pollution samples in the field, analysing data in a lab, or working with community members in a clinic) as you never know what will pique your interest.

Does city life negatively affect wildlife?

If you have ever seen the beautiful sight of hundreds of starlings sweeping through the sky in unison, you will know how at ease these birds look in their environment, even in an urban setting. Starlings seem to have adapted well to cities, but how healthy is this for them? At **Kennesaw State University** in the US, **Dr Sarah Guindre-Parker** is an ecologist investigating the effects of urban life on starlings – and the implications for us all.

Dr Sarah Guindre-Parker

Department of Ecology, Evolution and Organismal Biology, Kennesaw State University, Georgia, USA

PROFILE

Field of research
Ecology

Research project
Toxicity in the city: the cumulative effects of heavy metals on the behaviour and physiology of urban-adapted birds

Funder
US National Science Foundation (NSF)

Talk like an ...

ecologist

Biomonitoring tool — an indicator species that can be used to assess the health of an environment

Heavy metal — a high density metal that can cause health problems

Mass spectrometry — a laboratory technique used to identify chemical substances

Lead-based paint — any industrial or household paint that contains the metal lead. It can be highly toxic, especially to children

Nestling — the name for a baby bird which has not yet left its nest

Ornithology — the study of birds

Physiology — the scientific study of the way that an organism functions

Trace element — a chemical element only present in tiny amounts

Urbanisation — the increasing number of people moving to and living in urban areas, i.e., towns and cities

If you are familiar with starlings, it might be because when they flock together, their flight creates swooping aerial patterns in the sky. These glossy, dark birds can often be spotted in towns and cities. They eat worms, spiders, caterpillars and insects, which they find on short grassy areas such as garden lawns, sports fields and parks. Overflowing rubbish bins and household waste in flimsy, plastic bags also provide starlings with easy meals.

At Kennesaw State University, ecologist Dr Sarah Guindre-Parker is studying these birds to see how their tendencies for city life might affect them – and what this might mean for all living organisms, including humans.

What are heavy metals?

Heavy metals are high density metals such as lead, arsenic, cadmium and mercury. While heavy metals do occur naturally in the environment, urban areas often have increased concentrations of them because of human activity. "Heavy metals can be released into the environment in diverse ways, ranging from mining to metal corrosion to agricultural fertilisers," explains Sarah. High levels of these metals can affect an area's soil, water and air quality, resulting in negative health effects for people and wildlife.

"Heavy metals can persist in homes or in the environment for long periods of time, often undetected, which is why scientists are concerned about heavy metal pollution," says Sarah. Heavy metals have also been added to common, everyday items, such as paint. Although lead-based paint was banned from use on houses in the US in 1978, older houses are still likely to contain lead-based paint, which can have serious implications for human health.

How do starlings come into this?

When Sarah decided to study the effects of these metals on birds, she knew starlings would be a great species to focus on. "European starlings or common starlings (*Sturnus vulgaris*) are a common species that is known as an 'urban-adapter' species," explains Sarah. "This means that they can be found in urban habitats, as well as more rural habitats."

Sarah is retrieving a handful of starling nestlings from one of her nest boxes
© Jason Getz / Kennesaw State University

As a result of this tendency, Sarah's team can study starlings from both urban and rural areas to see what differences the change in habitat might cause. Another useful aspect of starling behaviour is that while they will often nest in cavities and vents in buildings, they will also lay their eggs in nest-boxes. Compared to the more particular nesting habits of other bird species, the starlings' behaviour makes Sarah's work easier, as she can put out nest-boxes and begin monitoring the starlings immediately – without having to find hidden breeding sites.

What does studying starlings involve?

Sarah is based in the US state of Georgia, and, so far, alongside the rest of her team, she has sampled over 300 starlings across 11 different sites in the metro-Atlanta area, the most populous area in the state. The team samples starlings on various properties, ranging from busy, urban parks – such as the city's well-known Piedmont Park – to rural, private farms.

"Typically, we head out in the early morning, set out big bird traps and place bird food inside the traps," says Sarah. "There are small tunnels through which the starlings can walk in but then can't find their way out of easily." These traps catch the birds but do not harm them. The researchers can then carefully attach a metal band with a unique reference number onto a bird's leg. This allows them to know when and where they saw the starling, and prevents them from accidentally analysing the same bird again.

The team then collects a tail feather before conducting an 'open field test'. This involves placing the starling in a small, enclosed tent and filming it for 12 minutes, during which time an unfamiliar object is shown to the bird.

What happens next?

Sarah and her team watch the 12-minute open field test videos to gather detailed insights into the behaviour of each bird. These videos show how confident different birds are in new environments (by how much of their time is spent exploring the new space compared to hiding) and how aggressive they are (by how they treat or attack the unfamiliar object).

> **"Heavy metals can persist in homes or in the environment for long periods of time, often undetected, which is why scientists are concerned about heavy metal pollution."**

Secondly, the collected tail feathers are washed and sent to the University of Georgia's Agricultural and Environmental Services Laboratories to be analysed for heavy metal concentrations. The laboratories use an advanced chemical technique called mass spectrometry to measure the precise concentration of any trace elements of heavy metals in the feathers.

Combining the results of these two data sources, the team can see if birds with higher heavy metal concentrations in their feathers behave differently.

What has the team found?

Sarah's team is still analysing the test videos, gathering data and collating its results. "We might predict that birds with higher lead contents in their feathers would be more aggressive and more likely to attack the new object in the tent," explains Sarah.

The tail feather analysis has shown that nestlings from urban habitats have higher lead concentrations in their feathers than nestlings from rural habitats. Interestingly, there is not a difference between lead concentrations in rural and urban adult starlings. "This tells us that nestling birds, rather than adults, may be a better indicator of elevated lead in urban environments. If we wanted to pick starlings as a biomonitoring tool to identify which urban habitats have high lead, we would want to use nestlings and not adults," explains Sarah.

The team is yet to fully understand how these increased lead levels might affect starlings. However, a study on mockingbirds (a bird species found in the Americas) from researchers at Tulane University discovered that urban mockingbirds with elevated lead in their tissues behaved more aggressively. "This is a great study, with the researchers suggesting that being overly aggressive could be negative for the birds, because it could be a waste of their energy, lower their survival, or increase human-wildlife conflict," explains Sarah. Covering a larger geographical scale and looking at a species of bird found all over the world, Sarah's research will add to these findings, providing further insights into this field of study.

Where might this research go next?

Sarah is also interested in how her research might be applied to humans. For example, the results from another study which researched heavy metal concentrations in soil ended up helping local communities to know which gardens were safe to grow vegetables in, and which were not. Keep an eye out to see where Sarah's work might end up taking her to.

About *ecology*

The scope of ecology is massive, as it includes studying any process or organism that occurs in the natural world, as well as how these organisms interact with each other and their environment.

Humans rely on and are affected by the natural world. Equally, human activity impacts the natural world. Urbanisation (which sees human-made infrastructure encroaching on the natural world) and pollution have a huge impact on organisms and the environments they live – or used to live – in. As climate change continues to impact our world, pushing species out of their regular habitats into new areas and changing air and water temperatures across the globe, ecologists have a huge number of important questions to answer.

Ecology is fascinatingly interconnected, as research on one species is often relevant to other species as well. "The findings of research on heavy metals in birds, for example, might be applied to benefit humans by using bird samples to map where dangerous hotspots of heavy metals occur," explains Sarah. "This could lead to initiatives to remove heavy metals from the environment."

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

Sarah says, "It is important to understand how human activities are impacting not only wildlife but humans themselves. Environmental scientists, ecologists, city planners, government officials and conservation biologists will all need to work together to study the issue of urbanisation and find ways to minimise the negative impacts of building large cities."

Pathway from school to *ecology*

- At high school and post-16, take classes in biology and geography. "Ecology can also benefit from topics in chemistry and, even, physics," says Sarah.
- Outside of school, try to volunteer with a botanical garden, community garden, or a local ornithology group.
- Study an undergraduate degree in ecology, environmental science, physical geography or biology. You will then need to complete a master's degree if you want to work in scientific research. Many researchers also complete a PhD, although this is not always the case. Sarah explains, "In the US, many ecology jobs in private sectors do not require a PhD, but becoming a scientific team leader in the field usually does."
- Aim to get some hands-on research experience as soon as possible. "If you are interested in becoming a researcher in the field of ecology, you should test out whether you really like it early on by getting research experience in an ecology lab," says Sarah. "Whether you are attending high school or are already in college or university, contact a professor who conducts research that you are interested in helping with. Sometimes, there can even be remote options to participate in from afar. Some positions are paid and others are voluntary; it is always worth sending an email to ask about what opportunities might be available."

Explore careers in *ecology*

- Have a look at the Environmental Science website for some great information on how to become an ecologist and what an ecologist typically does: **www.environmentalscience.org/career/ecologist**
- "One of my favourite job boards for ecology opportunities is run by the Ecological Society of America (**www.esa.org/career-development/job-sites**)," says Sarah.
- Ecologists can work in academia, for private companies, or on environmental estates. As an ecologist, you can expect to spend a lot of time out in nature, collecting samples, and at the computer, handling big datasets and analysing how different species fit together and affect one another.
- "If you are interested in bird ecology research more specifically, my favourite website is the Ornithology Exchange job board (**www.ornithologyexchange.org/jobs/board**). Here, you can find bird-specific volunteer or paid opportunities, as well as graduate position openings if you wish to get a master's or PhD degree in bird ecology," Sarah adds.
- According to Payscale.com the average annual salary for an ecologist in the US is around $55,000.

Four starling nestlings sampled as part of Sarah's research. You can see the metal numbered band on one of their legs, along with a green plastic band which indicates the year the bird was captured.
© Jason Getz / Kennesaw State University

Q&A
Meet *Sarah*

Who or what inspired you to become a scientist?
I always loved biology in school and, without really knowing what else to do with that, I planned to go to medical school. One year, I was looking for related work to do over the summer holiday and found a research assistant position that focused on the physiology of birds. I thought this would be good experience for my medical school applications... until I held my first bird. I fell in love with the intriguing little creature I was looking at close up. That summer job changed the course of my life; I realised we can learn things from animals that can help humans too. The way the environment impacts birds is not dissimilar to how it impacts human health and physiology.

What experiences have shaped your career as a scientist?
I was a research assistant for Dr Sophie Bourgeon (who is now at the Arctic University of Norway) when she was a postdoctoral researcher. She was a fantastic mentor. She taught me so much about studying birds but also about how to cope with a tough day in the field and how to laugh when things go wrong. She was incredibly patient, kind and encouraging. I feel very lucky that my first research job was in such a supportive environment where I could ask questions and learn so much. It made me want to be a great mentor for future students too.

What are your proudest career achievements so far?
My proudest achievement is seeing the students I have worked with and mentored go on and be successful. I am always so happy when I can write a recommendation letter for someone, and they later let me know they got the role that they were applying for. It is the best part of my job as a professor.

Secondly, I am really proud when a student, researcher or professor uses my scientific papers in their classes or to shape their research. Every paper takes a long time to write and publish, so it feels great when it can be useful to someone else, especially the next generation of ecologists.

What are your ambitions for the future?
My aim for the future of my research is to produce findings that benefit local communities more directly. While I find it fascinating to study birds for the sake of it, I want to make sure the results of my research can be applied to benefit humans. Not only is this the mission of the US National Science Foundation, which is funding this work, but it is also a personal goal of mine to make the world better for future generations, including my daughter, Emi.

Sarah's *top tip*

It is never too late to change your mind about what path you are pursuing. I changed my mind about my career path, and it was a great decision! I've worked with many students who felt they were discovering their passion too late, and they are all accomplishing great things in their new field of expertise now. I think it is easy to assume everyone figures out their path early on in life, but that isn't the case.

How can statistical models answer ecology's big questions?

Ecology involves studying the interactions between living things and their environment. These interconnections can be very complex, leading to the creation of some hefty datasets. At the **Université de Sherbrooke** in Canada, **Professor Guillaume Blanchet** specialises in building sophisticated statistical models that can analyse these datasets, producing fascinating and unexpected results.

Professor Guillaume Blanchet

Assistant Professor, Department of Biology and Department of Mathematics, Université de Sherbrooke, Canada

PROFILE

Field of research
Quantitative ecology

Research project
Developing statistical models to uncover the complex relationships organisms have with each other and their environment

Funder
We acknowledge the support of the Natural Sciences and Engineering Research Council of Canada (NSERC)/Nous remercions le Conseil de recherches en sciences naturelles et en génie du Canada (CRSNG) de son soutien

Talk like a ...

quantitative ecologist

Ecology — the branch of biology that studies the relationships organisms (including humans) have with each other and their environments

Ecosystem — all the living and non-living components of an environment

Endangered species — a species at risk of going extinct

Invasive species — a species not native to the region in which it is now found, usually introduced there (intentionally or accidentally) by humans

Quantitative ecology — the branch of ecology that uses statistical and mathematical models to study ecological systems

Statistical model — a mathematical model that relies on observed data to better understand and predict events

Variable — a component in a model that can take on different values, e.g., altitude or temperature

While the popular image of ecology may involve scientists tramping around fields and forests armed with measuring tapes and butterfly nets, this picture is only the first half of the story. Once an ecologist has collected samples and measurements from the field, the next job is to analyse these data to discover what they tell us about ecosystems. And this is where quantitative ecologists, such as Professor Guillaume Blanchet at the Université de Sherbrooke, come in.

Quantitative ecology involves taking the complex datasets generated by field ecologists and creating statistical models to uncover secrets the data hold. As ecological studies often generate complex datasets that must be analysed, quantitative ecologists are in high demand, and Guillaume has worked on a wide range of projects, from investigating the population dynamics of bighorn sheep to conserving endangered fish species to modelling bird migration.

From the field...

Ecologists are interested in how living organisms interact with each other and their environments. Studying these relationships involves data collection, which can take a variety of forms. "Many ecologists still collect data 'manually', by going into the field and using techniques such as traps or active sampling techniques (to collect animals or plants), tagging (to track and monitor animals) and species surveys (to study animals, plants and other organisms)," says Guillaume. "This might involve catching butterflies by brushing nets over vegetation, identifying all the plants in a specific area, or tagging a migratory bird to monitor its movements."

Increasingly, ecology is benefitting from advances in technology. For example, satellite imagery can be used to measure forest cover, algal blooms or even the locations of large animals, such as whales, from space. Motion-sensitive camera traps can automatically record the wildlife passing through an area when scientists are not present to observe them. Environmental DNA (eDNA) involves taking soil or water samples and using sophisticated lab techniques to identify the origin of the small fragments of DNA found within them, providing a powerful way to understand what organisms are in an area without ever seeing them.

Some ecological methods include conducting experiments to manipulate the environment, such as modifying the amount of water plants receive, to investigate how organisms respond. Others rely on citizen science, in which the public participate in science projects by gathering ecological information, for example, by recording animal sightings. "These are just a few examples," says Guillaume. "Ecological data gathering techniques are really diverse, and ecologists are constantly developing new methods. My colleague studies ants, and he loves to browse in hardware stores and think about how he could use the equipment there to gather data in new ways!"

... to the computer

Effectively processing and analysing the datasets generated by these ecological data collection techniques relies on specialised skills. "Statistical models help us answer ecological questions and give a measure of the certainty of the answers," says Guillaume. "For example, I could record when the flowers in my garden bud every year. Because some years are warmer than others, the budding time may fluctuate when we compare data from different years, so we need to account for this uncertainty. Statistical models help us identify trends in data and the level of uncertainty."

This is a simple example, and models can undertake much more complex tasks. For instance, there may be many more variables involved that affect flower budding – how much sunlight or rainfall they receive, what soil they are growing in, what pests or diseases are around, and so on. As ecological data collection is increasingly conducted using technological methods, which can capture vast amounts of data, the need to account for the complexity of these data only grows.

Models and efficiency

"When I receive an ecological dataset, the first thing I do is to work with my colleagues who gathered the data to understand the details of what they did when sampling the data," says Guillaume.

> **"If we can understand what features of an environment are favourable for a particular species, we can help conserve it if it is endangered or control it if it is invasive."**

"I then consider which statistical models would best answer the question they had when sampling the data and implement the analysis by running the models using computer programs."

While many statistical models already exist, some datasets require new approaches to answer specific questions. Guillaume develops his own models to achieve this, which requires knowledge of algebra, statistics and probability. "My models have been applied to better understand where species should (or should not) occur, how they interact with other species, and what components of the environment influence their distribution," he says. "If we can understand what features of an environment are favourable for a particular species, we can help conserve it if it is endangered or control it if it is invasive."

A big challenge for ecology is that the collection of data can often take up a lot of funding, time and resources. "I aim to develop a more efficient way to sample ecological data that would require less effort and still give the same results," says Guillaume. "I've found that some studies would produce the same results if only a fraction of the sampled data had been collected." These findings are contributing to making ecology an increasingly efficient and effective discipline.

Best of the beetles

Guillaume's work has introduced him to some fascinating collaborations. "I worked with a colleague who is an expert on ground beetles in the boreal forests of northern Alberta, Canada," he says. "We wanted to understand how commercial forests, where logging takes place, can be managed to ensure biodiversity is protected." Guillaume used statistical models that incorporated data on a wide range of species and discovered that, to effectively preserve beetle biodiversity in northern Alberta, areas of forest left uncut must be at least 1 km^2 in size. "This result was quite surprising for us!" he says.

In another study, Guillaume collaborated with two teams of researchers from Finland and Japan to compare their data on a group of insects known as oak leaf miners. "We wanted to understand if the factors that affect the abundance of these insects through time are the same in different regions of the world," says Guillaume. "Both teams had worked on their respective projects for many years and had gathered large quantities of data." Guillaume built a sophisticated statistical model that could account for all the different types of data, combining all the information in a single model. "Our model indicated that some factors, including the insects' microhabitats, anatomy and behaviour, correlate with fluctuations in species' populations over time," says Guillaume. "On the other hand, other characteristics, such as the frequency of reproduction and the species' mode of feeding, did not."

Statistical models are the only way to uncover such findings. Without them, and without quantitative ecologists such as Guillaume, these ecological secrets would remain hidden in the data forever.

About *quantitative ecology*

Quantitative ecology involves using statistics and other mathematical tools to answer ecological questions. While quantitative ecologists tend not to gather data themselves, they work closely with field ecologists to process their datasets and discover what they contain. "The best thing about my work is that I get to learn about the immense diversity of life on Earth," says Guillaume. "As my work focuses on ecological methods, rather than a specific ecological system, I have contributed to research about lions, jaguars, bighorn sheep, birds, coral, algae, insects, crayfish, freshwater fish (including the copper redhorse, an endangered species found only in Quebec, Canada), marine organisms, desert and arctic plants, and tropical and boreal trees. On every project, I work with specialists who teach me something new every day. It's also thrilling to use models to find out things that nobody ever knew before."

What does the future hold for quantitative ecologists?

Climate change is affecting biodiversity in significant and unexpected ways. To conserve species and ecosystems, quantitative ecologists must develop statistical models that can efficiently predict how organisms and environments will respond to future changes. "It is hugely challenging to create models that can predict what will happen in the next 10 to 100 years, especially due to the unprecedented nature of climate change and its often-unexpected impacts on biodiversity," says Guillaume.

As technology continues to advance, new techniques for gathering ecological data will present new challenges for quantitative ecologists as they try to analyse them. For example, LiDAR (the use of lasers to determine the physical characteristics of the environment, including the vegetation) and eDNA data require new analysis methods and new statistical modelling techniques.

One area of focus in quantitative ecology is the development of a single all-encompassing model that could account for the entire complexity of a whole ecosystem. "This is very appealing," says Guillaume. "However, it is also very challenging. At the moment, we simply don't have the computational power to develop such models."

What skills do quantitative ecologists need?

"First and foremost, you need to be passionate about the environment and everything that lives in it. Don't hesitate to wonder about the beauty and complexity of nature," says Guillaume. "Ecologists are some of the most passionate people I have met. They are highly invested in making the world a better place." Knowledge of mathematics and computer programming is also essential for developing the models used by quantitative ecologists. While field ecologists may spend their days measuring trees in the rainforest or hunting lizards in the desert, the quantitative side of the subject provides a route into ecology for those who do not want to, or cannot, participate in fieldwork, creating accessible opportunities for anyone to contribute to conservation efforts.

Explore careers in *quantitative ecology*

- "Now, more than ever, people are realising that climate change is affecting our lives and the planet," says Guillaume. "Companies and governments want to know how to manage the situation, which requires gathering and processing data on the natural world." This means there is an ever-increasing need for ecologists, especially quantitative ecologists, who can analyse these data and understand and explain the results.
- Many private sector companies employ ecologists, so you could work as an ecologist in construction, mining, forestry, manufacturing or insurance. Ecologists also work for governments and non-governmental organisations that advocate for the natural world.
- Two of the largest ecological societies both have sections dedicated to quantitative ecology. The Ecological Society of America's Statistical Ecology Section (**www.esa.org/stats**) and the British Ecological Society's Quantitative Special Interest Group (**www.britishecologicalsociety.org/membership-community/special-interest-groups/quantitative-ecology**) each provide opportunities for prospective quantitative ecologists to network, learn and attend events.

Pathway from school to *quantitative ecology*

- At school and post-16, study biology, mathematics and computer programming to learn about ecology and statistical modelling.
- At university, a degree in ecology, biology, environmental science, conservation, mathematics, statistics or computer science could lead to a career in quantitative ecology.

© Kien/Shutterstock.com

Q&A

Meet *Guillaume*

What were your interests when you were younger?
I had many interests as a kid, ranging from video games to basketball. I was always interested in science, beginning with dinosaurs and then evolution. I had a book on evolution that I read as often as I read my Astérix and Tintin comic books.

Who inspired you to become a quantitative ecologist?
When I finished high school, I knew I wanted to be a researcher. Back then, medical science was the only scientific field I was aware of, but I didn't get the grades I needed to study medicine at university. Instead, I studied biology, where I discovered the possibility of a career in ecology. During my degree, I met Professor Pierre Legendre who founded the field of numerical ecology, and who is an amazing ambassador for ecologists who want to do quantitative work.

> ***I love the fact that, in most of our projects, results are rarely what we expect them to be!***

What are your favourite ecology projects to work on?
I am always interested in learning about new things, so being able to work on such a range of ecological systems and species is amazing. The projects that most stand out to me are those where I could develop a new method that had never been thought of before, or else when I could use existing methods in entirely new ways. I love the fact that, in most of our projects, results are rarely what we expect them to be!

What do you enjoy doing in your free time?
Outside of work, I love spending time with my family. I particularly enjoy kayaking with my sons.

Guillaume's *top tips*

1. Be passionate and don't be scared to follow your dreams.

2. There is never only one way to reach where you want to go. I always loved math and nature, but never realised I could make a living by combining these two passions.

How can we unravel the complex history of networks?

Infectious diseases, such as COVID-19, can spread rapidly from person to person, resulting in a vast and complex network of infected individuals. Throughout your life, you will meet new people, make new friends and form new relationships, building an ever-evolving social network. At **Rutgers University** in the US, **Dr Min Xu** has developed a model that can unpick the history of networks such as these, helping everyone from epidemiologists to counter-terrorism investigators.

Dr Min Xu

Department of Statistics, Rutgers University, USA

PROFILE

Fields of research
Network analysis, probability, statistics

Research project
Developing a probabilistic model to describe the growth and evolution of real-world networks

Funder
US National Science Foundation (NSF), grants DMS-2113671 and DMS-2311299

Talk like a ... network analyst

Bayesian statistics — the branch of statistics based on the Bayes rule, which states the probability of an event if a related event is known to have occurred

Community — a cluster of tightly connected nodes

Edge — the connection between two nodes in a network e.g., the relationship between two people in a social network

Epidemiology — the study of how diseases spread through populations

Markovian model — a model that describes how a random system changes over time

Network — an interconnected group of individuals

Node — an individual that is part of a network e.g., a person in a social network

Root node — the first node in a network

Transition kernel — a mathematical equation that states the probable ways in which an event could occur

Weight — the strength of an edge in a network

In December 2019, people in the Chinese city of Wuhan began to fall ill from an unidentified illness. Most people suffered no more than a bad cough, a lack of energy, and a loss of taste and smell. However, on the 11th of January 2020, the first confirmed death from this new type of coronavirus was reported. The victim was a 61-year-old man who was a regular customer at a local seafood market, where the COVID-19 pandemic is believed to have originated. Within three years, almost 7 million people around the world had died from COVID-19. How did this disease spread from a seafood market in central China to become the most disruptive global pandemic in living memory?

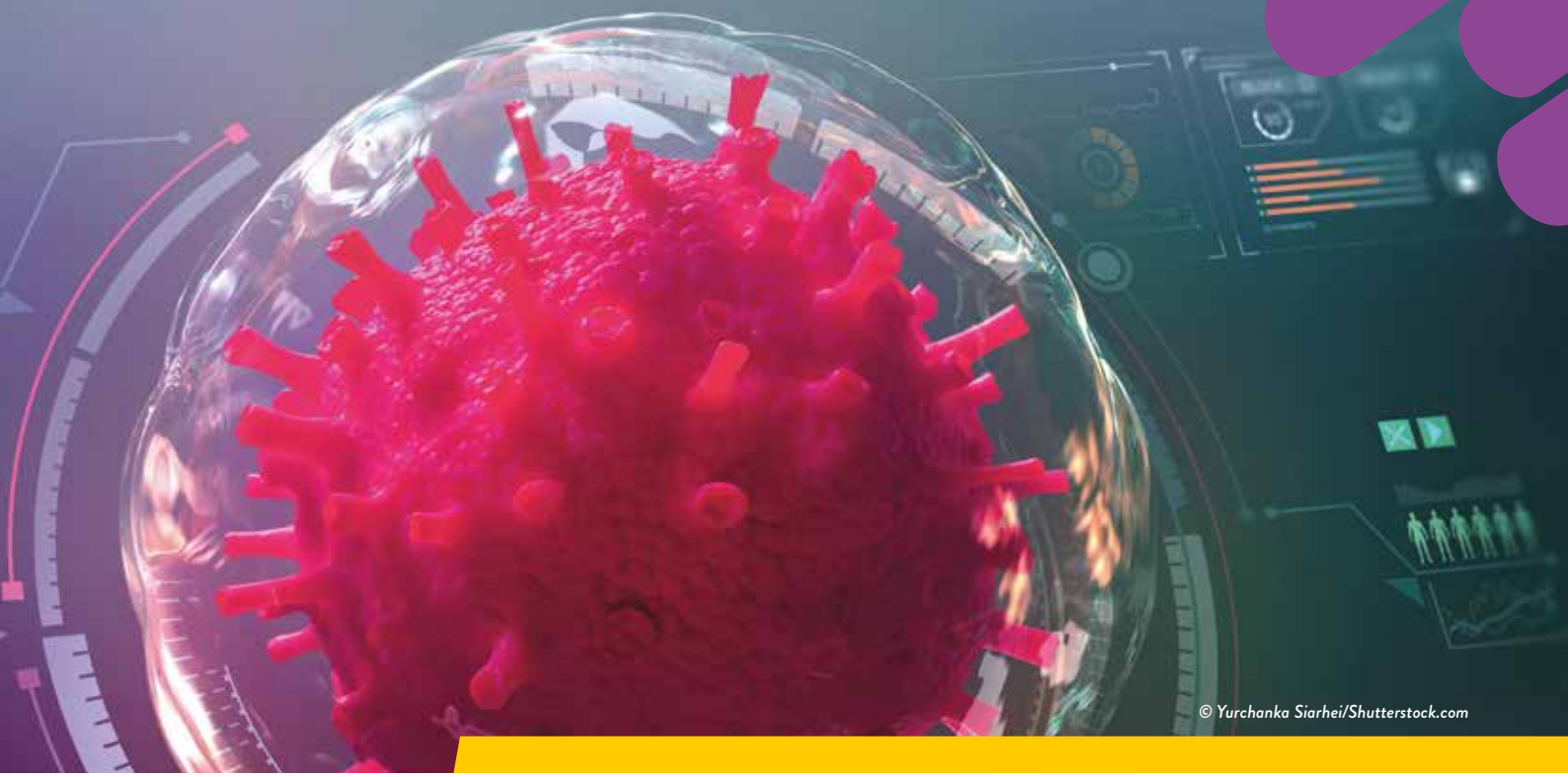
COVID-19 is an airborne virus, meaning it spreads via tiny droplets that are coughed, sneezed or breathed out by an infected person. If, over the course of a day, an infected person is in close proximity to ten other people, by the end of the day, those ten people may have breathed in the virus and become infected. The next day, each of these ten newly infected people may be in close contact with another ten people, meaning one hundred more people may become infected. In this way, diseases such as COVID-19 can spread rapidly among populations.

To understand how this happens, epidemiologists study the network of interactions between infected individuals. By tracking who an infected person has had contact with, they can predict where new outbreaks are likely to occur in the future and determine where the disease originated in the past.

However, these networks of interactions are highly complex, and analysing them is no easy task. Dr Min Xu, a statistician specialising in network analysis at Rutgers University, has developed a probabilistic model that can determine how a network has grown, which not only has applications in epidemiology, but is also useful in social science, genetics and counter-terrorism efforts.

What is a network?

"A network is a mathematical model used to describe relationships (known as edges) between individuals (known as nodes)," explains Min. "Each edge may have a weight (that represents the strength of the relationship) and direction (if the relationship is one-way), and the root node is the first individual in the network." For example, in a network of disease transmission, the root node would be 'patient zero', the first person to be infected. The nodes connected to the root node would be people infected by patient zero. As



the network grows, extra nodes could be added as these newly infected people infect others. Within a network, there may be smaller communities of closer interactions. For example, while everyone who has had COVID-19 is connected in a huge global network, this can be broken down into smaller communities representing how people became infected in a single town or school.

What are other examples of real-world networks?

"Social networks are perhaps the most famous example of networks," says Min. In a social network, each node is a person, and each edge represents a relationship between two people. In your social network, you are connected to your family members, friends and acquaintances by relationships of different strengths, forming communities that represent different social interactions in your life. For example, you may have communities of siblings, close friends, sports team members and classmates. Your family members, friends and acquaintances may also be connected to each other, forming a complex interconnected network. Researchers often gather information about social networks from social media platforms, where relationships can be identified when individuals are 'friends' or 'following' each other.

Geneticists model networks of gene expression, where each node is a gene and edges exist between genes that are often expressed together. Counter-terrorism investigators study the networks within terrorist organisations, where each known terrorist is a node, and edges represent communications between terrorists. Academics collaborate with each other when they conduct research, forming networks of researchers (nodes) who work together (edges) on projects.

Why is it useful to study the history of a network?

"Real-world networks start small and grow over time," says Min. For example, your social network has grown as you have grown because, as you got older and met new people, you formed new relationships. Throughout your life, your social network will continue to evolve – you will add new nodes as you make new friends, and the weight of some edges may diminish as you lose contact with old friends.

> ***"Real-world networks start small and grow over time. The history of a network gives us important information about how the network is organised."***

"The history of a network gives us important information about how the network is organised," explains Min, "and it can tell us about the formation of different communities in the network." For example, determining the history of a disease network could enable an epidemiologist to uncover how a disease has spread through a population, including how it has spread between and within different regions, by locating 'patient zero' in each community.

How does Min infer the history of a network?

It is very challenging to uncover the history of a network. "We only see the final network in its current form," says Min. "We cannot look back in time to see what it was like in the past." This means it is impossible to definitively reconstruct a network's full history, but statisticians can make educated guesses about the network's early history.

Min has developed a Markovian model that can analyse networks and infer their history. "A Markovian model describes how a random system evolves over time," he explains. "It breaks down the evolution process into a sequence of steps and specifies the transition kernels that state the probable ways in which each step could occur."

Min's Markovian model allows him to assess the probability that different potential histories have resulted in the final network. To apply his model to real-world networks, Min uses tools from Bayesian statistics, which uses the Bayes rule to invert a probabilistic statement. "If we know how likely event B is to occur, given that event A has occurred, the Bayes rule lets us calculate the reverse – how likely is event A, given that event B has occurred?" he explains. "In the context of Markovian network models, the Bayes rule lets us 'invert' time." Based on the final state of a network and the transition kernels, Bayesian statistics allows Min to determine which network histories are most likely to be correct.

Why is this model important?

Min has collaborated with researchers from other disciplines to apply his model to real-world networks. "We worked with geneticists to apply our model to a gene interaction network related to a genetic abnormality that can cause miscarriage during pregnancy," says Min. "From the network alone, we identified important genes linked to this genetic condition." Min is continuing this collaboration to help geneticists understand which genes are important in different genetic diseases. He has also applied his model to examine research collaborations between academics. His model accurately identified communities of researchers who work together and extracted root nodes that corresponded to influential figures in each research community, highlighting the model's ability to analyse a network successfully.

Based on these results, Min is hopeful that his model will allow researchers to infer the history of a wide range of different networks, helping them to investigate everything from infectious diseases to terrorist organisations.

About *probability and statistics*

To analyse networks, Min relies on theories and methods from the related fields of probability and statistics. "Probability is the mathematical study of randomness and uncertainty, while statistics is the mathematical study of discovering information and patterns from data," explains Min. "Statistics uses probability to distinguish useful information from sheer coincidence in the data."

Researchers use probability and statistics to understand the relationships between sets of data and to create models (mathematical representations of real-world scenarios) that describe them. For example, a researcher could statistically analyse a dataset and use this information to create a mathematical model that represents the data. Then, they could use this model to probabilistically predict the outcome of a future scenario. "In summary, probability tells us how a model produces data, while statistics uses probability theory to find a good model for a given dataset," says Min.

How can probability and statistics help us in day-to-day life?

"Everything in the world has randomness," says Min. "But, as humans, we are inherently bad at thinking about randomness." For example, in 2010, an octopus named Paul correctly 'predicted' the outcome of 12 out of 14 matches in the football World Cup. As a result of his initial success, many people started placing bets based on his predictions. "However, we can reason that, based on the data and the fact that many other animals were also unsuccessfully 'predicting' the outcome of matches, it is most likely that Paul was just making random guesses," explains Min. Rather than being a psychic octopus, probability and statistics tell us that Paul simply got lucky.

"Humans tend to be over-confident in the conclusions that we draw from data," says Min. This may be due to a variety of biases, such as confirmation bias (the tendency to interpret information in a way that confirms our pre-existing ideas) or recency bias (placing more significance on recent events than historical events). "Understanding statistics and probability helps us overcome these biases and make better decisions," says Min.

Pathway from school to *probability and statistics*

- At school, you will learn the basics of probability and statistics in mathematics classes.
- Min also recommends learning computer programming ("Python is the best programming language to learn," he says), as this is a key skill for statistically analysing data and building probabilistic models.
- There are lots of online videos and tutorials where you can learn about statistical methods of data analysis and programming (e.g., **www.learnpython.org**). Gaining practical experience of programming is very important. "Learning probability without being able to create computer models is like learning chemistry without being able to do experiments," says Min.
- At university, degrees in statistics, mathematics, data science or computer science will all offer classes in statistics and probability.

Explore careers in *probability and statistics*

- "Statistics and probability are the foundation of data science, and data science is one of the hottest jobs around at the moment, due to the huge amounts of data we are continuously creating," says Min. "Today's computers and internet connectivity mean we are generating far more data than we know what to do with."
- Knowledge of statistics and probability is vital in all fields of science. "A big part of a statistician's job is to help other scientists!" says Min. "Many scientists know all about their specific field of interest, but they don't know how to use the latest statistical models and methods." This means many research projects require a trained statistician, so you could find yourself collaborating with anyone, from astrophysicists to zoologists, to help them analyse their data.
- The American Statistical Association has a wealth of resources, including information about careers in statistics and fun practical statistics activities: **www.amstat.org/education/k-12-student-outreach**
- The Royal Statistical Society lists some of the many jobs for statisticians: **www.rss.org.uk/jobs-careers/career-development/types-of-job**

Meet *Po-Ling*

Professor Po-Ling Loh is a statistician at the University of Cambridge, UK, who collaborates with Min.

I come from a very mathematical family. My father is a statistics professor, my mother has an undergraduate degree in math, and my two older brothers were interested in math from a very young age. This meant that, while my favourite subjects in different years of school were biology and American history, I grew up with the idea that everyone liked math and it was the most natural way to reason about the world.

It is important to realise that everyone's life journey is unique. Growing up with my family background in the university town of Madison in Wisconsin, USA, I thought it was completely normal for everyone to earn a PhD and become a professor. However, as I've seen more of the world, I've come to appreciate that this is not the case. A PhD is not for everyone, and I'm not sure I would suggest that younger people follow in my footsteps!

I conduct high-dimensional statistics research in the field of theoretical statistics. This involves determining how to perform estimation when the number of samples is relatively small compared to the number of parameters one wishes to estimate. I also develop new methods for making statistical procedures robust and private. This research has real-world applications in medical imaging, where images of the body can be viewed as high-dimensional objects that must be estimated in accurate, robust and potentially private ways.

I have two young daughters, so most of my free time is spent reading the Berenstain Bears and books by Richard Scarry. Prior to having kids, my favourite leisure activities included baking, singing and cycling.

Po-Ling's *top tip*

If you aspire to becoming an academic, it is important to figure out your own strengths and capitalise on them. This will lead to a smoother path and one with more potential to make deeper and more satisfying contributions. For example, are you good at making novel connections between existing topics? Do you derive a thrill from cracking open hard problems? Do you love coding up complex algorithms and making them more efficient?

Meet *Min*

I didn't like math until college. Initially, I was interested in architecture and physics, as I enjoyed building things and thought it was so beautiful how a few simple physical laws could explain so much of the world. At school, math was all about following complicated rules and formulas. It wasn't until college that I realised you can be very creative with mathematics. I discovered that instead of following the rules and formulas, you can invent them!

During my undergraduate degree in electrical engineering and computer science, I took a class in artificial intelligence (AI) and loved the math behind it. I thought machine learning was the perfect place to understand AI from a mathematical perspective, so I did a PhD in machine learning. I ended up as a statistician when I realised that statistics is the foundation of machine learning.

> ***Many bad decisions have been made because the people involved did not fully understand the Bayes rule.***

The Bayes rule is my favourite fact about statistics. Personally, I think it is the most important theorem in probability and statistics, and it is also extremely useful in real life. Many bad decisions have been made because the people involved did not fully understand the Bayes rule. A famous example is from a legal case in 1996, in which both the judge and jury were confused by the Bayes rule when trying to use Bayesian statistics to help determine the likelihood of DNA evidence belonging to a suspect, possibly leading to a wrongful conviction.

When I'm not analysing networks, I like being outdoors, either playing tennis, running long distances or hiking in nature. I also enjoy reading and listening to audiobooks. I can't think of anything better than to go on a long hike in a beautiful area while listening to an audiobook.

Min's *top tip*

Don't give up too early. When studying probability, statistics and machine learning, there are many points when things will suddenly feel impossibly difficult or complicated. This happens to everyone. Be patient and trust that it will get easier over time.

How can data management tools help us discover new treatments for a chronic disease?

Myalgic encephalomyelitis/chronic fatigue syndrome (ME/CFS) is a complex disease that can take a huge toll on a person's everyday life. There is still much we do not know about the disease, and researchers are working hard to learn more about what causes it. **Dr Linda Brown**, an epidemiologist, and **Dr Megan Carnes**, a genomics research scientist, from **RTI International** in the US have developed a suite of data management tools to help ME/CFS researchers to collaborate in the hope of finding new treatments.

Dr Linda Brown

Senior Research Epidemiologist, RTI International, USA

Dr Megan Carnes

Genomics Research Scientist, RTI International, USA

Fields of research
Epidemiology, genomics

Research project
Developing tools that allow myalgic encephalomyelitis/chronic fatigue syndrome (ME/CFS) researchers to share data and collaborate

Funders
US National Institutes of Health (NIH): National Institute of Neurological Disorders and Stroke (NINDS); National Institute of Allergy and Infectious Diseases (NIAID); National Heart, Lung, and Blood Institute (NHLBI); National Center for Complementary and Integrative Health (NCCIH); and National Institute on Alcohol Abuse and Alcoholism (NIAAA)

This work was supported by the National Institutes of Health (NIH) under award number U24NS105535. The contents are solely the responsibility of the authors and do not necessarily represent the official views of the NIH or RTI International.

PROFILES

Talk like an ...

epidemiologist or genomics scientist

Biospecimens — materials taken from the human body, such as tissue or blood, that can then be used for research

Data analytics — processing, examining and analysing datasets to find patterns and trends and to draw conclusions about the information in the data

Data management — collecting, organising and storing data safely, protecting privacy and allowing access to researchers only

Data integration tool — software that can combine different datasets so they can be analysed further

Myalgic encephalomyelitis/chronic fatigue syndrome (MS/CFS) — a long-term disease that causes extreme tiredness and other symptoms such as pain, dizziness and memory loss. Other symptoms can include problems with sleep, thinking and concentration. Often, people with ME/CFS are unable to do their usual activities. At times, they cannot get out of bed. People with ME/CFS have severe fatigue that is not improved by rest. ME/CFS can get worse after any activity, whether it is physical or mental. This symptom is known as **post-exertional malaise (PEM).**

Sometimes, when we are ill or overworked, we wake up feeling as though we have not slept a wink. If you have had a bad night's sleep, it can take all your energy to open your eyes and get out of bed. At times like these, the thought of having to go to school or work can seem impossible.

Luckily, for most of us, these days are few and far between, and, although we may never get used to an early alarm clock, we are able to get up and tackle whatever the day has in store for us. For people with myalgic encephalomyelitis/chronic fatigue syndrome (ME/CFS), daily life is far more difficult. ME/CFS is a serious, long-term illness that can change a person's life completely, leaving them unable to do things that most of us take for granted, including going to school or work, taking a walk, or even getting out of bed.

People with ME/CFS have extreme fatigue and find it difficult, or even impossible, to get a good night's sleep. They may develop problems with their memory and ability to focus. They may also have debilitating and unbearable pain and dizziness. These

symptoms are associated with post-exertional malaise (PEM), when the brain and the body cannot recover from even tiny amounts of activity.

ME/CFS can affect anyone, no matter their age, gender or ethnic background. However, women are two to four times more likely to be diagnosed with ME/CFS than men. It is estimated that almost 17 million people around the world have ME/CFS; however, it is likely that many more people remain undiagnosed.

One of the biggest problems with ME/CFS is that we do not know what causes it. Researchers, medical professionals, and scientists all over the world are trying to understand what triggers the disease so that new treatments can be developed. To do this, researchers need access to as much data about ME/CFS as possible.

Dr Linda Brown and Dr Megan Carnes work at RTI International, a non-profit research institute that is dedicated to improving the quality of people's lives. They are working with a team of researchers to develop new data-sharing tools that will allow more collaboration and communication between ME/CFS researchers, medical professionals and people with ME/CFS.

Collaboration and data sharing

Encouraging researchers and medical professionals to share data and store them in centralised, easily accessible databases makes collaboration much more effective. Sharing data and encouraging collaboration can advance ME/CFS research by enabling researchers to better validate their results, reuse data that is difficult to generate, and perform stronger analyses by combining datasets. "By promoting communication between ME/CFS clinicians and researchers, we hope to accelerate future research," says Linda.

Current research

"A number of institutions and organisations around the globe are undertaking innovative basic and clinical research," says Linda. Some of this research focuses on finding the causes of ME/CFS and how it develops and changes over time. Other researchers are studying the different subtypes of ME/CFS and their different symptoms. However, most current research is focused on identifying potential treatments for ME/CFS. No matter what the focus of the research, access to data is very important.

A scientific community

In 2017, the US National Institutes of Health (NIH) established the ME/CFS Collaborative Research Network. The goal of this network is to conduct basic scientific and clinical research to better understand the causes, symptoms and treatments of ME/CFS.

"A basic research project might characterise cellular and molecular mechanisms of disease processes, while a clinical research project might follow a group of people with ME/CFS and a comparison group of healthy people," explains Linda. To support this research, the NIH supported RTI to set up a Data Management and Coordinating Center (DMCC), which helps the collaborative research centres manage their data.

"The DMCC supports research by providing administrative management and logistics, and expertise in data management and data analytics," says Linda. The team of researchers at the DMCC has developed three tools which help to facilitate collaboration and communication in ME/CFS research.

The DMCC has created a website, called MECFSnet, which contains information about ME/CFS. The website has tools and other resources to help support people with ME/CFS and the researchers who are studying it. The team has also created searchMECFS, a tool that allows researchers to obtain biospecimens for their research, and mapMECFS, a data sharing tool.

mapMECFS

mapMECFS is the largest data repository for ME/CFS data and serves as a primary location for researchers to share the results they generate in their laboratories. Research that involves human subjects requires careful planning and ethical reviews, as well as participant briefings, enrolment and follow-up. As a result, these studies can be costly and take many years to complete.

"It is essential that researchers share the data they generate with the scientific community to maximise what can be learned from each study," says Megan. mapMECFS allows researchers to access data from the latest research and use data from other studies to inform their own research.

"As a subject matter expert, my job is to understand the needs of the researchers, including their data and its complexity, and to translate those needs so the software developers can create new tools," explains Megan. These tools include a data explorer which can, for example, allow researchers to search for a gene of interest and find the studies that have investigated that gene. "We also developed a data integration tool that allows researchers to quickly merge clinical data files," says Megan.

The next steps

mapMECFS will continue to grow as researchers upload data. "The development of mapMECFS is 'user-centred', which means that we prioritise site changes based on the feedback we receive from researchers using the site," says Megan.

The needs of the researchers will determine how mapMECFS changes in the future. Megan expects that the team may create new data visualisation tools, increase the amount of data that the site's integration tool can process, and improve the site's ability to check the quality of the data. "The overall goal of this work is to make scientific data more accessible," she says. Linda and Megan hope that their work will continue to support researchers with the goals of understanding the biology of ME/CFS and developing new treatments.

About *epidemiology and genomic science*

Epidemiologists study the causes, distribution, control and prevention of diseases. Information gained from epidemiological studies can be used to understand how prevalent diseases are, how they are transmitted and how best to prevent them from spreading. Epidemiological research played a vital role in understanding the spread of COVID-19 and informing policies and strategies to reduce its spread. ME/CFS is not a contagious disease; however, epidemiology can still help us understand why it occurs in certain people and develop new treatments.

Genomic scientists study the genome of an organism, that is, all the genes, their characteristics and gene products (e.g., proteins) to better understand how they function. The goal is to learn about the biology of a disease and to identify new treatments or biomarkers. Biomarkers are objective evidence of disease that can be measured in a laboratory and used to help doctors diagnosis and treat diseases.

Challenges

"Some of the challenges epidemiologists and genomic scientists encounter include working with incomplete or inconsistent data and complex datasets that require advanced statistical methods to analyse them," says Linda. Epidemiologists and genomic scientists must also have excellent problem solving and communication skills. Their research is often complex, and they must be able to clearly communicate their findings to other researchers, medical professionals and people with the disease being studied.

Rewards

"One of the rewards of working in epidemiology and genomic science is the ability to work in a variety of different settings and on a variety of different diseases and conditions that affect the health of the public," says Linda. This keeps things interesting and allows epidemiologists and genomic scientists to have a real-life, positive impact on people's lives.

Opportunities

The next generation of epidemiologists and genomic scientists will have a lot to keep them busy, whether they are working on new infectious diseases or on chronic public health problems, such as obesity, substance abuse and mental health. "Because epidemiologists investigate the causes of disease and other public health problems, the need for epidemiologists is projected to grow by more than 25% over the next 10 years," explains Linda. The same is true for genomic scientists who may specialise in studying human diseases that are common, such as cancer, or rare diseases. Some fields of genomic science are disease agnostic, meaning the focus is more on understanding how the genome functions in a healthy organism. "Epidemiologists and genomic scientists work in a number of settings such as universities, government agencies, and private industry, including pharmaceutical companies," says Megan.

Pathway from school to *epidemiology and genomic science*

- It is important to gain a strong understanding of science at high school. Studying biology, chemistry, physics and statistics will prepare you for college or university.
- For epidemiology, you should obtain a bachelor's degree in a related field such as health science, biology or biostatistics. This will allow you to enrol in a graduate programme that specialises in epidemiology.
- For genomic science, you should obtain a bachelor's degree in a related field such as genetics, biology or computational biology. This will allow you to enrol in a graduate programme that specialises in genetics, genomics, bioinformatics or genetic epidemiology.
- Contact your local university for internship opportunities. Summer schools are another way to gain practical experience. For example, the University of Manchester in the UK runs a Public Health Summer School that provides students with an in-depth introduction to epidemiology: **www.bmh.manchester.ac.uk/study/summer-schools/public-health**

Explore careers in *epidemiology and genomic science*

- Have a look on some of the major societies' websites such as The Society for Epidemiological Research (**epiresearch.org**), the International Epidemiological Association (**www.ieaweb.org**), the International Society for Environmental Epidemiology (**www.iseepi.org**), and the National Human Genome Research Institute (**www.genome.gov/About-Genomics/Introduction-to-Genomics**).
- Have a look at the Your Local Epidemiologist blog run by Dr Katelyn Jetelina, an epidemiologist and data scientist: **yourlocalepidemiologist.substack.com**
- Get in touch with an epidemiologist or genomic scientist at your local university and see if they would be willing to answer some questions. Talking to a professional about what their job is like is a great way to learn more about a specific career.

Meet *Roman*

Roman Ruiz-Esparza is a Lead Software Developer at the RTI's Center for Data Science.

I first got into web development in high school using Notepad to edit HTML. From there, I got a few internships through college making web apps. Then, I worked at two other organisations doing similar work before arriving here at RTI and working on this project.

I work from home, so I always start my day walking my dog Chevi and making a pot of coffee. I sit at my desk and open up VS Code (a code editor) and a web browser and get to work. Work is either adding a new feature, like making the app able to process new data, or fixing a bug in prior work.

When I started on the project, the deployment process was very manual, which is prone to error. Ideally, you want to push your code, and it gets tested and deployed automatically. I learned this process at my last job, but here I got to implement it myself.

mapMECFS at its most basic is a file-sharing website. Researchers can upload their datasets for sharing with others, and download data that others have shared. We also enhance that experience by allowing users to search metadata or the actual datasets. And we automatically compute statistics on certain datasets, to give researchers even more information.

We use the same codebase for another project, and we've had interest in using it for additional projects, so I'm currently working on making the software more extensible and faster to develop on. This is a common problem in the field, so it's very interesting to me to work on it.

Roman's *top tips*

1. Be humble.
2. Have confidence in your abilities.
3. Remember that everything around you was built by people just like you.

Meet *Taya*

Taya McMillan is a Research Communication Analyst at the RTI International's Center for Communication Strategy and Design.

Early in my career, I created health education materials at a federal agency. My responsibilities increased over time, and I developed a deeper understanding of the importance of health literacy, plain language and compelling messaging. When done correctly, communications, whether digital, web-based or print, can increase knowledge, awareness and beliefs, which can lead to changes in behaviour. These changes, no matter how small, can help improve the overall health and well-being of individuals.

I work on several projects, and my role is different for each. I often spend the first few hours of my day writing or creating tools or content that require a lot of focus. I usually have a handful of meetings and follow-ups with people on my team, and often do some basic research to inform decisions that need to be made. I always have my eyes and ears open for new and creative ways to share information. In that way, each day is a learning opportunity.

We engage members of the ME/CFS community through our Community Outreach Working Group (COWG), which includes people with ME/CFS, caregivers, advocates and researchers from our network. To be successful, we need a collaborative approach that includes the voices of people with ME/CFS.

Consultations with the ME/CFS community proved invaluable when we were designing the website. We were able to take their insights and apply them directly to our web design. For example, because CFS is often emphasised more than ME, we decided to go with an eye-catching colour with bold font for ME and a grey colour for CFS when creating the logo for the website.

We wanted to create a website that was informative and easy to navigate for people with ME/CFS. For example, people with ME/CFS sometimes get tired when using a computer and may need to take a break. The return feature on the website allows a person to return to the last place they visited on the website without spending time or energy trying to find their last location.

Taya's *top tips*

1. Never be afraid to try something new.
2. Roll up your sleeves and don't be afraid of hard work.
3. Do your best every time.

How can we combat ageism in society and healthcare?

Whether we realise it or not, we all hold stereotypes about older people. Whether we view them as cute, forgetful, bad with technology or unproductive, these stereotypes are harmful to older people and ourselves. What is more, ageism in healthcare environments impacts the quality of care that older people receive. At the **University of Alberta** in Canada, **Dr Sherry Dahlke** and **Anndrea Vogt** are exploring the impacts of ageism on older people and developing educational resources to teach student nurses how to best care for older patients.

Dr Sherry Dahlke

Anndrea Vogt

Faculty of Nursing, University of Alberta, Canada

PROFILES

Field of research
Gerontological nursing

Research project
Developing a training programme to raise awareness of ageism among student nurses and improve their skills in caring for older people

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

Talk like a ...

gerontological nurse

Acute illness — a treatable short-term health condition

Ageism — prejudice or discrimination due to a person's age

Chronic illness — a long-term health condition that can usually be controlled, but not cured

Dementia — a general term for conditions that impair a person's ability to think, remember or make decisions, such as Alzheimer's disease

Gerontological — related to ageing and older people

Palliative care — medical care that involves relieving a person's symptoms rather than curing the illness, often used near the end of a person's life

Social learning theory — the idea that social behaviour is learnt by observing and mimicking the behaviour of others

One of society's less-visible prejudices is ageism: discrimination against older people. Stereotypes of older people may at first glance appear relatively harmless, but can, in fact, have far-reaching consequences. "When society holds negative views of ageing, we are all affected, because we are all ageing," says Dr Sherry Dahlke, a nurse researcher at the University of Alberta. If we view older people as infirm, inactive and not involved in society, then when we grow old, we are more likely to accept these stereotypes about ourselves and limit our lives accordingly. These stereotypes also impact the quality of healthcare older people receive, which is why Sherry has developed educational modules to make student nurses aware of the impacts of ageism and to teach them how best to care for older patients.

Ageism in society

Ageist behaviours may be benevolent or hostile, and they are often unintentional. "Benevolent ageism involves over-accommodating an older person, for instance helping them across the street when they are capable of crossing by themselves," explains Sherry. "Hostile ageism is overt discrimination, such as making negative comments about older people or excluding them from social activities."

Ageism can be internalised by older people themselves. For instance, they may not seek treatment when experiencing mobility or memory issues, because they believe they are inevitable parts of getting older, when in fact their symptoms may be treatable. For example, while it is commonly believed that ageing causes a decline in cognitive abilities, this is usually a symptom of a specific health condition, such as a treatable acute illness (e.g., an infection) or dementia, rather than the ageing process itself. Viewing certain health conditions as a natural part of ageing is, therefore, a dangerous misconception, as not only are older people and their families less likely to seek treatment, but it can also lead to a lack of action from healthcare professionals.

Ageism in healthcare

"Institutional ageism is when society's institutions are set up in a way that discriminates against older people," says Sherry. Anndrea Vogt, a former student of Sherry's, who has recently qualified as a nurse, has witnessed ageism first-hand within healthcare environments. "When taking an older person's medical history, many nurses

> ***Institutional ageism is when society's institutions are set up in a way that discriminates against older people.***

and doctors will ask questions to the accompanying family member rather than to the older person themself," she says. "Hospital staff may describe an older person as a 'cute little grandma' which, while benevolent, is also demeaning."

Such attitudes towards older people can directly affect the level of care they receive. "Most healthcare organisations, such as hospitals, are best equipped for caring for younger people with one acute illness," says Sherry. "As we grow older, we are more likely to accumulate chronic illnesses and may be on multiple medications. This can make older people's care more complex." Moreover, staff are often trained to recognise the symptoms of illnesses only when they occur in younger people, while older people may show different symptoms when affected by the same illness. "For example, if an older person is confused, healthcare professionals may think they have dementia," says Sherry. "However, the confusion may be caused by an infection or a new medication."

There is also a widespread belief in healthcare that caring for older people is less interesting and physically harder work than caring for younger people. "In my first year at nursing school, the stigma around working with older people meant I was initially influenced against working in this field," says Anndrea. "The nurses in my family told me that working with older people is unrewarding, and instructors in the hospital told us that it is the 'easiest form of nursing', suggesting it doesn't provide any intellectual or professional challenge." Now, Anndrea firmly believes the opposite is true. "It is so rewarding to work with older people because they have so much life experience and gerontological care presents unique challenges," she says. The complex conditions that may be presented by older people call for well-trained and dedicated professional healthcare providers.

Learning by example

Social learning theory suggests that how we learn is influenced by how people act around us. This can have a significant impact on how we perceive age and ageing. "Based on our research into the impacts of ageism, we found that many people learnt how to overcome internal ageism based on their observations of how family and friends grew older," says Anndrea. "For example, if someone had seen their grandparents successfully navigate mobility issues, they remembered their successes when they faced the same age-related challenges themselves."

On the other hand, if people do not have these positive experiences, Sherry and Anndrea discovered it is difficult to learn resilience – especially if they are constantly exposed to ageism. "If older people are consistently perceived as weak, mentally declining and a burden to society, then they will subconsciously begin to believe these things about themselves," says Anndrea.

Improving nursing education to improve gerontological care

Sherry believes these findings indicate a strong need to confront ageist prejudices to make healthcare more effective. "We need to present accurate information about ageing and demonstrate a more positive way of managing care for older people," she says. "To address this, I have developed educational modules for student nurses that incorporate case studies of good practice with older people." These modules help nurses build a richer understanding of the conditions that typically affect older people and how they present themselves. "We cover how to communicate with older people as sensory changes take place, and how to understand and account for cognitive impairments. For instance, people with dementia might be unable to verbally articulate that they are hungry or need the bathroom, so nurses must be able to understand how other behaviours might communicate these needs."

The modules also address challenges around and attitudes towards mobility, pain management and palliative care. The course ends with a module on leadership, which teaches student nurses how to be a clinical leader by championing fair and equitable treatment of older people. "The modules are all evidence-based and include videos, interactive elements and real-world scenarios to help student nurses understand best nursing practices," says Sherry.

Looking ahead

Sherry hopes her teaching modules will be adopted by other nursing degree programmes, helping to address ageism within healthcare. "Most people are unconscious of the bias they hold against older people," she says. "It can start very young – even the books we read to children may portray older people as less capable." She believes intergenerational contact provides a key opportunity for older people to share their wisdom with the younger generation. "I agree that the most effective way to change negative stereotypes about ageing is to increase awareness of ageism," says Anndrea. "Most people do not even realise what ageism is, let alone how it is embedded in society. If more people understand its effects, we can make progress on ways to eliminate it."

To conduct her research into the impacts of ageism, Sherry worked with age-related organisations, gerontological experts and older people themselves. With their help, she is now disseminating her findings to nurses and the public, to improve institutional and societal attitudes towards ageing. Looking ahead, Sherry plans to begin another research project that develops intergenerational learning activities, pairing student nurses with older people in the community to challenge negative stereotypes of ageing and build appreciation for the older generations.

About *gerontological nursing*

Gerontological nurses care specifically for older people. They focus on improving patients' quality of life by providing clinical care and tending to other aspects of their well-being. "Gerontological nurses look at older people holistically," says Sherry. "They must often investigate whether functional changes in a person are due to illness or general ageing. While many chronic illnesses, such as dementia and heart disease, are more likely to occur in older people, they are not inevitable with ageing, and it is important to understand that we all age differently."

Caring for an ageing population

As global development and improved healthcare raise life expectancies around the world, the global population is ageing. According to the World Health Organization, by 2030, 1 in every 6 people in the world will be over 60 years old. "This is significant because we need to have the resources to care for older generations appropriately," says Anndrea. "However, there is a growing disconnect between generations, and younger people are becoming less enthusiastic about caring for the people who raised us. I think more intergenerational contact can heal this and allow for the next generation to better care for the growing population of older people."

Gerontological nurses may work in a wide variety of settings. Many of them work in hospitals, as most hospitals see large numbers of older patients. They also work in long-term care and palliative care facilities, where they address the healthcare needs of residents. Gerontological nurses play a key role in caring for older people in their own homes. This is hugely important, as many older people may need some healthcare assistance, such as help changing dressings or taking medications, without needing to be in hospital. Home-care nurses, therefore, enable older people to continue living independent lives in their community.

The joys of gerontological nursing

Anndrea says that gerontological nursing brings many rewards. "I enjoy listening to and learning from every single person that I care for," she says. While some people may think providing end-of-life care would be depressing, Anndrea finds it incredibly meaningful and rewarding. "I enjoy this aspect of nursing as I can be the person who makes such a difference to the well-being of the patient and their family at the end of their life."

Pathway from school to *gerontological nursing*

- Sherry and Anndrea recommend studying science subjects in high school and post-16, especially biology and chemistry, as the knowledge you learn in these classes will be important in your nursing degree.
- "I highly recommend shadowing a nurse while at high school," says Anndrea. "This is the best way to find out if the career is right for you."
- Many colleges and universities offer degrees in nursing. Depending on where you want to study and work, you may also be able to qualify as a nurse without attending university. Nursing apprenticeships and practical training programmes can provide an alternative pathway to a career in nursing, while care worker roles in long-term residential facilities for older people often do not require nursing qualifications.
- Other health or healthcare related degrees could also lead to a career working with older people, such as medicine, public health or psychology.

Explore careers in *gerontological nursing*

- "There is such diversity in what you can do as a gerontological nurse," says Sherry. "You can work with patients in hospital, in the community or in long-term care facilities, or you could become a researcher, like me."
- Whatever aspect of gerontological nursing you choose, it is important that you have patience and compassion when working with older people. Critical thinking and the ability to think outside the box are also necessary when dealing with the complex healthcare needs that older people may have.
- Sherry suggests looking for gerontological associations in your area, such as the Canadian Gerontological Nurses Association ( ) and the Alberta Gerontological Nurses Association ( ). Many such organisations provide resources about gerontological nursing and arrange meetings you can ask to attend.

© Hananeko_Studio/Shutterstock.com

Meet *Sherry*

At the age of 65, my grandfather could jump a six-foot fence! He was always fit and positive-minded and lived to be almost 100. He deeply impacted how I think about the ageing process.

I spent many years working as a clinical nurse, where I enjoyed meeting a diverse range of people. It was rewarding to help them, whether through relieving their pain, assisting them moving or simply listening to their concerns. A typical day involved assessing patients' physical and mental well-being, administering medication, changing dressings and helping them attend to their daily activities, such as washing, mobilising and administering medical treatments.

Once, while working as the manager of a hospital surgical unit, a young nurse came and told me there were too many old people on our floor. This comment shocked me. It made me consider how we could better care for older people and prompted me to return to university to study for a master's degree, then a PhD. Now, I conduct research focused on improving nursing practice with older people.

When I was younger, I wanted to improve people's lives, so thought I'd either like to work in teaching or nursing. Now, I get to do both! As a teacher, I love interacting with student nurses to engage them in learning. As a nursing researcher, I love having the freedom to decide what I want to study. Every day is different.

I hope we can start addressing ageism and reframing older people as an essential and valuable part of society. Through my research, I want to equip student nurses with knowledge and positive perspectives of older people, so they then go on to disrupt the negative care practices that result from ageism.

In my free time, I love playing golf. I also enjoy riding my bike, doing yoga and attending music events.

Meet *Anndrea*

I have always been interested in medicine and originally wanted to be a doctor, so before entering university, I spent time shadowing a physician at my local hospital. I decided to study nursing as I thought it would be the quickest way to gain hospital experience, rather than taking the longer, traditional route to get into medical school. However, that part of my plan didn't work out because I fell in love with nursing!

There have been numerous times in my life when obstacles have forced me onto a different path from the one I anticipated. However, I am so glad they did, because these obstacles guided me to where I am today. I believe it is important to trust in the process, and everything will then work out.

> ***My favourite thing about gerontological nursing is hearing people's stories.***

I helped to create the educational module that teaches student nurses about responsive behaviours – the actions people with dementia might use to express their frustration or confusion. I also conducted my own research to understand how ageism impacts older people. For my honours project with Dr Dahlke, I interviewed older participants about their perceptions of age and ageing, then analysed their answers to find common themes and ideas that explained the impacts of ageism on older people.

My favourite thing about gerontological nursing is hearing people's stories. It was great to interview older people and hear about their experiences. It was also incredibly motivating and powerful to hear how older people have overcome stigmas and stereotypes throughout their lives, and it was inspiring to discuss how we can combat ageism in society.

I have recently graduated with my nursing degree, and I am currently working as a labour and delivery nurse where I help care for mothers and babies during childbirth. I hope to gain a few more years of experience in obstetrics (the branch of medicine concerned with childbirth) before returning to university for a master's degree and PhD. I would like to study the connections between obstetrical and gerontological nursing as I think there is such an interesting commonality between the beginning and end of life. Joy and grief can often be found in both, and I think that studying the similarities in caring for these specific populations could help us learn more about effective care.

When I'm not working, I love to explore. My fiancé and I often go canoeing, hiking and camping in the mountains.

How does physics allow us to look inside the body?

Biomedical imaging techniques enable doctors and scientists to view inside the human body, allowing them to diagnose medical conditions and uncover the biological processes that are essential for life. At the **University of California Davis,** USA, **Professor Simon Cherry** and **Professor Ramsey Badawi** have developed the world's first full-body scanner, which has the potential to revolutionise medicine and biomedical research.

Professor Simon Cherry

Professor Ramsey Badawi

Department of Biomedical Engineering, University of California Davis, USA

Fields of research
Biomedical imaging, biomedical engineering, medical physics

Research project
Developing EXPLORER – the world's first total-body biomedical imaging scanner
explorer.ucdavis.edu

Funder
US National Institutes for Health (NIH)

PROFILES

Talk like a ...

biomedical imaging specialist

Magnetic resonance imaging (MRI) — a biomedical imaging technique that uses magnets and radio waves to observe internal organs

Metabolism — the chemical reactions in cells that convert food into energy

Photon — a particle of light

Positron — a positively charged subatomic particle with the same mass as an electron

Positron emission tomography (PET) — a biomedical imaging technique that detects signals emitted from radiotracers injected into the body to measure biological functions

Radioactive decay — the emission of energy in the form of ionising radiation

Radioisotope — an unstable form of an element that undergoes radioactive decay

Radiotracer — a very small (trace) amount of a chemical compound to which a radioisotope has been attached

What do you think of when you hear words like 'positron', 'antimatter' and 'high-energy photon'? Physics is full of exotic-sounding terms that we might associate with science fiction, and even real physicists, such as Albert Einstein and Erwin Schrödinger, can take on surreal and almost mythical personas. It can be easy to forget that these words equate to real-life phenomena, and these scientists made discoveries that have practical implications in our daily lives.

Every day, in hospitals all over the world, doctors use the laws of physics to diagnose and treat their patients. X-ray machines, ultrasound devices, magnetic resonance imaging (MRI) scanners and positron emission tomography (PET) scanners were all developed using concepts and theories based in physics. These techniques capture internal images of parts of the body, allowing medical professionals to diagnose a wide range of health conditions, from broken bones to cancer.

At the University of California Davis, Professor Simon Cherry and Professor Ramsey Badawi have taken biomedical imaging one step further. They have developed the EXPLORER total-body PET scanner, the world's first biomedical imaging device that can capture an image of the entire body in a single snapshot.

What physics theories lie behind PET scanners?

"Before having a PET scan, the patient is injected with a tiny amount of radiotracer," explains Simon. "One common example is a sugar molecule that has been modified to contain the radioisotope fluorine-18." After injection, the radiotracer circulates throughout the body and is taken up by cells. The more metabolically active the

Ramsey and Simon peer through their invention, the EXPLORER total-body PET scanner

cells are, the more radioactive sugar they take up. This is diagnostically useful because, during certain diseases, the body changes how it uses sugars. For example, cancer cells often accumulate much more radioactive sugar than surrounding tissues, meaning they can be visually detected on a PET scan. The major clinical application of PET is to look for cancer cells in patients.

About an hour after the patient has been injected with the radiotracer (allowing time for it to be distributed throughout the body), they are placed inside a PET scanner, which can detect the signals coming from radioactive decay. "When a fluorine-18 atom in the radiotracer undergoes radioactive decay, it emits a positron," explains Ramsey. "Positrons are antiparticles of electrons, meaning radioactive decay produces antimatter!"

However, matter and antimatter cannot coexist for very long. Almost immediately, the positron will find a nearby electron and both particles will be annihilated. In the process, the positron and electron disappear, and their mass is converted into energy according to Einstein's famous $E = mc^2$ equation.

This energy is released as two high-energy photons emitted in opposite directions. The radiation detectors in the PET scanner look for this signature pair of photons arriving simultaneously on opposite sides of the body, indicating that radioactive decay has occurred. During a single PET scan, hundreds of millions of decay signals will be detected, which reveal where radioactive molecules are concentrated in the body, indicating the location of cancer cells or other abnormalities.

How does EXPLORER differ from conventional PET scanners?

The EXPLORER scanner is an incredibly complex machine with over half a million radiation detectors and more than 50,000 electronic channels. "This rivals the complexity of the detectors used in the big particle accelerators found at places like CERN, home of the Large Hadron Collider!" says Simon.

Conventional PET scanners have a small array of radiation detectors and can only image part of the body at a time. To study the whole body, a patient is moved through the scanner step by step (which is time-consuming) and then the individual scans must be 'stitched' together. In contrast, EXPLORER has many more radiation detectors that cover the entire length of the body. This allows it to capture images of the whole body in a single scan – the world's first biomedical imaging device to do so.

> ***"The real game changer is that EXPLORER can see the radiotracer wherever it is in the body at any moment in time."***

How does EXPLORER benefit patients and biomedical researchers?

With detectors covering the whole length of the body, EXPLORER can detect radiation much more efficiently, gathering a lot more information. For a given scan time or radiation dosage, EXPLORER can collect 40 times more signal than a conventional PET scanner, providing many benefits for patients and biomedical researchers.

For example, EXPLORER can collect higher quality images which could enable diseases to be diagnosed earlier. It can conduct scans 40 times faster, meaning a total-body scan can be completed in less than two minutes. "This is fantastic for patients who can't stay still for long periods of time, such as young children or patients in a lot of pain," says Ramsey. Or, for a standard scan time, the patient can be injected with a radioactive dosage that is 40 times lower. "This is great for patients who need regular PET scans."

"But the real game changer," says Simon, "is that EXPLORER can see the radiotracer wherever it is in the body at any moment in time." This allows scientists to observe how substances are transported around the body, delivered to tissues and metabolised by cells, providing insights into how the entire body functions. "This offers truly exciting prospects for the future!" says Ramsey.

How did Simon and Ramsey develop EXPLORER?

In addition to the technical challenges of developing such a complex machine, Simon and Ramsey also had to overcome the practical challenges that come with creating a new invention, in particular, the issue of money. "It was a 15-year journey from first ideas to first images," says Ramsey. "The first 10 years were very frustrating, as the idea of a total-body scanner didn't interest the biomedical community, so we couldn't get any funding."

This all changed in 2015, when Simon and Ramsey finally received a large grant from the NIH, providing the money necessary to start building the system. In 2016, they joined forces with United Imaging Healthcare, a medical imaging company with the physical resources to build the scanner. "After that, the project moved incredibly quickly," says Ramsey. "Our first full-body images were acquired in 2018, and we started using EXPLORER for clinical use in 2019. Now, there are almost 20 EXPLORER total-body PET scanners around the world, which have scanned well over 100,000 people. Other companies also are making similar scanners, which shows that the idea is now catching on."

"Looking back, it has been an exciting and worthwhile journey," says Simon. The team's dedication and persistence paid off, and thousands of people are now benefitting from the technology Simon and Ramsey have developed. Having improved the diagnosis of cancer, Simon and Ramsey envision that, in future, total-body PET will be combined with other advanced techniques (for example, genomics and proteomics) and artificial intelligence to predict how the human body responds to health challenges and diseases, revolutionising biomedical understanding.

About *biomedical imaging*

How does physics impact medicine?

Biomedical imaging is a good example of how physics impacts medicine, as many techniques use some form of electromagnetic radiation to produce images of the body. At the low energy end of the electromagnetic spectrum, radio waves create the signal for MRI scans, while X-rays and gamma rays (the high-energy photons in PET) are at the opposite end of the spectrum.

"X-rays and gamma rays are ionising radiation, meaning they can break chemical bonds," explains Ramsey. "Therefore, care is always taken to minimise the radiation dose during X-rays and PET scans." If you break a bone and have an X-ray, you will receive the equivalent of about 10 days of natural background radiation. If you have a conventional PET scan, you will receive the equivalent of about 8 years of background radiation. One of the advantages of EXPLORER is that, when necessary, it can do PET scans with extremely low radiation doses – equivalent to the radiation you would receive during a round trip flight from San Francisco to London!

In contrast, ultrasound imaging uses soundwaves, which are not part of the electromagnetic spectrum. These soundwaves are of such a high frequency that we cannot hear them. When the soundwaves bounce of different body parts, they create an 'echo' which is detected by the ultrasound probe and transformed into a moving image of the body's interior.

Why do so many different imaging techniques exist?

"Each imaging technique provides different information at different levels of detail and at different costs," explains Simon. X-rays are perfect for providing images of anatomical issues, such as broken bones and fluid in the lungs. Ultrasound does not expose the patient to any radiation, so is used to generate real-time images of a foetus in the womb. Both these techniques are low cost, so are widely used. On the other hand, MRI and PET scans are more expensive but can provide more detailed images. MRI scans generate 3D images of body parts, especially soft tissues, while PET scans produce functional images of biological processes, such as metabolism or blood flow.

Pathway from school to *biomedical imaging*

- At school, you will learn about the processes behind biomedical imaging in physics, about human anatomy in biology, and how to use and manipulate equations in maths. If classes are available, computer science and engineering will also be very useful.
- Depending on what area of biomedical imaging you would like to work in, there are different pathways you can take to a career in the field. If you want to design and build biomedical imaging devices, consider a degree in almost any field of engineering (biomedical, mechanical, electrical or even aerospace), biomedical imaging, physics or medical physics. If you want to use biomedical imaging techniques while working with patients, consider a degree in radiography or medicine.
- Look for research opportunities and internships with biomedical research labs to learn about and contribute to scientific advances in biomedical imaging. Most labs have websites where you can learn about their research (Simon's lab: **cherrylab.bme.ucdavis.edu**; Ramsey's lab: **badawilab.bme.ucdavis.edu**) and many host high school and undergraduate students.
- Look for work experience and job shadowing opportunities with radiographers and medical imaging technicians in your local hospital to learn how biomedical imaging is used in clinical settings.

Explore careers in *biomedical imaging*

- Careers in biomedical imaging are wide-ranging and varied, spanning engineering developments, scientific advances and clinical applications.
- Biomedical engineers and medical physicists, who may work in industrial companies or research institutions, such as universities, develop new biomedical imaging technologies and methods, while chemists develop new radiotracers for PET scanning.
- In hospitals, biomedical imaging devices are operated by radiographers or technologists and maintained by medical technicians and hospital physicists. Doctors, who may specialise in radiology or nuclear medicine, interpret the scans and use them to diagnose and treat patients' conditions.
- Biomedical researchers use biomedical images to learn more about the human body.
- The National Institute of Biomedical Imaging and Bioengineering has a wealth of resources for students, including fun facts, competitions, games and advice for future scientists: **www.nibib.nih.gov/science-education**

Meet *Simon*

I was football crazy as a kid. I was always kicking a ball about, and I loved watching my local team, Sheffield United. I've also always enjoyed music, especially classical music. I started piano lessons when I was six and have continued on and off to this day. In my teens, I became interested in astronomy, so I got a telescope and joined a junior astronomical society.

My father was a biophysicist, and I would visit his labs during the holidays. This, combined with my love of astronomy and my great physics and chemistry teachers, gave me a love of science. I never really considered doing anything else for a career, except when I was ten, when I wanted to be a Formula 1 racing driver!

At university, I studied physics with astronomy. I wanted to continue with physics research for a PhD, but I didn't know which area I wanted to work in. I had never heard of medical physics, but when I discovered it involved the atomic and nuclear physics topics that interested me, combined with very direct practical applications in medical imaging and radiation therapy, I decided to focus on it. I was accepted to work on project studying PET imaging. At the time, I didn't have a clue what I was getting myself into, but it turned out to be a perfect fit for me.

A willingness to trust and collaborate with others is important for scientists, and I am proud of the interactive, collaborative research environment in biomedical imaging that we have created at the University of California Davis. My success has also stemmed from perseverance and an aptitude for bold, difficult challenges.

I love the fact that with PET imaging, we are using fundamental theories and discoveries of physics. Radioactive decay, antimatter and the conversion of positrons and electrons into photons based on Einstein's famous $E = mc^2$ equation sounds like science fiction, but we use this every day in hospitals to help patients.

Simon's *top tips*

1. Believe in your ideas, even when others do not.
2. Be kind and respectful to those you work with – you will be repaid many times over.
3. Always pay attention to work-life balance. Having interests and time away from research will make you a better researcher.

The EXPLORER total-body PET scanner

Meet *Ramsey*

I was interested in aircraft when I was younger, and I memorised the shapes and designs of many civil and military aeroplanes. As I grew older, I became fascinated by strategy games, and my friends and I developed various 'world conquest'-style board games. All very nerdy!

I always knew I wanted to be a scientist – strangely enough, from even before I really knew what it meant! In high school, I was good at physics and chemistry, and I had tremendous teachers in those subjects. I loved learning about the Voyager space probes, which sent remarkable images of the planets back to Earth. So, when I had the opportunity to study physics at university, it was a natural choice.

I worked in aerospace software engineering for a while, then got a job as a systems administrator at the Clinical PET Centre at St. Thomas' Hospital in London. This was the first clinical PET service in the UK. I barely knew what PET was at the time, but it caught my interest and before I knew it, I was doing a part-time PhD in PET imaging!

I have worked with some tremendous young scientists over the years and helping them develop their full potential as researchers has been enormously rewarding. That's a gift that will keep on giving and will hopefully outlast me and the various projects I have been lucky enough to participate in.

Science is too broad for one person to master. If you want to make an impact, you need to collaborate, so the ability to work with and get on with other people is really important.

I love the way that PET allows you to see fundamental processes of biology, like the metabolism of sugar, happening right before your eyes in the living body. It's an astonishing trick!

Ramsey's *top tips*

1. Believe in your dreams. Listen to the nay-sayers (you might learn something), but don't let them stop you pursuing your ideas.
2. Have a 'back-up' plan. While Simon and I spent 10 years persuading people to fund EXPLORER, I was also working on other projects to pay the bills and keep the lights on in the lab.
3. Always stay in touch with your inner child that jumps up and down with excitement at your latest scientific idea!

Harnessing the power of music to improve mental health

Engaging with music has proven positive impacts on mental health and well-being, yet musical interventions are rarely used in healthcare settings. **Professor Gilles Comeau**, from the **University of Ottawa** in Canada, hopes to change this. He has established the **Music and Mental Health Research Clinic** to explore the relationships between music and mental health and to develop ways of integrating music into healthcare services.

Professor Gilles Comeau

Director of the Music and Health Research Institute, University of Ottawa, Canada

Director of the Music and Mental Health Research Clinic, University of Ottawa Institute of Mental Health Research, The Royal, Canada

Fields of research
Music, mental health, wellness, well-being

Research project
Investigating the effects of music participation on mental health and well-being, and how to integrate musicians and music educators into healthcare settings

Funders
Public Health Agency of Canada, Social Sciences and Humanities Research Council (SSHRC), Brain and Mind Research Institute, Canadian Foundation for Innovation, Private Donors

PROFILE

Talk like a ...

music researcher

Cognitive — the processes related to conscious intellectual activity, such as thinking and remembering

Dalcroze Eurythmics — a method of music education based on the connection between music and body movement, developed by Émile Jaques-Dalcroze in Switzerland in the early 1900s

Dementia — an umbrella term referring to a range of progressive conditions with symptoms including memory loss, confusion and impaired cognitive ability

Electroencephalography (EEG) — the measurement of electrical activity in parts of the brain

Hormone — a chemical that regulates the body's functions

Motor control — the ability to control your own movements

Physiological marker — a biological state that can be measured to evaluate the body's function or response to an intervention, e.g., heart rate

Have you ever felt happier after listening to music, playing an instrument, singing a song or dancing along to your favourite tunes? Interacting with music can have significant benefits for both your physical and mental health, meaning music can play an important role in your well-being. "Participating in musical activities can help cognitive function, reduce the risk of developing mental illnesses and reduce the severity of existing mental health conditions," says Professor Gilles Comeau, Director of the University of Ottawa's Music and Health Research Institute and of the Music and Mental Health Research Clinic at The Royal, a specialised mental healthcare centre. Gilles is convinced of the power of music for improving health and well-being. His mission is to make healthcare-related music participation accessible to all who will most benefit from it.

The benefits of music

"Music is particularly powerful because it is a complex, but accessible, activity," explains Gilles. "Music is complex because it involves multiple senses. For instance, sound, vision and touch are integrated together when playing an instrument." The benefits of music are spread across the spectrum of physical and mental health. For example, engaging with music triggers the release of dopamine, the 'feel-good' hormone that elicits feelings of pleasure and reward. "Music is also a powerful tool for promoting cognitive well-being," Gilles adds. "Introducing new skills and new knowledge ignites curiosity and cognitive growth, which can be especially valuable for older adults." Collective music-making can be a form of social cohesion. It has the power to connect people, which helps to combat social isolation. However, many individuals who could most benefit from such music-making activities are commonly excluded from mainstream music participation. "People with mental health issues, physical limitations or cognitive impairments often experience an unwelcome reception when trying to involve themselves in musical activities, even if their impairments do not hinder their ability to participate in collective music-making," says Gilles. "Bringing music to these vulnerable populations can help overcome feelings of exclusion and isolation." This is not just about improving the well-being of individuals; it is also supporting a fundamental human right. "The Human Rights Act emphasises the need to provide equal opportunities for engagement in

Gilles is exploring whether Dalcroze Eurythmics, in which participants move to music, improves mental health © Steven West Photography

the arts," says Gilles. "That means all people, including marginalised populations, should have the chance to foster their artistic aspirations and take advantage of the health benefits of music participation."

The Music and Health Research Institute

The Music and Health Research Institute aims to increase the body of research into the links between music and both physical and mental health, and to provide ways to implement these research findings. "We explore interactions between music and health with the aim of developing solutions to improve well-being for individuals and communities," explains Gilles. "Our vision is to increase our understanding about how best to integrate musicians and music educators into healthcare and social settings."

In practice, this takes a variety of forms. The institute develops music programmes for vulnerable populations and individuals with certain mental health conditions, ranging from mood disorders to substance dependencies to dementia. "We also provide best-practice guidelines and strategies for training musicians and music educators, so they can bring their skills and knowledge to healthcare settings," says Gilles. "On the healthcare side, we raise awareness among health and social care professionals about the benefits of community-based musical activities."

Gilles' own research focuses on how music can benefit older adults and combat age-related health conditions. "Playing music can help combat conditions including dementia, depression, anxiety and signs of physical decline such as frailty, loss of balance and poor posture," says Gilles. "Moreover, collective music-making combats social isolation and loneliness, which are often serious issues among older people."

Moving to music

Research has demonstrated that music participation involving movement is especially impactful for improving physical and mental health. "We are using a method of interactive music education called Dalcroze Eurythmics, which focuses on body movements to music," says Gilles. "A typical class involves participants moving to music, using a mix of improvised movements alternating with structured, choreographed rhythmic sequences, and sometimes featuring props such as balls or hoops." Dalcroze Eurythmics has promising health benefits for many different populations, including children, adults with post-traumatic stress disorder (PTSD) and older adults with cognitive impairments. "Musical activities that involve movement also build strength and motor control," says Gilles. "The dual tasks of listening to music and translating what is heard into movement have benefits to physical and cognitive health."

> **"All people, including marginalised populations, should have the chance to foster their artistic aspirations and take advantage of the health benefits of music participation."**

Gilles emphasises that programmes such as Dalcroze Eurythmics are not necessarily a one-size-fits-all solution, and that research is needed to show what works best for different people. "It is important to test each programme multiple times with different people experiencing various mental health conditions to establish its full benefit – what works, for whom and in what context," he says. At the Music and Mental Health Research Clinic, the team is now developing additional interactive music-making programmes, including percussion ensembles and drumming improvisation workshops.

Exploring the science behind music for mental health

It is important to provide evidence that musical intervention programmes, such as Dalcroze Eurythmics or percussion ensembles, are actively benefiting their participants. "Research into music and mental health requires expertise from many fields," says Gilles. "This is why the Music and Mental Health Research Clinic has established partnerships with a wide range of researchers across Canada and beyond."

For instance, some researchers are measuring physiological markers to quantitatively assess individuals' well-being before, during and after participation in musical activities. "Physiological markers of anxiety include breathing rate, heart rate, sleeping patterns and levels of the stress hormone, cortisol," says Gilles. Other techniques measure participants' physical capabilities, for example by conducting tasks to assess motor control or using thermal imaging to measure muscle inflammation. Cognitive tests, such as puzzles, and electroencephalography (EEG) can measure participants' mental performance. "We also use qualitative measurements, including questionnaires to ask participants about their moods, such as feelings of depression and anxiety, and their overall sense of mental well-being," explains Gilles. "In combination with interviews and focus groups, we can gain an understanding of how our programmes benefit participants' mental health."

Through these research efforts, Gilles hopes that the benefits of music will become available to everyone to improve health and well-being.

About *music for mental health*

Studying the interactions between music and mental health calls for collaboration across different academic disciplines, along with practitioners from the health and social care sectors. The work of the Music and Health Research Institute and the Music and Mental Health Research Clinic presents useful case studies of how a diverse range of careers can work together to address a common theme.

"For our work, we assembled a multi-disciplinary team of researchers, practitioners and community organisations to pursue action-based original research," says Gilles. "On the research side, our team brings together music educators, biomechanists (who study the mechanics involved in the movement of living organisms), kinesiologists (who study human movement), psychologists, neuroscientists, computer engineers with experience in the medical field, physicians specialised in geriatrics (the branch of medicine focused on the health and care of older people), and psychiatrists specialising in particular mental illnesses."

Beyond the academic research world, Gilles' team includes health workers, clinical practitioners, social workers and community workers. "We also work with the people who can benefit from our research," says Gilles. "This includes people with disabilities, people experiencing mental illnesses, older people, patients in care, and their families and support groups."

The fact that this research brings together such diverse fields indicates the vast range of career opportunities related to music and mental health. "For instance, those interested in neuroscience or psychology can study how the brain processes music under various health conditions," says Gilles. "Those interested in music and education can develop innovative teaching and learning practices, while those interested in healthcare and rehabilitation can study how music improves health outcomes."

Pathway from school to *music for mental health*

- "It is important to note that you do not have to choose between studying music and science," says Gilles. "Many students think that they must make a decision to study one or the other, but if you are interested in music and science there are a number of university programmes that now allow you to combine both."
- Gilles emphasises that the broad range of careers available in the field of music for mental health means you can pursue whichever subjects most interest you (e.g., psychology, rehabilitation, biomedical engineering, etc.) and integrate these with music, allowing you to tailor your study programme to lead to your desired career.
- Studying social sciences, health sciences, biology, medicine or engineering, as well as music itself, could lead to a career using music to improve people's mental health and well-being.

Explore careers in *music for mental health*

- As Gilles highlights, a huge range of people are involved in his research investigating the impacts of music on mental health, meaning there is a wealth of career opportunities available in the field.
- The Music and Health Research Institute offers a variety of ways to get involved, such as training and mentoring opportunities for undergraduate students and a programme of events throughout the year: **www.uottawa.ca/research-innovation/music-health/training-mentoring**
- Music therapists combine healthcare and musical expertise to provide therapeutic support for individuals: **www.careerexplorer.com/careers/music-therapist**


© University of Ottawa

Meet *Gilles*

I have always had a passion for music and teaching. I am fascinated by how people learn and how teachers develop teaching strategies, and I have played music from a young age. I started teaching piano lessons when I was in my late teens. Then, while I was at university, I established a community music school for preschool children and a summer music programme for children of all ages. After graduating, I organised a programme to train music teachers.

My career has been driven by my strong desire to always learn new things and to develop initiatives with real impact. When I was hired at the University of Ottawa, there was no research into piano pedagogy (the theory and practice of teaching) and most piano teaching was based on traditional methods along with trial and error. This led me to establish the Piano Pedagogy Research Laboratory, a long and fruitful partnership with colleagues from across scientific disciplines.

When I became aware of the physical and mental health problems that many musicians experience, which often begin at a young age, I established the Musicians' Wellness Centre to educate, conduct research and provide treatment related to musicians' wellness.

Recently, I have become interested in the health benefits of music-making. I began to research how musicians and music educators can be integrated into healthcare settings so that music can be used to provide health benefits. I have a fundamental belief that music can make a unique and positive contribution to the well-being of individuals and communities.

We are seeing a move towards a more holistic approach to health. This is leading researchers and healthcare practitioners to investigate alternative approaches to aiding well-being. One such therapy, which is in increasing demand, is music-making.

Interestingly, sport is widely recognised as an important platform for inclusion and well-being for people with impairments. Sport has played a key role in advancing equity, through programmes such as the Paralympic Games. However, nothing similar exists for music, despite music being arguably just as universal and as important for health and well-being. I hope to see music-making positioned in a similar way.

I have a sincere hope that young people can help bring about an increase in music accessibility. Equity, diversity and inclusivity should be the new face of music-making. These increase the potential for rich and meaningful interactions and contributions to self-expression, as well as connections to self, others and the community. I hope that the next generation will work to make it possible for all people to have equal opportunities to foster their musical aspirations.

Are there 'rules' for conveying emotion through art?

While art and science are often separated in academia, there is a lot to be learnt by considering them together. **Dr Dirk Bernhardt-Walther** and **Dr Claudia Damiano**, at the **University of Toronto** in Canada, and **Dr Pinaki Gayen**, at **Visva Bharati University** in India, are combining their expertise in cognitive neuroscience and visual art to investigate patterns in how abstract art conveys specific emotions.

Dr Dirk Bernhardt-Walther

Associate Professor, Department of Psychology, University of Toronto, Canada

Fields of research
Perception, cognition, cognitive neuroscience, visual aesthetics

Dr Claudia Damiano

Research Associate, Department of Psychology, University of Toronto, Canada

Previously: Postdoctoral Researcher, GestaltReVision Lab, KU Leuven, Belgium

Fields of research
Visual cognition, perception, visual aesthetics

Dr Pinaki Gayen

Assistant Professor, Department of Design, Visva Bharati University, India

Field of research
Visual aesthetics

Talk like a ...

visual cognition researcher

Abstract art — a loosely-defined field of art that does not attempt to represent physical reality, but rather aims to convey emotions and effects through shapes, colours and other properties

Angularity — the degree to which something has sharp points or corners

Cognitive — relating to conscious brain activity, such as thinking or remembering

Contour — lines that typically form an outline of a shape

Neuroscience — the study of the structure and function of the brain and nervous system

Orientation — the position and direction of something (e.g., a line)

Quantify — to measure the number or amount of something

To what extent can art be used to communicate specific emotions? While we all know that art evokes emotion, it is less well-understood whether there are themes and patterns in this effect. For instance, do certain colours or symbols always lead to a certain emotion in the viewer? Or are their effects unpredictable?

To investigate these questions, a team of researchers from across the world combined their skills and expertise to perform some intriguing experiments.

"We explored how people use associations with colours and line properties to communicate emotions," says Dr Dirk Bernhardt-Walther, Associate Professor at the University of Toronto's Department of Psychology. "In particular, we sought to measure which visual features are associated with each emotion."

Culture and biology

"For thousands of years, art has been used to communicate the experiences and emotions of daily life," says Dr Claudia Damiano, previously a Postdoctoral

Research project
Using cognitive experiments to test how art and artists evoke specific emotions through lines and colour

Funders
Shastri Indo-Canadian Institute (SICI), Natural Sciences and Engineering Research Council of Canada (NSERC), Social Sciences and Humanities Research Council of Canada (SSHRC), Flemish Government

PROFILES

Researcher at GestaltReVision Lab, KU Leuven, in Belgium, and now Research Associate at Toronto's Department of Psychology. "Through intuition and practice, artists know how to visually evoke certain emotions through their work."

These associations between emotions and visual cues are probably partly cultural and partly biological in origin. "Some associations between colours, lines and emotions are grounded in the real world – such as a person's face turning red when angry," says Dr Pinaki Gayen, Assistant Professor of the Department of Design at Visva Bharati University in India. "Others, however, are cultural. For example, a 'blue' person is sad in English, but drunk in German!"

The experiment

The team recruited 46 arts students from the Ontario College of Art and Design University and 45 STEM students from the University of Toronto to take part in the experiment. The students were asked to draw six emotions in abstract form: anger, disgust, fear, joy, sadness and wonder. "First, participants used only drawing pencils, to emphasise line properties; then, they used pastel crayons to emphasise the effects of colour," says Claudia.

All drawings were scanned, and the distribution of colours was analysed via counting the number of pixels with a particular range of hues. "For the line drawings, we traced the contours with custom-made computer vision algorithms," says Dirk. "We then measured the lengths of contours, their angularity, and the distribution of orientations." These methods are a systematic way of quantifying something that might seem unquantifiable.

> **"For thousands of years, art has been used to communicate the experiences and emotions of daily life."**

Guessing games

The next step involved seeing whether a computer could accurately predict the intended emotion from the drawings. "For each drawing, the computer compared it to a set of 'reference' drawings that was created by averaging all other drawings in each emotion category," says Claudia. "We wanted to see whether there were enough consistent features in each category for the computer to be able to accurately categorise any one image." The computer was instructed to make its guesses based on the properties the researchers had measured. For line drawings, the computer was able to correctly guess the emotion depicted in 25% of cases. When it came to colour drawings, 51% of predictions were correct for drawings by STEM students, but only 39% for drawings by arts students. If the computer had only guessed randomly, it would have had an accuracy of 17%.

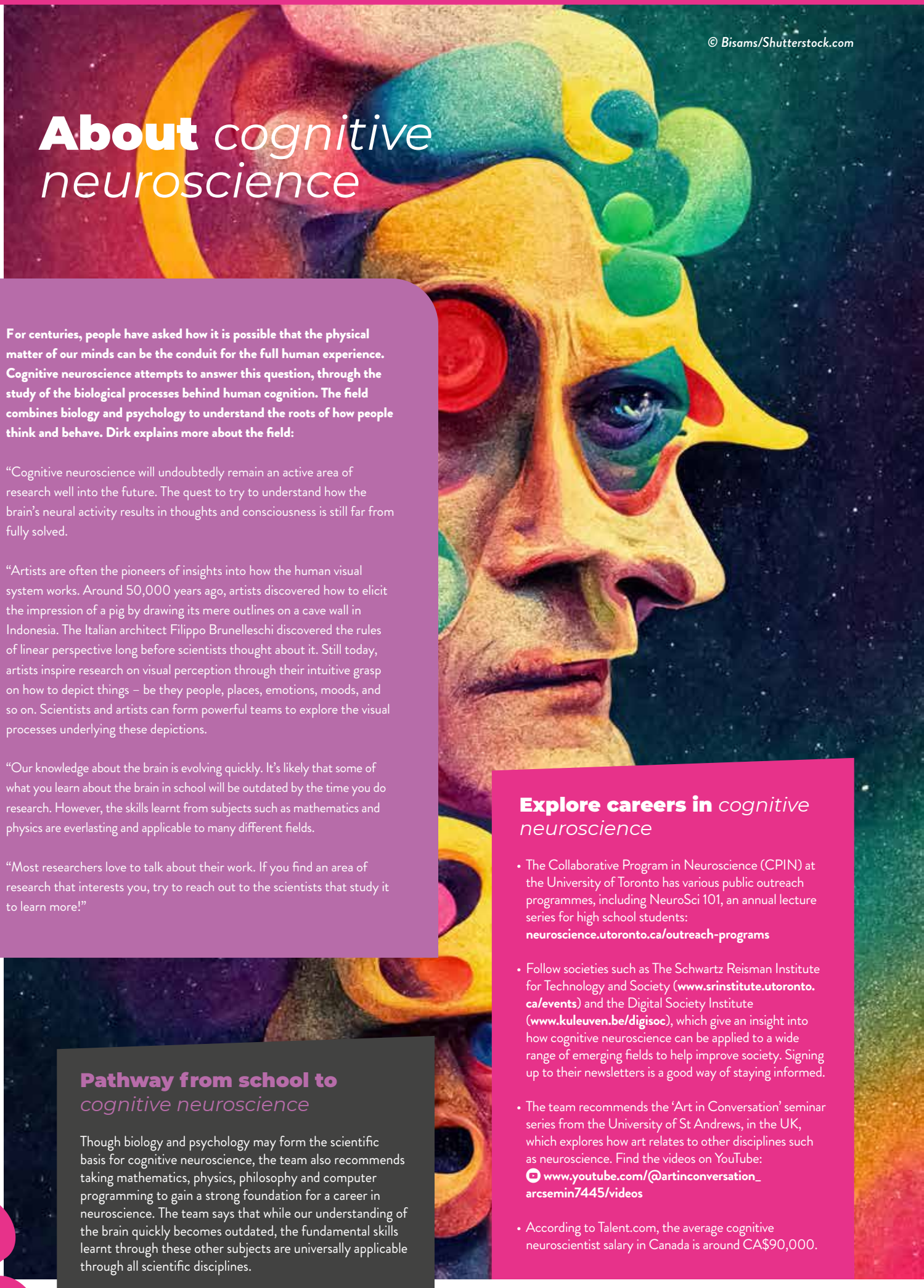
The team then got people involved, recruiting 244 psychology students in Belgium to guess the emotions from the drawings. "The results were similar to the computational analysis," says Dirk. "Emotions guessed from line drawings had a 32% accuracy, colour drawings by STEM students a 43% accuracy, and colour drawings by arts students a 40% accuracy." In both cases, guessers were more accurate for drawings by STEM students. "Our best guess is that artists tend to aim to break cultural conventions, while non-artists adhere to them more consistently," says Claudia.

Interestingly, people and the computer made similar mistakes, such as mixing up joy and wonder. "This suggests that people use the same features as the algorithm," says Pinaki. "Therefore, people do use colours and line properties to make inferences about emotions from abstract artworks."

From abstract to reality

While the effects of art are difficult to measure, it is undoubtedly a core part of the human experience. "This research can help us uncover the emotional language of abstract art, which could lead to exciting collaborations and practical applications," says Dirk. "For instance, it could aid communication efforts by utilising colours and shapes to evoke specific emotions, such as yellow to express joy, or red to inspire action against injustice."

Other potential uses include for cinematographers and make-up artists to enhance the conveyance of emotions on screen and stage, or for interior designers and architects to create environments designed to evoke a specific emotion. "This could involve creating calming spaces in airports, fostering wonder in educational settings, or promoting joy in retirement communities," suggests Pinaki.



© Bisams/Shutterstock.com

About *cognitive neuroscience*

For centuries, people have asked how it is possible that the physical matter of our minds can be the conduit for the full human experience. Cognitive neuroscience attempts to answer this question, through the study of the biological processes behind human cognition. The field combines biology and psychology to understand the roots of how people think and behave. Dirk explains more about the field:

"Cognitive neuroscience will undoubtedly remain an active area of research well into the future. The quest to try to understand how the brain's neural activity results in thoughts and consciousness is still far from fully solved.

"Artists are often the pioneers of insights into how the human visual system works. Around 50,000 years ago, artists discovered how to elicit the impression of a pig by drawing its mere outlines on a cave wall in Indonesia. The Italian architect Filippo Brunelleschi discovered the rules of linear perspective long before scientists thought about it. Still today, artists inspire research on visual perception through their intuitive grasp on how to depict things – be they people, places, emotions, moods, and so on. Scientists and artists can form powerful teams to explore the visual processes underlying these depictions.

"Our knowledge about the brain is evolving quickly. It's likely that some of what you learn about the brain in school will be outdated by the time you do research. However, the skills learnt from subjects such as mathematics and physics are everlasting and applicable to many different fields.

"Most researchers love to talk about their work. If you find an area of research that interests you, try to reach out to the scientists that study it to learn more!"

Pathway from school to *cognitive neuroscience*

Though biology and psychology may form the scientific basis for cognitive neuroscience, the team also recommends taking mathematics, physics, philosophy and computer programming to gain a strong foundation for a career in neuroscience. The team says that while our understanding of the brain quickly becomes outdated, the fundamental skills learnt through these other subjects are universally applicable through all scientific disciplines.

Explore careers in *cognitive neuroscience*

- The Collaborative Program in Neuroscience (CPIN) at the University of Toronto has various public outreach programmes, including NeuroSci 101, an annual lecture series for high school students: **neuroscience.utoronto.ca/outreach-programs**
- Follow societies such as The Schwartz Reisman Institute for Technology and Society (**www.srinstitute.utoronto.ca/events**) and the Digital Society Institute (**www.kuleuven.be/digisoc**), which give an insight into how cognitive neuroscience can be applied to a wide range of emerging fields to help improve society. Signing up to their newsletters is a good way of staying informed.
- The team recommends the 'Art in Conversation' seminar series from the University of St Andrews, in the UK, which explores how art relates to other disciplines such as neuroscience. Find the videos on YouTube: **www.youtube.com/@artinconversation_arcsemin7445/videos**
- According to Talent.com, the average cognitive neuroscientist salary in Canada is around CA$90,000.

Meet *Dirk*

When I started out, the field of neuroscience did not exist as it does today. I was fascinated by the physical processes that underlie information processing, so studied physics and computer science initially. For my PhD, I switched to information processing in biological systems, and have been fascinated by how the brain interprets sensory information ever since.

My PhD in computational and neural systems was a formational time. I experienced collaborations between biology, engineering and social sciences with a playful attitude. This interdisciplinary spirit and playfulness still shape my approach to research to this day.

A single-minded approach to work has never worked for me. I thrive by having fun side projects, sometimes against my advisors' advice. For instance, I have collaborated with people from a huge range of disciplines to develop algorithms for detecting animals in underwater videos, exploring how crooked teeth change the perception of faces, and monitoring moisture transport in laminated wood. This cross-disciplinary work often yields unexpected benefits, sometimes years later.

It is very gratifying to inspire young, budding minds. I have been proud to see four PhD students graduate and succeed with my support and guidance to help them become scientists in their own right.

I want to tackle seemingly fuzzy problems with rigorous science. When we struggle to clearly define a concept, we cannot understand its causes and mechanisms. This includes topics such as attention, the perception of complex real-world scenes, and the concept of beauty. Undertaking the intellectual work to study these is appealing to me.

Dirk's *top tip*

Take all the mathematics classes you can! Maths helps me in my work all the time, even if it doesn't take the limelight. Maths trains your brain to think clearly and methodically.

Meet *Claudia*

As a child, I was fascinated by human behaviour. I wanted to understand why people do what they do, say what they say, think what they think. That inspired me to pursue a career in psychology.

Collaborations with other researchers have shaped my career. Being able to discuss philosophical and scientific questions with brilliant and kind people is such a privilege. Learning that everyone experiences self-doubt about their research, career path and life decisions was also an epiphany for me.

When I started my PhD, I had a false impression that the journey had to be difficult to be meaningful. The idea was that it had to entail long hours and sleepless nights to be truly 'earned'. In reality, conducting research is a job like any other – it's a part of your life, not your whole life.

My proudest career achievement has been obtaining a Marie Skłodowska-Curie Postdoctoral Fellowship from the European Commission. In the future, I hope to continue doing research in psychology and cognitive science, and hopefully run my own lab one day.

Claudia's *top tip*

Explore different topics until you find one that truly interests you! The rest – taking relevant classes, gaining research experience, applying to PhD programmes – will come naturally if driven by interest.

Meet *Pinaki*

In my early years, I used to watch my brother draw animals, people and landscapes. Sometimes, I would visit my artist neighbours, one of whom demonstrated to me how to paint with watercolour. That experience impacted my thinking profoundly. I kept thinking about how he had painted, and I dreamt again and again of being able to do the same.

At school, an art teacher taught me the basics of drawing and painting. I learnt about the great painters of the world – Picasso, van Gogh, Michelangelo, da Vinci, and many others. I started experimenting with my drawings and paintings to develop my own styles.

When I told my family of my intentions to enter art college, one relative suggested I should go for history or geography instead. Fortunately, I did not listen to him, and, later on, he understood that he was wrong!

I've been fortunate that many of my dreams to see landmark pieces of art have become reality. In recent years, I have visited the Louvre in France and seen Picasso's Guernica in Spain.

I want to be one of the greatest artists of all time. This has always been my ambition, and I continue to work towards it.

Pinaki's *top tip*

Dream big. Don't compromise or limit the size of your dreams. The great artist Michelangelo said, "The greatest danger for most of us is not that our aim is too high and we miss it, but that it is too low and we reach it."

How do prison leavers find employment?

There are currently more than 80,000 people in prison in England and Wales, and many with valuable skills, but what are their options when they leave? CEO **Duncan O'Leary** explains how **New Futures Network**, a specialist employment team in His Majesty's Prison and Probation Service (HMPPS), is connecting companies with prison leavers to help them create a new future for themselves.

What was the inspiration behind New Futures Network?

If you have a job after you leave prison, you're much more likely to thrive in the community. A job provides you with all sorts of benefits, with income being the most obvious one, but also structure in your daily life, self-esteem and a sense of purpose. It can help repair relationships with families, too.

Research had indicated that some employers were reluctant to offer opportunities to people who had a criminal record or been to prison. Whilst there was a prison service team talking to employers about bringing employment into prisons, to help them do something purposeful with their time, there wasn't a service to encourage employers to offer jobs to people after their release.

When was New Futures Network set up?

In 2018, the UK Ministry of Justice published an education and employment strategy document aimed at getting more people into employment after their release from prison, and our team was brought in following that publication. New Futures Network was set up over the subsequent two years, during the pandemic, to cover England and Wales. The pandemic was a challenge, but, happily, we're now on the other side.

What does New Futures Network do?

We have three initiatives. The first supports employers to provide work in prisons. Examples include furniture-making or industrial fabrication. We even have call centres operating in some prisons for incoming calls because outgoing calls aren't permitted.

ID & Banking Programme information booklets available in the Employment Hubs © Ministry of Justice Campaigns

The second initiative supports the employment of people who are in open prisons, which means they're eligible to work in the community on day release and be paid. This is a really good way for people to accumulate a track record of work, build positive working relationships with an employer, and save money for a deposit for a flat, for example.

The third initiative involves finding employers who are interested in recruiting people who are leaving prison.

What other support does New Futures Network provide to prison leavers?

When people leave prison, they must have a bank account and a form of identification such as a birth certificate. It's illegal for employers to employ anyone without this documentation. We work with seven banks and help people apply for a bank account before they leave prison. We also help people get replacement birth certificates, driving licenses and other forms of ID.

We've also set up the equivalent of job centres in almost every prison, which we call employment hubs. A specialist member of staff at the hub serves as a point of contact between people in prison, employers and charities.

How do you support people leaving prison with soft skills such as customer service and team-work?

Good soft skills are the first thing employers look for. It's fine to be able to make a great cup of coffee if you work in a cafe, for example, but can you work in a team and provide great customer service even when someone is being rude to you? Many people in prison will have had their confidence knocked, and there may be elements of shame, which can be challenging for them to deal with.

Part of the work we do involves bringing employers into prisons to give talks, explain the opportunities they offer and highlight the value they see in prospective employees. We also invite speakers in who have left prison, found a job and are doing well. When people in prison see others who have been in their position succeeding, it shows them that they can do the same.

What are the benefits of hiring prison leavers for employers?

Many employers recognise that lots of people in prison will have valuable skills that were gained before or during their time in prison. And if someone can give a prison leaver a second chance, they will show a great deal of commitment in the job.

The hospitality and construction sectors are typically the biggest emplyers of prison leavers.

Employers may also be socially motivated, in that it not only works for their business, but they also want to demonstrate to their customers that they're contributing to society, as well.

Which sectors are the biggest employers of prison leavers?

The construction and hospitality sectors are typically the two biggest employers, but the logistics sector is also growing. For example, a driving job works well for people on day release. Other sectors include retail and the civil service.

Who are some of the pioneering organisations?

The Timpson Group, a British and Irish service retailer, has recruited hundreds of prison leavers over the years, and its chief executive James Timpson is a well-known advocate for this. Other organisations that have been doing this for a long time include Greggs (a bakery chain), Cook (a frozen food retailer), Iceland (a supermarket chain), Halfords (a motoring and cycling retailer), DHL (a logistics and courier company), and Kier (a construction services company). Greene King, the pub retailer and brewer, is new to this but doing fantastically well.

Are there similar programmes in other countries?

I haven't come across anything similar. We've had various prison services from around the would show interest. For example, a member of my team was invited to present in Canada, so I think we're achieving something that not many others are doing.

What are the programme's successes to date?

The proportion of people who were in prison and are now in employment has gone up quite dramatically. Just over two years ago, around 14% of people were employed six months after their release. We're now up to around 30%. It's important to say that this is not all down to us; staff in prisons, charities and other organisations in the sector are all part of this work, too.

What's your vision for New Futures Network?

With low unemployment levels, companies are becoming more creative about where to look for new employees. There are an increasing number of companies offering opportunities to people leaving prison and many of these companies are at the start their journey.

I'd like to see this becoming a normal part of companies' recruitment drive so that employing people who have left prison is no longer unique or unusual. Even if unemployment rates change, I'd like to see organisations continue doing this because it has worked well for them and it's something their company values. That's the real goal.

> ***"Many employers recognise that lots of people in prison will have valuable skills that were gained before or during their time in prison. And if someone can give them a second chance, they will show a great deal of commitment in the job."***

The logistics and courier company DHL is among some of the well-known UK employers employing prison leavers. © Gorodenkoff/Shutterstock.com

Driving jobs work well for people on day release from prison.
© DuxX/Shutterstock.com

> ***With low unemployment levels, companies have become more creative about where to look for new employees. There are an increasing number of companies offering opportunities to people leaving prison and many of these companies are at the start their journey.***

© PHOTOCREO Michal Bednarek/Shutterstock.com

Meet Duncan

I studied history at university, which has provided me with lots of skills that I've ended up using as a civil servant. When you're a civil servant, you report to ministers who then report to Parliament. We write a lot of briefings that either explain what we're doing or advise ministers on key matters. My background in history helps me bring lots of different information together, set it out in a logical format and write it in a clear way.

I've had various jobs in public policy since leaving university. I've worked for a political think tank, a member of Parliament, and for the Government's Home Office, as well.

> ***The best advice someone gave me is that, when you're in a job, there will be things that you're more interested in doing than others, and it's within your control to move closer to what interests you.***

Employment Hub at HMP Wormwood Scrubs
© Ministry of Justice Campaigns

I was part of the policy team that worked on the 2018 education and employment strategy for people leaving prison. I then followed it into the prison and probation service and, ever since, I've been heading the New Futures Network team. It's perhaps the most satisfying job I've done so far because it's very closely connected to people's lives.

I was always interested in politics growing up. I wanted to do a job where I could make a difference, and working in policy and operations is one way of doing that.

I'd advise people to experience as many different things as they can. Try to involve yourself in different types of workplaces and sectors but also think about your interests. You'll have a far more successful career if you can put your whole self into your work, rather than counting the hours until you go home each day.

The best advice someone gave me is that, when you're in a job, there will be things that you're more interested in doing than others, and it's within your control to move closer to what interests you. For example, you can talk to your employer and work on things that are outside your job description. My jobs have always evolved and often towards things I'm really interested in.

Another piece of advice is not to undersell yourself too much! As a manager, I've noticed that men are often more confident about putting themselves forward for roles than women. Somebody once said to me that every promotion is slightly outside your comfort zone because you won't have done the job yet. I've noticed that some women want to reassure themselves that they can do the job and so wait a few years when, realistically, they were always just as capable as the men who applied straight away. So don't be afraid to put yourself forward for something you haven't done before – that's why it's a promotion!

Find out more

- **@new-futures-network**
- **@NewFutrsNet**
- **newfuturesnetwork.gov.uk**

Flying high with careers in aviation

When it comes to careers in aviation, the sky is the limit! Five professionals at **Cranfield University's Centre for Air Transport Management** and the **National Flying Laboratory Centre** in the UK explain the breadth of possible careers in the aviation industry and discuss how the industry is adapting to modern challenges.

PROFILE

The Centre for Air Transport Management and the National Flying Laboratory Centre, Cranfield University, UK

www.cranfield.ac.uk/centres/centre-for-air-transport-management

www.cranfield.ac.uk/centres/national-flying-laboratory-centre

Talk like a ...

member of the aviation industry

Aerodynamics — the study of interactions between air and solid bodies moving through it

Aviation — the flying or operating of aircraft

Carbon offsetting — compensating for carbon dioxide emissions by funding schemes that reduce atmospheric carbon dioxide

Composite material — a material made by combining several materials with different properties

Flight dynamics — the study of an aircraft's performance and stability during flight

G-force — the force felt during acceleration

Glider — an aircraft that does not have an engine

Lift and drag — forces that act on an aircraft as it flies. Lift is the upwards force generated as air flows over a wing, while drag is the force that opposes the aircraft

Stall — when lift is reduced so an aircraft no longer experiences the upward force needed to keep it airborne

Zero-emissions fuels — fuels that do not produce carbon dioxide

From the well-known roles of pilots, cabin crew and engineers, to lesser-known occupations in safety, compliance and air transport management, careers in the vast field of aviation are diverse, interesting and exciting. Careers in aviation require rigorous professionalism, as many roles impact people's safety, as well as a curious mind, as the field is constantly evolving to address modern-day challenges. Members of the Centre for Air Transport Management and the National Flying Laboratory Centre (NFLC) at Cranfield University are keen to share their insights into the joys of these wide-ranging career opportunities. As Rob Harrison, Head of the NFLC, says, "Aviation remains one of the most exciting career options out there for young people!"

Flying high

Over the course of his career as a pilot, Rob has flown military jets on the front line of warzones, transported goods and passengers around Europe in commercial planes, and educated students about the intricacies of flight in the NFLC's aircraft. "A career as a pilot offers huge variety," he says. With good salaries, options for career progression and great opportunities to travel the world, being a pilot can be an illustrious career.

As well as having a deep understanding of the technical complexities of the aircraft they are flying, a pilot needs to understand weather systems, as environmental conditions can have a significant impact on the ability of a plane to fly safely and comfortably. Pilots also need to be quick thinking, analytical and calm. Being able to constantly assess situations, and respond accordingly, is essential. "Having a Plan B is crucial when you're a pilot," says Rob. "If something goes wrong, you can't just stop and get out!"

Building planes

In 1903, Orville and Wilbur Wright flew a plane for a grand total of 12 seconds, covering a distance of less than 55 metres. While this achievement does not sound impressive today, when huge 'jumbo jets' fly hundreds of people thousands of kilometres around the world (at over 15,000 km, the world's longest non-stop flight is from New York to Singapore), the Wright brothers' accomplishment marks the most important milestone in the history of aviation – the day humans first took to the skies in a motor-powered aircraft.

Being a pilot is just one of the many exciting careers available in the aviation industry © Cranfield University

"I love to remember that the Wright brothers not only flew the first powered aircraft, but they also designed and built it from scratch, including components such as the propellers and engine," says Rob. "To test their designs, they even built their own wind tunnel!" Not only were the Wright brothers the world's first pilots, they were also some of the first aeronautical engineers.

Aeronautical engineers are responsible for designing, developing and testing all aspects of an aircraft, which, in modern planes, involves everything from the electronics in the navigation system to the turbines in the engines, plus the aircraft as a whole. Aeronautical engineers also design other flying devices, such as helicopters, uncrewed aerial vehicles (UAVs, also known as drones) and gliders.

Other fields of engineering also contribute to the technological advances in aviation. For example, Rob's colleague, Dr Simon Place, is a mechanical engineer with a background in flight dynamics who specialises in air transport engineering, aircraft systems and aviation safety. With an engineering career in aviation, you could find yourself studying the aerodynamics of aircraft wings using wind tunnel experiments and computer simulations or testing new composite materials to build more efficient aircraft.

Working together in the air and on the ground

While visible roles at airports and on aircraft include check-in agents, baggage handlers, pilots and cabin crew, the aviation industry is supported by a huge diversity of behind-the-scenes workers. From air traffic controllers (who schedule when planes can take off and land) to technicians (who maintain the aircraft) to fleet managers (who oversee the operations of an airline's entire fleet of aircraft), it takes many different people to keep airports, airlines and aircraft operating smoothly, safely and efficiently. "The aviation industry succeeds because it has amazing people who, working together in a complex and safety-critical environment, each play an essential part in making air transport possible," explains Professor Anna Smallwood, who has previously spent many years managing the aircraft fleets and airline operations for Thomson Airways and TUI Airlines and is now Head of Cranfield University's Centre for Air Transport Management. "A career in air transport can provide opportunities to experience different roles, creating a breadth of knowledge and understanding that helps further a career in management and executive leadership."

> **"The aviation industry succeeds because it has amazing people who, working together in a complex and safety-critical environment, each play an essential part in making air transport possible."**

Staying safe

The aviation industry has an enviable track record when it comes to safety. Your chance of being in a fatal plane crash is 1 in 11 million. In contrast, your chance of being in a fatal car crash is 1 in 5,000. Safety is a top priority in aviation and is taken very seriously. After all, carrying hundreds of people over 9 km above the Earth's surface in a metal contraption is no small endeavour.

Every part of the aviation industry includes roles specialising in safety to ensure that every aspect of flying is as risk-free as possible. Rhiannon Daye is the NFLC's Aviation Safety and Compliance Manager, a role that includes monitoring the safety of the NFLC's flights and keeping an eye on aviation incidents around the world. This involves investigating any issues around aircraft safety, finding out how and why aviation incidents occurred and proactively analysing data to identify potential hazards before they become a safety concern. "Once we have this information, we can take measures to reduce the likelihood of an incident happening," Rhiannon explains. "These measures can include training, communication, devising new procedures or even changing physical structures." In addition, Rhiannon runs the NFLC's compliance monitoring system to ensure the NFLC is always following aviation laws and staying up to date with regulations.

Protecting the planet

The aviation industry is infamous for its contribution to climate change. "If aviation was a country, its carbon dioxide emissions would be the same as those of Japan," says Dr Thomas Budd, who specialises in aviation sustainability. "The pressing need to reduce aviation's environmental impact is an important issue for the sector." As a result, virtually every role in the industry now includes aspects aimed at improving sustainability, as everyone working in the sector has a duty to contribute towards making aviation more environmentally friendly.

The number of careers specifically focused on aviation sustainability is also rising, with roles in airport and airline management, aircraft manufacture, industry and government regulatory bodies, and specialist consultancies. "For example, many airports now employ carbon strategy managers, who monitor carbon dioxide emissions from the airport and devise strategies to reduce these," says Thomas, "while airlines employ sustainability managers who address a range of environmental impacts, including carbon dioxide emissions, noise pollution and waste management."

In addition, the aviation industry needs people to

> **Because there is currently such a focus on aviation sustainability, it's a really exciting time to be thinking about a career in this sector!**

design and implement the technological advances that will reduce the sector's negative environmental impacts. "For example, in recent years, there has been a lot of interest in potential zero-emissions fuels, such as hydrogen, to power planes," says Thomas. However, adopting new 'clean' fuels will require a lot of changes in the aviation industry, including the design and operation of aircraft and the methods used to handle and refuel them at airports. "People working in this aspect of the industry will require new skills to develop these new technologies and ensure they are used efficiently and safely," says Thomas. "Because there is currently such a focus on aviation sustainability, it's a really exciting time to be thinking about a career in this sector!"

The future of aviation

Climate change presents a massive challenge for the aviation industry, but not an insurmountable one. It takes a lot of fuel to get planes airborne, hence the industry's large carbon footprint, and solving this issue requires new ideas and new technologies. Not only do aircraft and related infrastructure need to become more efficient, they also need to have their designs overhauled, and the public needs to accept these changes. As Rob explains, the industry is tackling this challenge head-on. "In the last ten years, we've seen the rapid development of fuel-efficient engines, sustainable aviation fuel and composite materials to increase the efficiency of aircraft design," he says. "In the next ten years, I foresee the development of viable electric and hydrogen powered aircraft."

Cranfield University, the Centre for Air Transport Management and the NFLC aim to be at the forefront of these advances. Researchers are working on technological and engineering developments, as well as studying the important but less tangible aspect of passenger perceptions and experiences of flight. The team is confident that the aviation industry has a bright future and encourage you to join them in it!

The team's top tips *for getting started on a career in aviation*

- "Join your local air cadet squadron, even if you're not interested in a military career," advises Rob. "You will be with other aviation-minded young people and have access to flying opportunities that do not exist elsewhere." In the UK, you can gain flight experience and pilot training as a Royal Air Force (RAF) Air Cadet (www.raf.mod.uk/aircadets).
- Stay up to date with developments in the aviation industry with websites such as Aviation Weekly (www.aviationweek.com) and Simple Flying (www.simpleflying.com).
- The International Air Transport Association (www.iata.org) and the Airports Council International (www.aci.aero) host free webinars and release interesting reports about different topics relating to air transport.
- "It's never too early to start growing your network," says Thomas. "Do some research to find people who work in the aviation industry, and don't be afraid to reach out to them and ask questions about their career. LinkedIn is a great place to do this."
- "Attend relevant careers fairs," advises Rhiannon, who found an internship through a fair organised by the Royal Aeronautical Society (www.aerosociety.com/careers-education).

Pathway from school to *aviation*

- "There is no pre-prescribed route to aviation," says Thomas. With such a wide range of careers in aviation, you can follow any path that suits your interests and direct it towards your desired career.
- "Focus on STEM subjects if you are interested in the more technical aspects of aviation," advises Rob. "Maths and physics are particularly useful if you hope to become a pilot or engineer."
- However, the skills and knowledge you gain from other subjects can also be applied to careers in aviation. For example, geography will teach you about weather systems, which is important for pilots, and foreign languages will open overseas travel opportunities for pilots and cabin crew. In psychology you will learn about human behaviour which will help you understand the human factors in aviation safety, and English will improve your communication skills.
- Your choice of university degree will depend on your target career. If you want to design and build aircraft, consider a degree in aeronautical, aerospace, mechanical or electrical engineering. A psychology degree could be useful if you want to work in aviation safety and compliance. Careers in air transport management would benefit from a degree in business or management.
- There is no set degree for becoming a pilot, but you will need to undertake theoretical training and clock up many hours of flying before you qualify for a pilot licence.
- Cranfield University (www.cranfield.ac.uk) is a postgraduate university that offers courses in a wide range of aviation-related topics, from airport planning and aerospace dynamics to aircraft engineering and aviation safety.
- If you want to learn on the job, without attending university, look for apprenticeships in the aviation industry with companies such as **Airbus**, **BAE Systems**, **Marshall Aerospace**, **Rolls-Royce**, **British Airways** and the **RAF**.

The National Flying Laboratory Centre's Flying Classroom allows students to study flight while experiencing it for themselves © Keith Wilson/SFB Photographic

About *the National Flying Laboratory Centre*

"Cranfield University is a unique place to study," says Thomas. "We are the only university in Europe to own and operate our own airport, aircraft and air traffic control." As such, Cranfield attracts students and staff from around the world, forming a vibrant community of people enthusiastic about everything related to aviation. The university is a globally recognised leader in the field of aviation and aerospace engineering, and it has strong collaborative links with the aviation industry, meaning students have access to a network of useful contacts and opportunities for future employment.

A classroom in the sky

The figurehead of the NFLC is its 'flying classroom', a modified aircraft that allows up to 24 students at a time to learn about flight while experiencing it for themselves. During a lesson in the flying classroom, students can access real-time flight data (including aircraft aerodynamics, engine performance and navigation) through tablet screens mounted on the back of each seat. "Students can observe and record performance data, while at the same time feeling and seeing the actual movement of the aircraft as it flies, making for a unique learning experience," says Rob, one of the flying classroom's pilots. "Lessons in the flying classroom allow students to experience the lift and drag characteristics of the aircraft, its stability during manoeuvres and the effectiveness of the controls. Sometimes, we demonstrate how the aircraft's stall prevention system works." Unlike in a flight simulator, the flying classroom operates in a real-world environment, exposing students to the real interactions of an aircraft.

After the flight, students return to a classroom on the ground to analyse the data and the results of any experiments. "We conduct flight experiments so students can carry out in-depth research projects," explains Simon, a demonstrator for the flying classroom. "The flight data are used for a host of different research topics, including alternative fuels and sustainable aviation."

Experiencing flight in action

In addition to the flying classroom, the NFLC has two light aircraft, each of which can accommodate one student plus a pilot. "These aerobatic aircraft provide students with a much more sensory experience of flight, rather than the data gathering exercises in the flying classroom," explains Rob. The light aircraft conduct specific flights to support the learning of students on different aviation-related courses at Cranfield. For example, students studying flight dynamics or aircraft design take a flight that focuses on aircraft stability and performance, while students studying space engineering have the opportunity to experience the effects of microgravity and increased g-forces, and students studying aviation safety fly in the light aircraft to understand the impacts of spatial disorientation during flight.

"Each flight lasts about an hour," explains Rob. "Before the flight, I carry out preflight aircraft checks, assess the weather conditions (we avoid flying through clouds as we want students to enjoy the view) and brief the student. During the flight, I demonstrate how the aircraft is controlled and how it performs in flight. If the weather (and the student's stomach) permit, I also perform some aerobatic manoeuvres. It is incredibly satisfying to see the smiles on students' faces when we land!"

© Graham Braithwaite

Meet *the team*

Rob Harrison

Head of the NFLC and pilot for the NFLC flying classroom and light aircraft

I flew a plane for the first time when I was 14 years old. I've always wanted to be a pilot, and I've always been fascinated with the idea of flight, so, aged 13, I joined the Royal Air Force (RAF) Air Cadets. I really enjoyed my time in the Cadets, and it allowed me to achieve my dream of becoming a fighter pilot.

I studied astrophysics at university and spent as much time as possible flying with the University Air Squadron. After graduation, I returned to the RAF. I flew the Tucano aircraft as a flight instructor and display pilot, then the Jaguar aircraft as a military pilot on the front line. Highlights of my time in the RAF include flying low-level aerobatics and completing incredibly complex operational missions. It was a privilege to be surrounded by colleagues who were so experienced and motivated.

After leaving the RAF, I gained my commercial pilot licence and worked as a business jet pilot for ten years. This allowed me to travel from the Arctic Circle to North Africa and from beaches to high up in the Alps. Sometimes, I'd visit five different countries in a single day.

Being a pilot gives me a sense of freedom that is difficult to replicate through anything else. The job is always a challenge, and there is a constant need to train and prepare. Every flight is different and there is always something to learn, so it's never boring.

As a pilot at the NFLC, I love seeing our students enjoying flying. It's true that some students do suffer from airsickness during their flight, but even they will smile once we've landed!

Rhiannon Daye

Aviation Safety and Compliance Manager

In January 2009, US Airways Flight 1549 lost all engine power and landed on the Hudson River in Manhattan, New York. Miraculously, everyone survived. I remember watching it on the news and wondering what led to such success in an emergency situation. This sparked an interest in aviation accidents and how to prevent them.

While studying psychology at university, I had an assignment to apply psychology to a real-world event. I chose the 'Miracle on the Hudson', which introduced me to the field of human factors and led me to a master's in safety and human factors in aviation at Cranfield University.

After graduating, I struggled to find a suitable job and ended up working as an elf over the Christmas period! I attended aviation careers fairs and was offered an internship at Monarch Aircraft Engineering Ltd. From this, I carved out a role as a safety analyst, comparing the company's safety data against official safety performance indicators. Unfortunately, I was made redundant when Monarch went into administration.

I have felt 'lost' at several points during my career, but it has always worked out in the end. At the time, it can be hard to see the light, but the right opportunity will come your way. Even when it feels like you're taking a step backwards, you will learn new things. For example, working as a Christmas elf taught me how to conduct risk assessments on the spot, which is a skill I still use today.

I enjoy working in aviation safety because I like being able to make a difference, even in a small way. It's interesting to find out why people do what they do, and to come up with ways to make sure that things are done safely.

Almost everything on an aircraft is designed with safety in mind, from the lights in the aisle to the overhead storage. So, next time you are annoyed about your carry-on luggage being the wrong size, remember that the limits are for your safety!

© Keith Wilson/SFB Photographic

Dr Thomas Budd

Senior Lecturer and Digital Aviation Research and Technology Centre (DARTeC) Fellow in Airport Planning and Management

I was not always sure that I wanted a career in aviation. However, my older sister, who is also an academic in air transport management, inspired me to follow this path. She has always been passionate about aviation and her enthusiasm was infectious. I'm glad I listened to her!

At school, I was fascinated by the environment and climate change. I studied physical geography at university, which gave me a good understanding of the Earth's natural processes and how human activity is affecting this balance. For my dissertation, I chose to investigate carbon offsetting, where people 'offset' their carbon dioxide emissions by paying for services that reduce carbon dioxide in the atmosphere. This set me on the path to working in aviation sustainability.

My role at Cranfield has three main parts. I teach students, giving lectures, running workshops and supervising them doing individual research projects. I also collaborate with other academics and industry partners to conduct research into aviation sustainability. Currently, we are investigating whether hydrogen could be used as a zero-emissions aviation fuel. Finally, I am sometimes commissioned to consult for private clients on a particular topic.

Climate change is *the* defining challenge facing society, and aviation has a crucial role to play in this. Once carbon dioxide is emitted, it stays in our atmosphere for 300-1,000 years. This means that the impacts of the carbon dioxide emissions of the past few decades will be felt by generations long after we're gone. It's not yet too late to change things, but we need to act now. My job allows me to be part of the solution.

Dr Simon Place

Senior Lecturer in Aviation Safety and NFLC Demonstrator

I have always had a passion for aviation. My father and grandfather both served in the RAF, and my secondary school was right next to the airport on the Isle of Man. I'm sure both these factors rubbed off on me!

At school, I enjoyed sciences and languages, and I studied engineering at university. I have worked in a variety of aviation related jobs over the years. I was an engineer in the RAF, where I was responsible for ground radar and communications, a software engineer at an aerospace company, and I spent three years studying helicopter gearboxes for my PhD. I am glad to say that I use the knowledge and experience gained from my previous roles in my current job at Cranfield.

I applied, unsuccessfully, for a job as a demonstrator on the flying classroom in 1996. Years later, the position became vacant again, and I was appointed in 2020. So remember – never give up!

Being a demonstrator in the flying classroom is amazing. I work as a member of the flight crew while teaching students during their flight. I don't know anywhere else in the world where I could teach flight control theory while airborne!

Aviation connects the world and has resulted in improved communication. From a technical perspective, many innovations that we take for granted (such as GPS and radar) were developed for applications in aviation.

Professor Anna Smallwood

Head of the Centre for Air Transport Management

I was inspired to pursue a career in aviation when, as a teenager, I went to an airport for the first time. Having grown up in a small Yorkshire village, I looked up at the large departures board and realised that there was a big world out there to be explored. A friend who was a pilot encouraged me to follow my dream and apply for jobs in the industry, and I have never looked back!

At school, I loved English literature because books had the power to transport me to other societies and cultures and allowed me to travel in my mind. I also enjoyed economics, and almost went to university to study economics as I knew it would be helpful for a business career in the aviation industry. At the last minute, I changed my mind and got a degree in English literature and language.

The biggest highlight of my career was taking delivery of the first Boeing 787 Dreamliner aircraft into the Thomson Airways Fleet. This was the culmination of many months of hard work that involved examining every aspect of operating the aircraft, from studying its performance and safety to determining its engineering and maintenance requirements, as well as training crew and preparing IT systems and ground service equipment and personnel to be ready to deal with this new type of aircraft. The first time the Dreamliner took off with holidaymakers on board was a very special day.

Aircraft are incredible feats of engineering and technology that allow us to connect across countries and continents. I feel a sense of wonder every time I stop to think about this. I also love the fact that aircraft designs are often inspired by nature. For example, the Airbus wingtips were inspired by the dorsal fins of sharks!

Growing new and beginning farmers

Beginning a career in farming is not simple or straightforward. As well as learning how to care for crops and livestock, farmers need to have solid business acumen, understand complex regulations, and know how to make their practices as environmentally friendly as possible. Based at **Alabama A&M University's Small Farms Research Center**, in the US, **E'licia L. Chaverest** heads up the 'New and Beginning Farmers Program', which supports projects that educate and train farmers in how to run an effective and sustainable farming operation.

E'licia L. Chaverest

Assistant Director, Small Farms Research Center, Alabama A&M University, USA

PROFILE

Fields of research
Small farms research, agriculture economy, plant and soil science

Research project
Providing new and beginning farmers in Alabama with education, support, resources and training

Funder
US Department of Agriculture (USDA) - National Institute of Food and Agriculture (NIFA)

Talk like a ...

small farms outreach provider

Biodiversity — the variety and richness of organisms found in an area

Capital — a person's financial assets, including money and property

Credit — in finance, the ability to borrow money

Entrepreneurship — taking on financial risks to start and grow a novel and innovative business

Financial literacy — the ability to effectively understand and manage finances

Heir property — family-owned land with unresolved estate issues, usually when the original owner dies without leaving a will

Mentoring — advising or training a less experienced person

Minority — a relatively small group of people with particular characteristics (e.g., ethnicity), often facing discrimination

Sustainable — maintainable far into the future by avoiding depletion or contamination of natural resources

Underserved — not provided with sufficient help or services

If you are interested in running a farm, where do you begin? Many farmers find starting their careers a daunting process, especially if they are from disadvantaged backgrounds or lack a network for support or advice. To counter this, the US Department of Agriculture (USDA) runs the Beginning Farmer and Rancher Development Program (BFRDP), which aims to help new and beginning farmers by funding programmes or services that support them.

One such programme is run by Alabama A&M University's Small Farms Research Center (AAMU-SFRC). "Since the COVID-19 pandemic, there has been a sharp increase in the number of minority farmers entering the agricultural industry," says E'licia L. Chaverest, Assistant Director of the AAMU-SFRC. "To help this process, we run a programme designed to cater to their specific needs." The programme targets military veterans, who are often in need of a new career after leaving the armed forces, as well as young people who are seeking a career in agriculture, due to having inherited agricultural land or having a passion for the sector.

Education and empowerment

The programme, 'Developing Capacity for Veterans and Socially Disadvantaged Beginning Farmers in Black Belt Alabama', works to support farmers through a range of methods, including farm planning, farmer-to-farmer mentoring, experimental learning through hands-on demonstrations, and research based educational courses across a wide range of topics.

Alabama's Black Belt gets its name from the area's rich, black soil. Writing in the 1930s, American sociologist Arthur Raper described it as the historical home of "the richest soil and the poorest people" in the US, with nine out of Alabama's ten poorest counties being found within the belt. Almost 100 years later, Raper's description is still valid today. The region focuses on agriculture and has a low population density, high unemployment

A group of urban and rural farmers

and insufficient access to medical care and education. The AAMU-SFRC is working on improving this situation by giving upcoming farmers a helping hand in running profitable and sustainable agribusinesses.

"For many new and beginning farmers, the main challenges they face are access to resources and technical assistance," says E'licia. "They may be unaware about the USDA programmes and services that are available, as well as agricultural institutions such as AAMU-SFRC." The centre's programme focuses on supporting new farmers through education and empowerment. "We provide comprehensive programmes on topics such as business structure, financial literacy, risk management strategies, diversification, food safety, and marketing," says E'licia. "These programmes include workshops, seminars, certification courses and case studies to build this knowledge."

Money and law

Legal and financial matters are notoriously complex, especially when dealing with large amounts of land and capital, as is typically the case with farms. "Many historically underserved farmers are facing heir property issues, meaning they encounter legal problems in proving ownership of their land," says E'licia. "Racial barriers and financial literacy also pose big challenges."

AAMU-SFRC provides educational programmes to tackle this. "We have courses on estate planning, heir property and land access," says E'licia. "Other courses educate farmers about financial credit, record keeping and managing both business and personal finances," says E'licia. The AAMU-SFRC also provides one-on-one consultations and specialist appointments to help farmers meet their specific needs.

Entrepreneurship and leadership

These days, it is not enough for farmers to know how to farm; they also need to be business-savvy. "In the digital era, entrepreneurial and leadership skills

> **"New farmers will be required to be innovative, creative and visionary to operate their farms."**

are so important," says E'licia. "New farmers will be required to be innovative, creative and visionary to operate their farms. As leaders, they will need skills such as strategic development, planning and delivery, and management of employees."

In the age of industrialised farming, it can be difficult for smaller farms to keep up – but they remain highly valuable. Smaller farms tend to be more sustainable and friendlier to biodiversity, which is critical for ensuring the future of food supplies. Smaller farms also help build local resilience; if food supply chains are disrupted, they can help provide for local communities. This highlights the need for the farmers who run smaller farms to understand the business landscape and compete against the agricultural giants.

Farmer-to-farmer mentoring can be a powerful way of facilitating this process. Instead of relying on traditional 'classroom' settings, the programme connects beginning farmers with experienced farmers who can pass on their invaluable knowledge and expertise gained from years of farming. "Farmer-to-farmer mentoring is critical for new and beginning farmers," says E'licia. "It gives them the opportunity to shadow traditional farmers and learn through hands-on experience." The programme also offers apprenticeships and internships, helping prospective farmers to build their understanding before getting fully involved in farming as a career.

A legacy of success

The AAMU-SFRC has a substantial history of successes. "Over 28 years of operation, AAMU-SFRC has reached nearly 20,000 farmers and landowners, including the education and empowerment of over 12,000 who are new or beginning a farming career," says E'licia. "Throughout that time, we have learnt about a number of approaches that are keys to success." For instance, meeting the farmer in the field – taking the classroom to them – can be vital for ensuring that their specific needs are being addressed. The value of networks is also powerful, helping farmers to access people and opportunities that otherwise may have been inaccessible.

All this has only been possible due to a passionate and driven team at the AAMU-SFRC. "Without my team, we would not have been able to accomplish what we have over so many years," says E'licia. "I am proud to acknowledge my coworkers and the essential roles they all play in our projects."

The AAMU-SFRC Team

Dr Duncan M. Chembezi, Director

E'licia L. Chaverest, M.S., Assistant Director

Aminat Amunigun, Graduate Student

Oppia Burke, Program Assistant

Shuniya Hutton, Program Assistant

Virgina Ward, Program Assistant

About *farming and farming research*

Farming has formed the backbone of civilisation for thousands of years and continues to be vital for a well-fed and healthy society today. However, farming practices are constantly changing, adapting to technological and societal progression, and now increasingly embracing a deeper knowledge of sustainability. This makes farming – and research into how to make farming a more efficient, resilient and environmentally friendly process – an exciting career choice. E'licia explains more.

"The study of farming can be a hugely rewarding career. It lets you enjoy the great outdoors, enjoy high-quality food, and learn how the food we consume is grown. There is a strong sense of accomplishment in helping farmers and landowners build their community.

"Careers are shifting towards the advance of sustainability practices and embracing technology. Within farming research, there are more and more openings in data and analytics, food safety, natural resources, environmental sciences and public policy. Farming has a huge role to play in addressing climate change, and this will undoubtedly shape agriculture for years to come."

Pathway from school to *farming and farming research*

- At high school and post-16, E'licia recommends subjects such as biology, business and economics to gain a grounding in the fundamentals of farming.
- E'licia says that college and university courses in food science, animal science, economics, plant science, social science and public policy are all beneficial for a career in the farming sector.

Explore careers in *farming and farming research*

- E'licia says, "Starting a career in farming or farming research can seem intimidating, but there are resources out there to help. For those interested in starting your own farm in the US, I recommend connecting with your local USDA Service Centre (**www.farmers.gov/working-with-us/service-center-locator**) which can offer support and pair you with an experienced mentor."
- "If you are interested in a career in farming research," advises E'licia, "visit a nearby university or college to learn about the youth programmes they offer. For instance, the AAMU-SFRC is collaborating with Alabama Cooperative Extension System and Climate Initiative to develop a programme focusing on how agriculture can encourage, and benefit from, biodiversity."
- Future Business Leaders of America High School (**www.fbla.org/divisions/fbla**) helps high school students prepare for careers in business, through competitions, educational programmes and leadership development. Such skills are highly useful for careers in farming.
- Minorities in Agriculture, Natural Resources and Related Sciences (MANRRS) (**www.manrrs.org**) promotes academic and professional advancement for minorities in agriculture and related fields. Junior MANRRS membership grants opportunities to develop academic and leadership skills.
- According to salary.com, the average salary for a farmer in the US is around $46,000.

Mr Eddie Smith, veteran farmer located in rural Alabama

Meet *E'licia*

I thrive on being able to make a difference to farmers' livelihoods. Farmers motivate me to learn various aspects of agriculture so I can provide assistance on various levels. When you love what you do, there are no obstacles too large to assist the people you serve.

I've worked at the same university for 20 years now! Initially, I wanted to work for the USDA in Washington D.C., but over the years I learnt that I'm more valuable working directly with farmers. I've found unexpected joy in being a productive outreach provider, helping farmers with every aspect of growing their farm operation. Recently, I was proud to be selected as a member of the USDA New and Beginning Farmers Advisory Council.

Having a good work-life balance helps me overcome obstacles. I have a strong network of friends and professionals to advise me, and having a life outside of work helps me keep the perspective of not taking everything too seriously. My prayer life also gives me a sense of sanity.

My colleagues and I aim to grow, inspire and mentor the next generation of farmers. We want all ages to learn more about agriculture and to connect with our food system as farmers, gardeners or community leaders – to be curious about sustainable agriculture practices and where the food system can go next.

E'licia's *top tip*

There is a very broad range of career paths within farming, so keep an open mind to opportunities. Try different areas of agriculture, such as getting work experience with local government, in universities or in agricultural communities.

Ms Oppia Burke, Program Assistant, assisting a local farmer

How can we improve cranberry production?

Indigenous Peoples have been using cranberries in food, medicine and fabric dye from as early as the 1500s, and these fruits are still widely used and produced across the US today. However, fruit rot diseases can cause tremendous damage to these plants, leading to substantial yield losses if they are not properly managed. At the **University of Wisconsin-Madison** in the US, **Dr Leslie Holland** is a plant pathologist working to understand fruit rot and how we can better protect cranberries.

Dr Leslie Holland

Holland Lab, University of Wisconsin-Madison, USA

PROFILE

Field of research
Plant pathology

Research project
Developing a S.A.M.E. (systems approach for managing the expression) of cranberry fruit rot

Funder
US Department of Agriculture (USDA) - National Institute of Food and Agriculture (NIFA)

This work is supported by the USDA National Institute of Food and Agriculture Specialty Crop Research Initiative Award No. 2022-51181-38322. The contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

Talk like a ...
plant pathologist

Bogs or marshes — the farms where cranberries grow in beds. In the northeast US, they say 'bog' and in the midwest, 'marsh'

Cranberry beds — the individual production units for cranberries; usually, one bed contains a single variety

Cranberry fruit rot (CFR) — a disease complex, caused by fungi, that impacts the quality of cranberry fruit

Fungi — organisms that get their food from decomposing organic matter or other living things, the plural of fungus

Fungicide — products used to kill or prevent the growth of pathogenic fungi

Pathogen — an organism that causes disease, such as bacteria, viruses, fungi or parasites

Pathology — the science of the causes and effects of diseases

Yield — the amount produced of an agricultural or industrial product

At the University of Wisconsin-Madison, Dr Leslie Holland is studying cranberries and the diseases that affect them. Cranberries are native to North America and grow best in the climates of the northern US states and southern Canadian provinces. The US is leading the world in the production of cranberries – according to Statista, around 403,000 tons of cranberries were produced there in 2022!

However, when Leslie's research team surveyed growers in the US, 83% of them said that cranberry fruit rot (CFR) had caused them to lose fruit in the last five years. "CFR is the main factor reducing yields of cranberry in the US," explains Leslie. When a cranberry is infected by fruit rot fungi, the fruit quality is greatly reduced, often meaning that the fruit is unable to be sold.

What causes cranberry fruit rot?

There are at least 15 fungal species associated with CFR. "These pathogens infect developing plants during bloom, then remain inactive until fruit begins to mature and rot symptoms develop," explains Leslie.

Each of these 15 pathogens might have unique characteristics and life cycles, their own method of surviving varying conditions, and their own resistance to different fungicides. "Managing multiple fungal species simultaneously can be complex and requires a tailored approach," says Leslie. Cranberry beds – where cranberries are grown – also provide convenient environments for fungi to grow in, making it difficult for cranberry growers to keep on top of controlling fruit rot.

Environmental conditions, such as heat and humidity, affect the development of CFR fungi too. This is similar to how fungal pathogens work on humans. Have you ever heard of athlete's foot, a common skin

Flooded cranberries during harvest in central Wisconsin. © Holland Lab, UW-Madison.

infection caused by a fungal pathogen, that causes extremely itchy feet? Sweaty and damp socks and shoes, and any other warm, humid conditions, help this fungal pathogen to grow. These conditions are the same ones which help the fungi affecting cranberries to grow. "High humidity, prolonged leaf wetness, and warm temperatures favour the development and spread of fungal pathogens," explains Leslie. This means that if a summer is particularly wet or warm, the disease can be even more of a problem for growers. Fungi can also survive from season to season; if CFR affects a plant one year, the pathogens might still survive in leaves and last season's plant tissue to infect the following year's fruit as well.

What else makes CFR such a challenge?

The challenge of controlling fruit rot is made even more difficult because of the delay between when fruit gets infected and when symptoms of the rot start showing. "Infections occur early in the season, while visible signs of the disease show up later," says Leslie. This means that several pathogens can be present within the cranberry plants, but growers have no idea of the problem until it is too late. "This adds complexity to managing fruit rot since understanding the factors triggering rot development becomes crucial, particularly in situations where the fungi are present, but the plants are not actively showing symptoms," Leslie adds.

To combat these issues, Leslie has developed a research project called S.A.M.E. (Systems Approach for Managing the Expression) of Cranberry Fruit Rot. Her team is aiming to understand more about CFR fungi, how CFR can be prevented, how growers can recognise it, and how they can better protect their cranberries in the future.

S.A.M.E. of CFR

Leslie's research project is focusing on five major cranberry-producing states across the US: Wisconsin, New Jersey, Massachusetts, Oregon and Washington.

> **"Managing multiple fungal species simultaneously can be complex and requires a tailored approach."**

Cranberries grow on low-lying vines in levelled soil beds, commonly referred to as bogs or marshes. These plants have small shoots which flower and, eventually, turn into cranberry fruits. Leslie and the rest of the project team collect samples from two popular cranberry varieties at different plant developmental stages, such as when the shoots are flowering and when they change into berries. The researchers take all these samples back to the laboratory to identify which fruit rot fungi are growing on the plants and how frequently they appear. "This work will provide valuable insights into the biology of these fungi and contribute to our understanding of how rot develops in the field," explains Leslie.

Once they have analysed the samples, Leslie and her team evaluate fungicides to understand how fruit rot fungi responds to these chemical products. The fungi's response can vary between being sensitive to the product, meaning that the fungicide is able to kill off the fungi, to being resistant, meaning that they can continue to survive.

The team conducts these tests with a range of fungicides including ones which are already approved as viable products for controlling CFR, as well as ones that are still waiting to be approved. "Since there are limited control options for CFR, exploring the efficacy of new products allows us to potentially expand our toolkit of control measures," says Leslie.

What has the team found so far?

The team has discovered that the species of fungi present in cranberries varies depending on where the cranberries are growing. This might be due to differences in climate between these regions, which is allowing some types of fungi to grow better than others.

Leslie's goal is to eventually develop a disease risk model that will help manage CFR and can be distributed to growers throughout the US. "Currently, there are no reliable ways to predict and manage CFR," says Leslie. The model will take into account what type of fungicide growers should use based on the specific conditions on each farm, environmental factors and which type of fungus is present in the field. The team also wants to include information around the role of plant stress in developing fruit rot infections, which cranberry varieties are more resistant to CFR, and the pros and cons of different management strategies.

The S.A.M.E. of Cranberry Fruit Rot project is still in the early stages of its work, and Leslie is excited to see what comes next.

About *plant pathology*

Plant pathologists are effectively plant doctors. It is their job to study plant diseases and devise new, effective methods for treating and managing diseases. "Figuring out what causes these diseases, finding fast ways to detect them, and coming up with ways to manage them are crucial areas to pursue in plant pathology," says Leslie. Plant pathology combines many different areas of expertise, including genetics, epidemiology, food security, physiology and molecular biology, and it often takes an interdisciplinary approach to solve issues.

Climate change has a huge influence on plant pathology, as changes in weather and environment affect the frequency, distribution and severity of plant diseases. "New plant diseases are emerging, and existing diseases are spreading to new regions where they have not been seen before. Understanding how environmental factors impact diseases and how plants interact with pathogens can help us deal with disease outbreaks associated with a changing climate," explains Leslie.

Plant pathologists now have more cutting-edge technology available to them, and advanced techniques such as remote sensing are becoming more important for managing plant diseases. "There are numerous exciting opportunities for the next generation of plant pathologists!" says Leslie

Why is diversity important in this field?

Leslie is a mentor for the MOSAIC (Mentoring Opportunities in Science and Agriculture for Individuals of Color) programme at the University of Wisconsin-Madison, which is a support system for people of colour on campus. "Initiatives like MOSAIC are very important for fostering connections, especially in predominantly white institutions, where persons of colour may have fewer opportunities to engage and feel included," says Leslie. With the goal of combatting social isolation, the programme connects students of colour with staff of colour. "By encouraging and empowering students of colour to pursue careers in these fields, the programme helps to address the underrepresentation of diverse voices and perspectives."

Find out more: **mosaic.cals.wisc.edu**

Pathway from school to *plant pathology*

- During high school and post-16 years, study chemistry and biology, as well as any gardening or plant-based courses that your school or college might offer.
- Reach out to your local botanical garden or horticultural society to see if you can get some hands-on experience.
- Study a bachelor's degree in plant pathology or a relevant field such as molecular biology, plant science, botany or agriculture. "If you want to learn and do research in this field, it's helpful to have knowledge in various subjects," says Leslie. "Classes often include biology, chemistry, statistics, agricultural sciences (such as agronomy or horticulture), microbiology, botany, genetics, plant pathology, plant physiology and research methods."
- "Summer internships are a great way to gain hands-on experience and provide opportunities to connect with other scientists in career fields that may interest you," says Leslie. Have a look for practical experience such as research projects or work in plant pathology laboratories or research farms.
- Leslie's lab sometimes hires undergraduates or recent graduates for summer positions: **fcpp.plantpath.wisc.edu/opportunities/undergraduates**

Explore careers in *plant pathology*

- One of the best websites to explore plant pathology is the American Phytopathological Society (APS; **www.apsnet.org**). "APS hosts national conferences annually and collaborates with other phytopathological societies around the world, including the British Society for Plant Pathology (**www.bspp.org.uk**) and the International Society for Plant Pathology (**www.isppweb.org**)," says Leslie. The APS website also has a brilliant careers page which gives information on what plant pathologists do and what qualifications and experience you need to get into the field: **www.apsnet.org/careers/careersinplantpathology/pages/default.aspx**
- Listen to this great 25-minute podcast by Plantopia where Leslie talks to other plant pathologists about cranberry fruit rot: **www.plantopiapodcast.org/18**. Another episode covers different careers in plant pathology: **www.plantopiapodcast.org/33**
- Graduate students in Leslie's department have formed a group called WEMP (What's Eating My Plants), with the aim of educating people about the role plant pathology plays in our lives. Visit the group's website: **sites.google.com/view/whatseatingmyplants/home**
- According to Federal Pay, the average annual salary for a plant pathologist in the US is $118,000.

© Andrew Will/Shutterstock.com

Meet *Leslie*

My high school biology teacher inspired me to become a scientist. She was a great instructor and made the classroom an engaging experience. For me, biology was filled with exciting research questions and hypothesis testing, which inspired me to pursue a career in science. This led me to choose a career in research where I not only get to ask questions but can also find answers through my own research, and that has been an incredibly rewarding journey for me.

Participating in conferences and interacting with fellow scientists has been a valuable experience that has helped me grow as a scientist. Equally important has been the influence of supportive mentors who guide and promote my work and create an environment conducive to success.

> ***My main goal for the future is to become a leader in the field of plant pathology.***

One of my most memorable eureka moments occurred during my first research talk to an audience of growers. Unlike presenting to a group of fellow scientists, this audience had a different perspective and set of questions. They were highly focused on understanding the real-world implications of my findings, not just the theoretical aspects. This experience was eye-opening, as it made me realise the significance of translating scientific knowledge into practical applications. Until then, my focus had been mainly on lab experiments and field trials, but this moment highlighted the importance of bridging the gap between research and its practical implementation.

The worst piece of advice I've received is to unquestionably trust research already published in scientific literature. However, my journey as a scientist has taught me to unlearn this, as scientific theories, approaches and hypotheses can (and do) change over time. This is one of the most exciting things about science because advancements in technology and knowledge constantly shape our understanding. This doesn't mean that older studies are invalid; in fact, these studies provide the foundation from which we can expand our knowledge and explore new questions with the latest techniques and insights.

My most significant career accomplishments to date include completing my graduate studies and landing my dream job as an Assistant Professor and Extension Specialist specialising in fruit crop pathology. Since college, I wanted to become a 'plant doctor', to study plant diseases and share knowledge with growers. Most recently, I was selected as the Researcher of the Year from the Wisconsin State Cranberry Growers Association. This recognition is a great honour, as it acknowledges the hard work and contributions my research lab has made in supporting the cranberry industry.

My main goal for the future is to become a leader in the field of plant pathology, focusing on making meaningful contributions in the areas of cranberry fruit rot biology and management. As the principal investigator of my lab, I am committed to fostering a collaborative and supportive environment for all the students and staff involved. One of the most fulfilling aspects of my job is helping students recognise their full potential and guiding them as they progress in their academic and professional journeys.

Leslie's *top tips*

1. Take opportunities to explore different paths and interests. Learning what you do not enjoy doing is just as valuable as learning about the things you do enjoy.
2. While there are always new things to learn in the classroom, don't hesitate to get outside and get your hands dirty.
3. Don't be discouraged if you don't see many people that look or sound like you in the field you want to pursue. Your unique perspective can bring positive change and innovation to any field.

Ingenious solutions for outwitting plant pests

Pests and pathogens can be the bane of plant producers' lives. Fortunately, there are a range of inventive remedies out there. **Dr Elizabeth Lamb,** from **Cornell University** in the US, works closely with growers to find optimal pest control solutions depending on their specific situation, making the most of biological methods such as natural predators.

Dr Elizabeth (Betsy) Lamb

Senior Extension Associate, Ornamentals IPM Coordinator, NYS Integrated Pest Management
Adjunct Assistant Professor, School of Integrative Plant Science Horticulture Section, College of Agriculture and Life Sciences, Cornell University, USA

PROFILE

Fields of research
Horticulture, plant pathology, entomology

Research project
Integrated pest management of ornamental crops, including biological control methods and close stakeholder collaboration

Funders
New York State, US federal government, Northeast Sustainable Agriculture Research and Education (NE-SARE), US Department of Agriculture National Institute of Food and Agriculture- Agriculture and Food Research Initiative (USDA NIFA AFRI), USDA NIFA Crop Protection and Pest Management (USDA NIFA CPPM), Cornell University

Talk like a ...

plant scientist

Agriculture — the science or practice of farming

Agronomy — the science of crop production and soil management

Arthropods — a large group of invertebrate animals, including insects, spiders and mites

Biological control — the control of a pest through the use of other species, such as predators

Cultivar ('cultivated variety') — a variety of a plant produced through selective breeding

Entomology — the study of insects

Horticulture — the science or practice of growing garden plants, including vegetables, fruits and ornamental plants

Integrated pest management (IPM) — an approach used to control pests while minimising risks to people and the environment, by combining a variety of different types of management

Intervention — in IPM, methods that manage existing pest populations

Parasitoid — an insect whose larvae live as parasites on or in other insects that eventually kill their hosts

Pathogen — an organism that can cause disease

Pathology — the study of diseases, especially their causes and effects

Predator — an organism that feeds directly on another organism

Prevention — in IPM, methods that prevent pest populations from establishing

Pests can be a big problem for plant producers, but simply using chemical pesticides is not the optimal solution. This is not just for environmental reasons, but also in terms of effectiveness, cost and quality. Dr Elizabeth (Betsy) Lamb is an expert in integrated pest management (IPM), a field which involves examining the full spectrum of pest prevention and control methods, and working out which is most suitable for particular scenarios.

"When we survey crop growers on the biggest limitations to their crop yields and quality, pest management is always near the top – along with weather, labour and energy costs," says Betsy. "Pest management is a balancing act. Like Goldilocks, we want to get it 'just right'." Too little pest control can lead to severe impacts on yields and quality, but too much can be costly. This balance depends on individual scenarios, which often change every year. This demonstrates the importance of methods for deciphering which management techniques to use in any particular scenario.

IPM

"The fundamental basis of IPM is to find pest management methods that have the lowest environmental impact, while still controlling the pest," explains Betsy. "It involves combining cultural, physical, biological and chemical tools." Cultural methods involve making the plant's

© HHelene/Shutterstock.com

environment less suitable for pests (for example, by adjusting planting and irrigation methods) and, typically, have the least negative environmental impact. Chemical interventions such as pesticides, meanwhile, typically have the most impact on other organisms in the environment. "IPM begins with those methods that have the least negative impact, moving to more environmentally harmful methods only when it's necessary," says Betsy.

Betsy works mostly with ornamental crops – from flowers and garden shrubs to Christmas trees. Compared to food crops, ornamentals have some unique challenges when it comes to IPM. "Ornamentals have aesthetic value, relating to how pleasing their appearance is, which means that even if only a very small number of leaves have disease or insect damage, the quality is reduced dramatically," Betsy says. "We also grow a lot of different species and cultivars of ornamental crops – think of all the different types of flowers you might see in a garden. Each type of plant may have different pest management needs."

'Fighting fire with fire'

Biological methods of pest control often involve using other living organisms to combat pests. For instance, ladybirds are voracious predators of aphids, which can be a problematic plant pest. "Most of my work with biological control involves using arthropods to control other arthropods," says Betsy. "There are two types of biological control: conservation and augmentative."

Conservation biological control involves encouraging those species that occur naturally, for example, by growing crop-adjacent plots with plants that beneficial insects prefer for food or shelter. "We have what we call 'beneficial habitat' plots in a Christmas tree research field and urban vegetable farms in New York City to encourage the beneficial insects," says Betsy. "While we have a lot of information from this research on which insects are good, bad or 'just hanging out', it's much harder to determine to what degree the beneficial insects are keeping pest populations in check. But we do see evidence that biological control is going on there."

Augmentative biological control involves directly adding commercially-produced beneficial species, usually pest predators and parasitoids. This type of control is more often used in greenhouses,

> ***"The fundamental basis of IPM is to find pest management methods that have the lowest environmental impact, while still controlling the pest."***

as it is difficult for naturally occurring beneficial species to get into an enclosed greenhouse, and, once introduced, they tend to stay in place. "This process can be logistically challenging," says Betsy. "Beneficial species have to be grown and collected, shipped and distributed through the greenhouse, and remain alive and healthy throughout." This process may also have to be repeated regularly. "While we would like populations to establish themselves and reproduce in the greenhouse, typically they are so good at eating pests that they run out of food," says Betsy. "Sometimes, the environment isn't right for them to mate and produce young. And we might integrate biological control with chemical control, which makes things even more complicated!"

Viva la resistance!

Adding in other species is not the only biology-based method of pest management. Another way to fight off pests is to breed plant varieties that are innately resistant to pests. "Disease resistance is more common than insect resistance in ornamentals," says Betsy. "I wish we had more resistant cultivars, but it usually takes many years to develop a variety that's resistant and also has all the other characteristics that consumers want."

For instance, basil is grown commercially for consumers to transplant into their home gardens, but it can be very susceptible to a disease called downy mildew. "Researchers found a wild basil species with mildew-resistant genes, and crossed it with commercial basil," says Betsy. "Then, further selection had to be done until the cultivar also had all the other properties needed – namely, the taste and smell that consumers expect." The end result was worthwhile, as basil can now be grown without needing to use chemical fungicides for downy mildew.

Scouting for bugs

Betsy works extensively with plant producers to help them find solutions for pest problems and to learn about what methods they find most effective. "When we started working with greenhouse growers to implement biological control, it became clear that it involves processing a lot of information," she says. "We first hit on the idea to make a workbook to contain this information, but then decided to create an app, as most growers have smartphones with them every day." Betsy's team worked with a local app development company to create GreenhouseScout. "It was an interesting process to learn one another's vocabulary – my 'bug' is not the same as their 'bug', for instance," she explains. "They helped us realise the app's potential, from how to best display information to interactive elements."

The GreenhouseScout app provides growers with information on pest life history and ecology, how to pair biological control methods with specific pests, and what to expect if these controls are then combined with chemical methods. "The other main function of the app is interactive scouting," says Betsy. "This involves growers logging occurrence of pests, control measures taken, and how effective these were at reducing pests. The app will create graphs from this information, which can be used to fine-tune methods for the next season."

The next version of GreenhouseScout is in the works, including feedback from growers using the existing one. "We are adding the ability to include maps of a grower's greenhouse or farm, and to upload photos of pests for help with identification," says Betsy. "We're also adding lots of new information and making the whole experience more user-friendly." To supplement this development, Betsy is working on a training programme to help greenhouse workers and students learn how to scout for pests and diseases, and judge the efficacy of control methods. As the term integrated pest management conveys, Betsy's work in IPM continues to involve many different approaches.

About *plant science and integrated pest management*

Plant science involves understanding how plants function and how they are affected by different conditions, making it a very broad field. Much of the discipline is applicable to the agriculture and horticulture industries. Betsy works specifically on integrated pest management (IPM), which involves understanding the many interactions between plants, pests, the environment, and prevention and intervention measures.

"One of the best parts of my job is that I work with everyone! This includes greenhouse and nursery growers, Christmas tree producers and cut flower farmers, to find out what issues affect them and how pest management can fit into their schedules and finance systems. I work with other research and extension professionals, both at Cornell University and further afield, to learn from their knowledge and experience. I also work with government officials and policymakers, as their decisions can affect growers too.

"On a given day, I might be answering grower questions on a specific issue or going to visit their farms. I have responsibility for helping all ornamental growers across New York State, which is a big area! I can't visit them all, of course, but what helps one grower often helps another. I do a lot of outreach and extension, and sometimes speak at events. I also do research – right now, on how to avoid root diseases and weed competition in young Christmas trees.

"Often, it's a steep learning curve, but I enjoy this aspect. At the moment, I'm learning about cut flowers, as production has increased in the state and growers need help with pest management. It's exciting when I know an answer straight away, but more often I have to say: "I don't know, but I will find out!"

"When we look to the future, the sky's the limit. Technology is already well-integrated within plant science, but there is more to do, such as using sensors to measure plant or pest properties and drones to manage and survey plots. The integration of pest management with addressing climate change is a huge and growing area. There is also space to create new genetic tools to develop pest-resistant plant varieties."

Pathway from school to *integrated pest management*

- Betsy recommends gaining a solid basis in biology and chemistry, in particular to understand the scientific method.
- Betsy notes that IPM is often integrated into other disciplines at university. It could be approached through subjects or modules in entomology, plant pathology, weed science and wildlife sciences, all of which teach aspects of management of these pests. Subjects such as horticulture and agronomy will cover the growing-specific aspects. Betsy also suggests learning about policy, law and community action because IPM solutions often involve people across diverse areas.

Explore careers in *plant science and integrated pest management*

- New York Agriculture in the Classroom brings agricultural education into schools, helping students and wider communities learn about and engage with food systems. Find out more about their diverse programmes and resources: **newyork.agclassroom.org/about**
- The CALS Cornell Cooperative Extension Internship Program gives undergraduate students opportunities to gain practical experience within agriculture and life sciences. Betsy works on the 'Conservation Biocontrol on Urban Farms in NYC' internship: **cals.cornell.edu/cornell-cooperative-extension/join-us/cce-summer-internship-program**
- IPM is often integrated into other disciplines. There are scientific societies for all branches in the US, including the American Society of Horticultural Science (**ashs.org**), the Entomological Society of America (**entsoc.org**), and the American Phytopthological Society (**apsnet.org**). Betsy says, "All have regional meetings and love to have students participate. I also recommend looking into nearby research institutes or universities, finding people working on IPM and asking if they have internship, mentoring or shadowing opportunities. Most scientists are excited to see young people interested in their work."
- According to Salary.com, the average base salary for a plant scientist in the US is around $73,000.

© gooko/Shutterstock.com

Meet *Betsy*

My mother was a botanist and my father was a plant breeder, and both loved their professions. That undoubtedly inspired my interest, which was further kindled by good science teachers at school and support from my family to pursue whatever I wanted. Also, growing plants is a creative process as well as a scientific one, and that combination of skills attracted me.

When I was very young, I wanted to be a farmer. In some ways I still do, but my work in research and extension at least involves talking to a lot of farmers. Seeing them apply information and balance all the factors that go in to producing a beautiful, productive crop is awe-inspiring.

> ***Being on a steep learning curve is always an exciting place to be.***

In my first faculty position, I was surprised to find I was pretty good at teaching other people. I've grown to learn that communicating our research is just as important as the research itself, which draws me towards applied projects. I also love working in teams, which is really the only way that science ever has success.

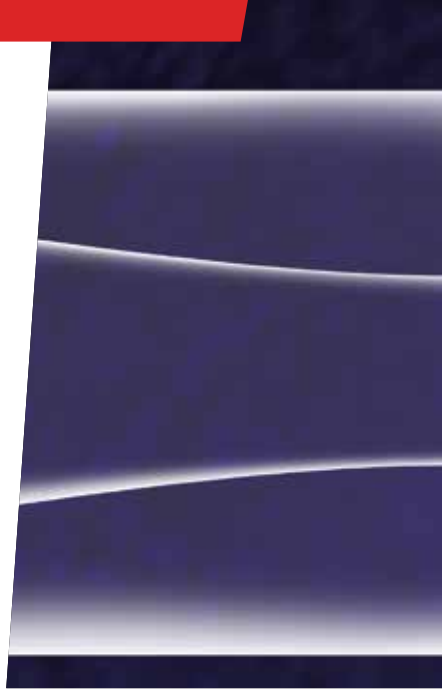
I'm nosy, which helps me be observant in my work! I like puzzles and discovering how things work, and I'm interested in people and finding out about them. My career hasn't been typical as it's involved jumping between places and topics, but I like that too. Being on a steep learning curve is always an exciting place to be.

My proudest moments come from when I see my work applied in real life. When I find an answer to a problem and then growers implement it, it's very satisfying. The same satisfaction comes from teaching, when you find that people were listening and then applied what they learnt. They may seem like small moments, but the world is made up of small moments, and we all stand on each other's shoulders.

Betsy's *top tips*

1. Be inquisitive and follow your curiosity. Don't worry if your path doesn't seem direct – as long as it's yours.
2. Be broad in your career thinking. While there may be thousands of science students, only a few may combine it with their other passions, such as photography, art or anything else. What sets you apart might be what makes you essential.
3. Find good mentors and role models. Ask all the questions – silly ones, profound ones, off-the-wall ones – and learn to ask for help.

Bringing revolutionary gene editing techniques to undergraduates



In recent years, the emergence of a new genetic modification technique called CRISPR-Cas9 has made gene editing a dramatically faster and easier process for scientists. As part of the **CRISPR in the Classroom Network, Dr Anil Challa** from the **University of Alabama at Birmingham** and **Associate Professor Dr Lynn Kee** from **Stetson University**, both in the US, are bringing CRISPR-Cas9 to the university classroom, teaching undergraduates how to use this important tool.

Associate Professor Dr Lynn Kee

Stetson University, DeLand, USA

CRISPR 360°: Design, Implementation and Evaluation of a CRISPR technology toolkit for Undergraduate Education (NSF Award Number 2044385)

Dr Anil Challa

College of Arts and Sciences, University of Alabama at Birmingham, USA

NSF Research Coordination Network-Undergraduate Biology Education: Bringing CRISPR-CAS9 Technologies to the Undergraduate Classroom: An Undergraduate Instructors' Network, Award #2120417

Fields of research
Molecular genetics, molecular and cell biology

Research project
CRISPR in the Classroom Network: introducing undergraduate students to CRISPR-Cas9 technologies through hands-on laboratory experiments

Funder
US National Science Foundation (NSF)

PROFILES

Talk like a ...

molecular geneticist

CRISPR-Cas9 — a genetic modification technology that allows the precise editing of genes

DNA — a nucleic acid that acts as the self-replicating carrier of genetic information in almost all organisms

Gene editing — a type of genetic modification that typically involves a small, precise change to a living organism's existing DNA

Genetic modification — a broad term that involves using laboratory-based technologies to alter the DNA of an organism

Genome — the complete set of genetic material present in a cell or organism

Genotype — the genetic makeup of an organism; the specific genes that an organism carries

In vitro — a laboratory process involving biological molecules or cells that takes place outside an organism, e.g., in a test tube or culture dish

In vivo — a laboratory process that takes place within a living organism

Polymerase chain reaction (PCR) — a technique for rapidly producing multiple copies of a specific segment of DNA

Phenotype — the observable characteristics of an organism, resulting from the interaction of its genotype with the environment

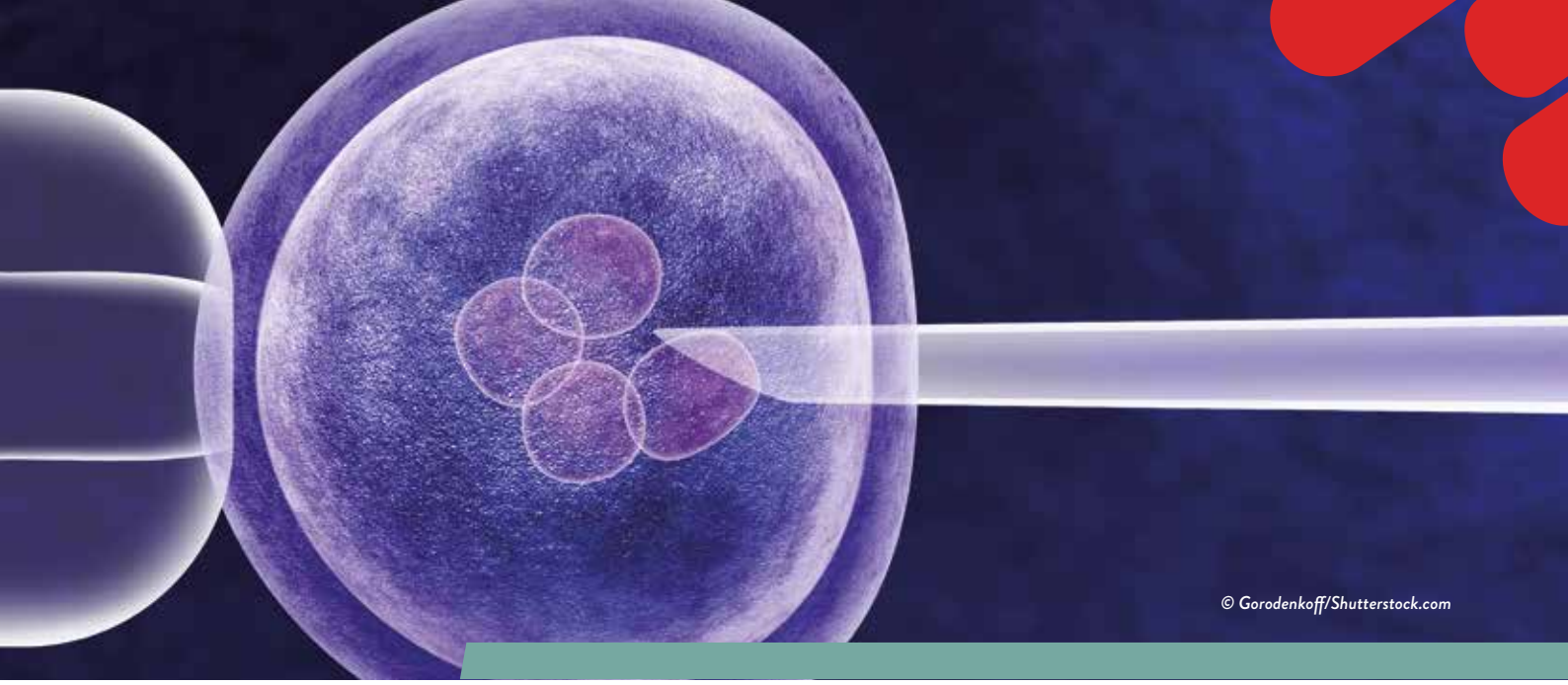
RNA — a nucleic acid that typically acts as the intermediary between the reading of genes in an organism's DNA and their expression, via the creation of proteins

Gene editing is allowing scientists to learn more about how our genes work than ever before, and to find groundbreaking solutions to real-world problems. The emergence of CRISPR-Cas9 has made this process dramatically easier and more accessible. "The technical ease with which CRISPR-Cas9 experiments can be designed, assembled and tested makes it very exciting," says Dr Anil Challa, from the University of Alabama at Birmingham's College of Arts and Sciences. "Additionally, progress made in other areas of chemistry and molecular biology has accelerated the pace at which CRISPR-Cas9 tools are being improved and reimagined." Associate Professor Dr Lynn Kee, from Stetson University, agrees: "The ease with which CRISPR technologies are being programmed and deployed has allowed the tool to be implemented in arenas applicable across biology, medicine and wider society."

Anil and Lynn are part of the CRISPR in the Classroom Network, which aims to develop a national community of biology educators and empower them to integrate CRISPR-Cas9 into their courses. They both run courses for undergraduates at their respective universities, where they give them direct experience in using the technology to modify organisms' genomes.

How CRISPR-Cas9 works

CRISPR-Cas9 allows scientists to edit parts of an organism's genome by precisely removing, adding or altering sections of its DNA. It has two core components. The first is an enzyme called Cas9, which acts as a pair



of 'molecular scissors', cutting the DNA at a specific location. It is accompanied by a piece of guide RNA, which is tailored to complement the DNA sequence of interest, and guides the Cas9 enzyme to the right point to cut. "The tool adds or removes DNA by manipulating natural DNA repair mechanisms," explains Lynn. Anil adds, "Because cells targeted by CRISPR-Cas-9 do not tolerate the double strand breaks (DSBs) it creates, they repair themselves using their own biochemical machinery."

CRISPR technology is already changing lives. "The first human clinical trial using CRISPR technology for immunotherapy cancer treatment is underway," says Lynn. "It involves removing patients' immune cells, editing them *in vitro* using CRISPR to specifically attack cancer cells, and reinserting them into the patient." Similar techniques are being used to treat blood disorders too. Clinical trials are also using *in vivo* approaches. For example, modified viruses are inserted into patients' retinal cells, where they release CRISPR components that modify the gene that controls the genetic eye disorder Leber congenital amaurosis 10. "CRISPR is also penetrating our everyday lives in other ways," says Lynn. "For instance, crops such as tomatoes and mushrooms are being modified to be bigger and to stay fresh for longer."

In the undergraduate lab

"CRISPR-Cas9 technologies are becoming commonplace in both academic and industrial laboratories," says Anil. "A working knowledge of the system is highly valuable to undergraduate students for their future careers." The rapid pace of progress is exciting but also poses challenges for teaching students how to use the latest tools. "Course textbooks provide limited scope on the topic and do not reflect the most current advances, while most papers and reviews are too detailed and complicated for undergraduates to understand fully," says Lynn. "This raises the need to develop effective educational practices and experiences framed around CRISPR technology."

Alongside lessons on the fundamentals of molecular biology, direct exposure to CRISPR technologies in the lab is the most effective way of teaching students about these tools' capabilities and how to harness them. "CRISPR technology can be used to apply biological principles, in particular to build understandings of how genotypes affect phenotypes – in other words, how genetic information leads to the creation and organisation of proteins, cells, tissues and whole organisms," says Lynn. Students also learn key practical laboratory skills that are applicable across a range of disciplines. "Students learn that the scientific process is not linear, but made up of multiple progressive steps," says Lynn. "Experiments may not work as planned and need repeating, so students learn perseverance and focus. Students also develop critical thinking skills, specifically how to interpret their data and form a conclusion from their results."

Anil's zebrafish lab

Researchers often use a 'model organism' for their studies – that is, a non-human organism that helps them understand key biological processes. In Anil's lab, the model organism is the zebrafish. "The zebrafish is a powerful model organism, amenable to experimental studies and allowing us to learn more about vertebrate biology," he says. "Students can study this model organism to gain familiarity with vertebrate embryonic development, genome analysis, genetic and molecular biological investigations, and connections between genotype and phenotype."

A typical experiment to introduce undergraduates to CRISPR involves posing a question about a gene involved in the embryonic development, physiology or behaviour of the zebrafish. "After setting the question, students analyse the gene using bioinformatics tools, which then leads them to be able to design the CRISPR guide RNA," says Anil. "They prepare this single guide RNA (sgRNA) to be specific to the sequence of interest, and then validate whether it works *in vitro*." If it does, the next step is embryo injections for *in vivo* testing of what happens when the gene in question is 'knocked out'. "Students have a go at making microinjections and, later, observe for phenotypes caused as a result of the loss of gene function," says Anil. "Finally, they isolate the embryos with these phenotypes and perform PCR-based genotyping experiments to find out what genetic mutations have arisen due to CRISPR-Cas9 activity."

This project has had successes beyond the classroom. "The big highlight has been the publication of a peer-reviewed journal article, including contributions from all students who participated in the research experience," says Anil. "Several students have benefitted from this recognition in their later academic pursuits."

Lynn's butterfly lab

Lynn chose a less common model organism for her course: the painted lady butterfly. "We considered several commonly-used genetic model organisms, such as *Drosophila* fruit flies, *C. elegans* nematode worms and or *Xenopus* frogs," she explains. "However, it's not easy for students to deliver CRISPR into the eggs of these organisms, or to obtain sufficient eggs at all." The embryos of *C. elegans*, for instance, are only 50 µm across – invisible to the naked eye. "While other instructors perform the delivery of CRISPR into model organism eggs on students' behalf, I wanted my students to do the delivery through microinjection themselves," says Lynn.

This led to the selection of painted lady butterflies, which lay hundreds of eggs, each about 1 mm in length. "Using a stereomicroscope, students can use a microinjection system to poke a hole into the butterfly egg and push in the CRISPR components," says Lynn. "It's a process that requires strong hand-eye coordination, but, with practice, students become better and more confident."

And the experience has paid dividends. "The teamwork and class camaraderie has been amazing," says Lynn. "Students have been able to successfully create the desired CRISPR change, and some were even successful in rearing a butterfly with a physical change due to the CRISPR targeting, such as an unusual wing colour. From this, students learn that the gene they are targeting with CRISPR is responsible for normal wing colour development." Lynn also discusses the ethics involved in genetic manipulation with the class. "I showcase real-world CRISPR case studies, and we talk about the bioethical implications," she says. "It's important to me that the students are informed citizens of the world and can communicate about their work."

CRISPR technology has huge potential to benefit society, and the CRISPR in the Classroom Network is ensuring that educators, including Anil and Lynn, are preparing the next generation of scientists to truly make the most of it. How could you be using CRISPR-Cas9 technology in your future career?

About *molecular genetics*

Molecular genetics involves investigating how an organism's DNA affects their phenotype, and how changing the sequence, structure or expression of the DNA leads to changes in an organism's physiology, development or behaviour. Principally, this is achieved through using genetic manipulation techniques, such as CRISPR-Cas9, to genetically modify organisms. "I love how molecular genetics allows me to tinker, stay curious and keep exploring," says Lynn. "I enjoy working with students to answer new questions and to teach them lab techniques." Anil agrees about the excitement of crossing new frontiers. "Gaining new knowledge is one of the biggest rewards of pursuing research in molecular genetics," he says.

CRISPR technologies are rapidly advancing the field of molecular genetics. "CRISPR is becoming a routine tool in molecular biology," says Anil. "It is opening up new opportunities to address finer questions around cellular identity, genome accessibility and epigenetic modifications." CRISPR modifies genes by disrupting them, so they cannot be expressed, or altering them, so that a different version of the gene is expressed.

Previous technologies were capable of doing similar tasks but with a lower level of precision and requiring more resources, time and experience. CRISPR's reliability, universality and ease of use has opened up an endless array of possibilities. "CRISPR is also now being used in other ways," says Lynn. "For example, it can rapidly diagnose viral infections, such as human papillomavirus (HPV), which can cause cancer, and Zika, a virus spread by mosquitoes. Other variants of CRISPR can do different things – for instance, CRISPR-Cas13 targets RNA, not DNA."

Students plating E. coli bacteria on culture plates

Pathway from school to *molecular genetics*

- Anil recommends getting a good grounding in chemistry, mathematics and computational thinking at school and college.
- Both Anil and Lynn suggest taking university courses or modules in biochemistry, genetics, molecular biology and cell biology.

Explore careers in *molecular genetics*

- The University of Alabama at Birmingham, where Anil works, is home to the Center for Community Outreach Development, which offers high school students hands-on science experiences through classes and summer schools: www.uab.edu/cord
- Stetson University, where Lynn works, runs the Stetson Young Scholars programme, which runs weekend workshops, summer camps and more for middle and high school students: www.stetson.edu/administration/young-scholars
- The University of Chicago's Marine Biological Laboratory runs a residential High School Science Discovery Program, which includes a course on CRISPR-Cas9: www.mbl.edu/education/high-school-science-discovery-program
- The US National Science Foundation funds the Research Experiences for Undergraduates programme: www.nsf.gov/crssprgm/reu
  For biological sciences: www.nsf.gov/crssprgm/reu/list_result.jsp?unitid=5047
- According to ZipRecruiter (www.ziprecruiter.com/Salaries/Molecular-Geneticist-Salary), the average salary for a molecular geneticist in the US is around $100,000 a year.

Student using forceps and scissors to carefully cut butterfly wings for analysis

Meet *Anil*

Reading about the pursuit of scientific explorations through biographical and autobiographical works inspired me to become a scientist. I still read a lot today.

Good mentoring, peer interactions, and reading and discussing science all helped shape me as a scientist. These days, interactions with students drive me to continue improving.

Helping develop the 'CRISPR in the Classroom' college teacher network has been a career highlight for me. I'm proud to have developed a successful research experience for first-year undergraduates, to introduce them to CRISPR technology. I'm also leading a project that trains high school biology teachers to teach their students about gene editing and CRISPR technology – it's rewarding to pass on this knowledge and expertise.

I aim to build on these successes in the future. I want to continue to contribute to rich experiences for high school and college students.

Anil's *top tips*

1. **Read at least one biography or autobiography** about a key person in the history of science. It can open your eyes to the background of where we are now.
2. **Keep a childlike perspective** of the world when asking questions. It is always these fundamental questions that are actively pursued in research.
3. **Research is a team endeavour.** Find ways to experience the value of teamwork – it will help you in the future.

Meet *Lynn*

I grew up in Yokohama, Japan, and spent a lot of my childhood playing outside. I immersed myself in imaginative play and exploring nature, and I think this was the foundation for my curiosity about how the world works.

I sought out lab-based research experience as an undergraduate student. It was wonderful and had a profound effect on me, leading me to go on to study for a PhD in cell and developmental biology. My graduate supervisor, Dr Kristen Verhey, mentored me in how to think critically about scientific questions and ways to address them.

I remember the first time I 'stained' cells with dyes to label their proteins and DNA as a graduate student. I used a fluorescent microscope to see these components literally light up in red, green and blue. This is one of my most memorable experiences – peeking inside the inner workings of a cell, the basic building block of life.

A few years ago, I was awarded a grant to develop and implement CRISPR technology for undergraduate students. This allowed me to buy equipment for my classes and hire students to work with me. I am very proud of the students I have mentored, who have gone on to pursue their dreams.

I am proud to have found a balance between family and work. I had my first child when I first started working at Stetson University as a professor, and I now have three beautiful children. My husband is also a professor at a nearby university. Every day, we dedicate ourselves to our family and our professions.

Lynn's *top tips*

1. **Find what excites you and pursue it.** I thought CRISPR technology was interesting but had never been trained in it, so I read about it, figured out how to do it, and am now teaching it to my students and other faculty.
2. **Seek out mentors.** I was lucky enough to work in the lab of an inspirational professor, Dr Roland Kwok, during my undergraduate degree, where I learnt many lab techniques. Before then, I didn't really understand biology at the fundamental level and how to apply it.
3. **Community matters.** Find peers and mentors who can be a support system for you, and that you can talk to about all things science, opportunities, and ways to overcome challenges.
4. **It's okay to make mistakes.** I have made many, but I have learnt from these failures and found a way forward.

Should universities use differential treatment to admit students?

At first glance, a student's exam scores might seem like an uncomplicated way to measure academic ability. However, **Dr Emil Temnyalov,** an economist at the **University of Technology Sydney** in Australia, highlights the effects of socio-economic influences on these scores. The idea that exam results should be assessed differently based on a student's socio-economic background is known as differential treatment, and Emil is investigating whether such policies can improve equality and efficiency in education and labour markets.

Dr Emil Temnyalov

Economics Department, Business School, University of Technology Sydney, Australia

PROFILE

Field of research
Economics

Research project
Investigating whether differential treatment policies improve equality and efficiency in education and labour markets

Funder
Australian Research Council (ARC)

This work is supported by the ARC's Discovery Early Career Researcher Award, under award number DE200100590. The contents are solely the responsibility of the authors and do not necessarily represent the official views of the ARC.

Talk like an ... economist

Differential treatment — treating people differently based on their characteristics to help them overcome disadvantages. Examples of differential treatment policies include positive discrimination and affirmative action, both of which involve favouring individuals belonging to groups considered to be disadvantaged

Game theory — the branch of mathematics that examines strategic interactions in competitive situations, where people's choices dramatically affect one another

Public policy — government actions or guidelines

Socio-economic status — a term used to describe the combination of social and economic characteristics of a person, such as their household income, family circumstances, level of education or occupation

What do you think of when you hear the word 'economics'? Stock markets, unemployment, inflation and recession? While these are the areas of economics commonly in the news, the field is so much broader than this. "Economics is the study of how people make decisions, how we choose where to study and work, how we promote fairness in society and how our lives are shaped by market institutions and government policies," says Dr Emil Temnyalov, an economist at the University of Technology Sydney.

Differential treatment is an example of how economic theories can shape public policies and individual's opportunities. Differential treatment refers to economic and social policies (such as positive discrimination and affirmative action) whereby individuals are treated differently based on personal characteristics. For example, under differential treatment policies, a university offering places to students would not only look at students' exam results, but also consider whether they have been disadvantaged by factors such as their household income or where they live. An employer looking to hire or promote an employee would not only look at their performance at work, but also consider whether that performance had been affected by factors such as parental leave.

Why is differential treatment important?

Consider the following scenario: two students are applying for the same place at university. The first student has an extremely high grade point average (GPA) from their school exams, while the second student's GPA is still good, but not as high. At first glance, the first student seems the obvious choice for admitting to the university. However, upon closer inspection, the university admissions team can see that the second candidate worked part-time after school to financially support themself, so had less time to dedicate to their studies, and they lived in a poorer neighbourhood and attended a lower-achieving school. On the other hand, the first candidate did not need a job so could spend time on schoolwork. They grew up in an affluent neighbourhood with wealthy parents who could afford to send them to a top-class school and pay for one-to-one tutoring to help them prepare for their exams.

In light of these socio-economic factors, the university admissions team might decide to consider an extra advantage for the second candidate in addition to their good GPA, as they managed to do well academically despite the hurdles they had to navigate alongside their schooling. "If a student is clearly disadvantaged in preparing for their university admission exams, should we then interpret their score in the same way as that of a student who is advantaged?" asks Emil.

Is differential treatment fair?

When people think of differential treatment, they tend to think about it in the context of fairness. Is it fair that we let someone with lower school grades take a university

place instead of someone with higher grades? Is it fair to judge a student from a low-achieving school against a privately-tutored student? In employment contexts, is it fair to promote an employee who has missed a year of work because they had a baby, over an employee who has been working continuously for many years? As you can imagine, there are many arguments both for and against these ideas. Using different admission and promotion criteria for different students and employees to combat the disadvantages individuals may face is controversial.

In 2023, the US Supreme Court banned universities from using affirmative action policies to support students who may be disadvantaged by their race, causing heated discussions from both sides of the debate. In contrast, the Australian government has embraced policies to tackle socio-economic disadvantages, and many Australian universities actively favour students applying from high schools with fewer resources. In 2019, the University of Technology Sydney, where Emil works, made headlines when it adjusted the entry requirements for women candidates applying to engineering degrees, in the hope of encouraging more women to study engineering, a field where they are historically under-represented.

When Emil began his research, he found that most public policy debates on differential treatment focused on the idea of fairness. "However, there is generally no consensus in our society regarding what 'fairness' means in the context of socio-economic issues," he explains. Therefore, instead of using fairness as a reference point, Emil decided to study differential treatment from the perspective of efficiency.

What is efficiency?

If we return to our scenario with the two university applicants, looking at the situation from an efficiency point of view would mean choosing the candidate who will most benefit from the university place. Regardless of whether differential treatment is considered fair, the efficiency rationale gives researchers and policymakers another way to look at how and why public policies should consider socio-economic factors.

> ***"If a student is clearly disadvantaged in preparing for their university admission exams, should we then interpret their score in the same way as that of a student who is advantaged?"***

How does Emil study the efficiency of differential treatment?

Emil is using mathematical tools to develop models of education and labour markets, which allow him to definitively state how efficiency can be maximised to improve education and labour market policies. His first tool is game theory, which examines how people make choices in strategic interactions, specifically how we make decisions when other people's decisions affect our outcomes. In the context of university admissions, when a student decides to apply to a university, their choice affects the outcomes of any other students applying to the same university place, as a limited number of candidates can be admitted. Emil's second tool is mechanism design, an economic theory that examines how institutions can distribute resources in a way that achieves a desirable goal. "For example, how can universities allocate their places in a way that achieves efficiency?" asks Emil. Thirdly, he uses information economics, which investigates the informational content of a signal. "For example, what does a university admission score (the signal) mean in terms of a student's potential benefit from a university education?" he asks.

What has Emil discovered?

By combining these three mathematical tools, Emil found that, regardless of opinions about the fairness of differential treatment, it is generally necessary to include differential treatment in policies that aim to maximise efficiency. "If a university wants to admit the candidates who would most benefit from receiving an education, they cannot just reject everyone below a certain cut-off exam score," he explains. "Instead, the university needs to factor in the socio-economic characteristics that may influence a student's scores and customise admission policies for students from disadvantaged backgrounds." This means that efficient admission policies will typically have different admission cut-offs for students with different characteristics.

What other policies can reduce inequality in education and labour markets?

In addition to examining the effects of differential treatment, Emil has also been exploring other policies that could reduce inequality in education and labour markets. He advises that changing the structure of an organisation (such as a school district or a business), either to 'flatten' the structure or to make it 'top-heavy', will help to reduce inequality. In the context of a school district, a flatter organisational structure would separate schools into fewer tiers, while a top-heavy structure would provide more student places at top-tier schools. In a business context, a company with a flatter structure would have fewer levels of employment, while a top-heavy company would have more top-level positions available.

With these insights from his research, Emil hopes that future policymakers will design public policies that not only use differential treatment to improve access to education and promotion opportunities, but that also restructure school districts and businesses in ways that reduce inequality in education and labour markets.

About *economics*

What do economists study?

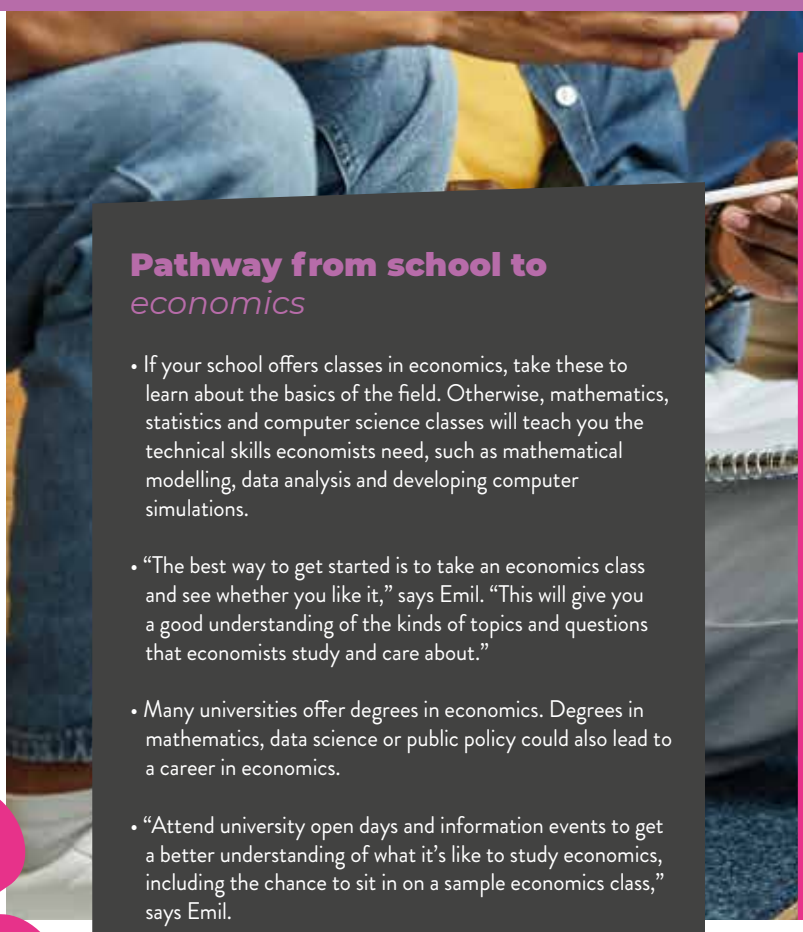
Economics is the field concerned with the production, consumption and transfer of wealth and goods around the world. But what does that actually mean? "Economists study many issues that significantly affect people's everyday lives, such as where we can study, what jobs we can get, what we pay for various products that we buy as consumers, and how we access healthcare," says Emil.

This means economics is about much more than just stocks and investments. It deals with social and public policy issues and is relevant to a huge number of different fields. "Economists study a very wide range of topics, from individual decision-making, to how firms and businesses make strategic decisions, to how markets are regulated and how public policies are designed by governments," Emil adds.

How does economics combine mathematics and social science?

People working in economics use a fascinating combination of both technical and soft skills to solve problems. "On one hand, we build mathematical models, we conduct statistical analyses, and we run computer simulations," says Emil. "On the other, we need good communication skills to write policy papers or communicate with stakeholders in government and in industry, and we also need a lot of creativity to develop novel approaches to solve problems."

"Economic theories allow us to draw very precise conclusions and insights, and to study problems in a formal and accurate way," continues Emil. Rather than explaining economic problems and theories in words, which can lead to vague and confusing conclusions, economists describe economic and social phenomena with mathematical models, representing the problem in a precise and specific language. "This means that we can debate issues and compare different possible solutions with a more rigorous approach," he explains. "In education and labour markets, there are major social issues and public policy problems, so I think it's important to develop clear insights into these using a precise methodology."



Pathway from school to *economics*

- If your school offers classes in economics, take these to learn about the basics of the field. Otherwise, mathematics, statistics and computer science classes will teach you the technical skills economists need, such as mathematical modelling, data analysis and developing computer simulations.
- "The best way to get started is to take an economics class and see whether you like it," says Emil. "This will give you a good understanding of the kinds of topics and questions that economists study and care about."
- Many universities offer degrees in economics. Degrees in mathematics, data science or public policy could also lead to a career in economics.
- "Attend university open days and information events to get a better understanding of what it's like to study economics, including the chance to sit in on a sample economics class," says Emil.

Explore careers in *economics*

- Working in economics could mean working in industry, government or academia. "In industry, economists are often employed by consulting companies, financial institutions and businesses which need data analytics," says Emil. Government work might involve working in central banks or treasury departments, overseeing different markets or evaluating infrastructure and public spending projects. "Universities hire academic economists as lecturers and researchers, because there is a lot of demand for their expertise from students who want to study economics."
- Discover Economics (**www.discovereconomics.co.uk**), a campaign to increase diversity among economics students, has a wealth of information about careers in economics, as well as blogs, podcasts and interviews with people working and studying in the field.
- "There are plenty of blogs and YouTube channels that introduce economics and apply economics to interesting issues in creative ways," says Emil. "Personally, I find game theory to be one of the most fascinating introductions to economics." This video provides a crash course on game theory: **www.youtube.com/watch?v=PCcVODWm-oY**

© SeventyFour/Shutterstock.com

Q&A
Meet *Emil*

What were your interests when you were younger?
During my school years, I was always very interested in computers, video games and foreign languages. In fact, I mostly learnt English from playing video games!

What inspired you to study economics?
Growing up in Bulgaria, I didn't have any exposure to economics in school, because it's not part of the high school curriculum. I first studied economics when I went to the US for university. I found it a fascinating field, which inspired me to study it further in graduate school and to embark on an academic career in economics.

What are your proudest career achievements?
Obtaining a PhD in economics is one of my proudest achievements. A PhD is a very serious and long-term commitment. During this long period of time, you focus quite narrowly on the topics you study, which requires a lot of personal motivation, dedication and self-discipline.

After becoming a university lecturer in Australia, I won a prestigious award from the Australian Research Council (ARC) that is only given to a handful of economists each year. I'm proud of the fact that my research project on equity and efficiency in education and labour markets was deemed worthwhile and awarded funding by the ARC.

What is your favourite fact about economics?
Economics can be applied to virtually anything that involves individual decision-making or public policy! This includes many things that at first glance don't seem to have much to do with economics. For example, during the COVID-19 pandemic, many economists re-focused their efforts towards coming up with ways to mitigate the impact of the pandemic, such as designing better lockdown policies, encouraging people to get vaccinated and improving the incentives for people to act in ways that helped society more broadly. Economics equips you with a very versatile set of skills and allows you to tackle problems creatively across a wide range of issues, far beyond stock markets, unemployment and inflation.

What do you enjoy doing in your free time?
I still love learning foreign languages, and I enjoy reading non-fiction books and watching movies. I also love playing board games, where I can put my game theory skills to the test!

Emil's *top tips*

1. If you are interested in economics, it is important to focus on both your technical and soft skills.
2. Don't be scared of math! In real life, math is a lot more fun than it may seem in school. I think it's exciting that math can be applied to study individual and social issues through the lens of economics. Game theory is a good example of a mathematical field that is great fun.
3. Remember that it's never too late to try something new. For example, I didn't study much math at school, and only really explored it when I went to university.

Why electoral systems matter for democracy

There is huge variety in the methods that democracies around the world use to elect legislators and leaders. **Professor André Blais**, from the **University of Montreal** in Canada, and **Professor Damien Bol**, from **King's College London** in the UK, believe that this variety can lead to very different outcomes – in terms of who gets elected and which policies get implemented.

Professor André Blais

Department of Political Science, University of Montreal, Canada

Professor Damien Bol

Department of Political Economy, King's College London, UK

PROFILES

Field of research
Political science

Research project
Using observational and experimental approaches to analyse how different electoral systems affect voter behaviour and electoral outcomes

Talk like a ...

political scientist

Civic duty — the responsibilities people have in a democracy

Electoral system — the rules on how people vote and how votes are counted to determine who is elected

First past the post (FPTP) — an electoral system where a candidate or party wins through achieving the highest number of votes/a relative majority

Government — the body that makes and enforces laws

Legislature — the body that votes laws into effect

Polarisation — when people are divided into groups that are strongly opposed to each other

Political party — an organisation whose members have similar political views and which puts forward candidates to stand in elections

Proportional representation (PR) — an electoral system where parties gain seats in proportion to the number of votes they receive

Seat — an elected position on a government body, representing, for example, a constituency or electoral area

For centuries, politicians and philosophers have debated what the 'ideal' democratic system is – which system best represents voters' interests. A lot of unknowns still remain around this question, which is made especially challenging to answer given the many other political, cultural and systematic variations between nations. Professor André Blais, from the University of Montreal, and Professor Damien Bol, from King's College London, are political scientists who have joined forces to examine how different electoral systems affect voter and party behaviour.

Variety in electoral systems

We might assume that democracies have similar electoral systems, but, in fact, there is huge variation across countries. "I think people often underestimate the variety of electoral systems that exist around the world," says Damien. "Most people understand the electoral system of their own country and, perhaps, a few others like the US or the UK, but there are so many more than that."

This raises the question of how a country decides on which electoral system it adopts. "Politicians prefer systems that they think will offer them an advantage, and there are also historical and cultural factors at play," explains André. "However, we have only a limited understanding of how these factors lead to such variation between nations."

This introduces a key challenge for the study of electoral systems. "Finding a way to isolate the effect of the electoral system from other political factors is not easy," says Damien. "Countries tend to be different in so many ways – so we have to get creative." This is why André and


© George Fontana/Shutterstock.com

Damien run experiments with simulated elections in the lab, to see how electoral systems influence participants' behaviour. "The first experiment I did with André was in a lab in Montreal, where we put volunteers into two groups and got them to participate in elections under various electoral systems," says Damien. "It was fascinating to see research happening right in front of our eyes like that."

Types of voting systems

While electoral systems vary hugely, many can be grouped into two broad categories: proportional representation (PR) and first past the post (FPTP).

In a PR system, the number of seats a party wins is in proportion to the share of the votes it receives. For example, if one party wins 42% of the votes, it will receive 42% of the seats. This system is used by the majority of European countries and many other nations around the world. "The advantage of the PR system is that it improves the representations of minority viewpoints in the legislature," says André. "PR does result in a more representative government, but this might not translate to policy change." This is because governments run by several parties will find it more difficult to agree on policies. "Differences in party perspectives and promises make it harder to react to shifts in public opinion and adjust the policies accordingly," explains Damien.

FPTP systems, on the other hand, see whichever candidate receives the most votes for a specific seat winning that seat. The party that wins the overall election is the party that wins the most seats. The votes for candidates that lose any specific seat have no direct bearing on the results. This tends to produce single parties holding a majority in government. This system is used in the US, Canada and the UK. FPTP systems can be criticised because they are typically less representative of the population's views; larger parties tend to the number of win proportionally more seats compared to the number of votes

> **"Politicians prefer systems that they think will offer them an advantage, and there are also historical and cultural factors at play."**

they receive, while smaller parties tend to win proportionally fewer seats, if any. However, there are also advantages. "There is evidence that governments are more likely to fulfil their electoral promises under majority systems such as FPTP," says André. "It's easier for parties to fulfil their promises when they govern alone," adds Damien.

Influencing voter turnout

Politicians often debate how to get more voters to turn up at the polls, but André believes voter turnout comes down to one simple variable. "Making voting compulsory increases turnout by 10-15 percentage points," he says. "This is, in part, because people want to avoid penalties, but also because compulsory voting makes people think about civic duty more."

Damien points to further influencing factors. "Many people think that PR systems have higher turnout compared to FPTP systems, but we don't have clear evidence of this," he says. "What seems to matter more is the number of parties involved, which tends to be higher under PR than FPTP; turnout is higher when there are more parties to vote for. We can increase the number of parties in many ways, such as by lowering the bureaucratic requirements to compete in elections."

Measuring democracy's success

Though the study of democracy is complex and multi-faceted, there is a fairly clear way to assess whether an electoral democracy is functioning well. "When parties peacefully accept the outcome of an election when they are on the losing side, electoral democracy works," says André. "Democracy still works well in most established democracies – though the fact that a substantial fraction of Republicans believe that Trump won the US's 2020 election is concerning."

Other factors also contribute to a democracy's success. "By and large, electoral democracies are working well around the world," says Damien. "Studies show that successful parties tend to fulfil most of their electoral pledges, and the policies adopted tend to follow the views of the population. To me, a key challenge right now is to preserve people's faith in elections and representative democracy." A loss of faith in the democratic process can destabilise democracy. "Although a majority of people support democracy, they might lose trust in politicians, especially those not from their preferred party," says Damien. "This might lead them to contest electoral results."

Political science still has many unanswered questions, and André and Damien aim to keep delving deeper into electoral systems. "I am particularly interested in systems that allow voters to support more than one party or candidate, and whether this helps decrease polarisation," says André. Damien aims to look further into how different electoral systems affect losers' consent. "I'd like to find ways to ensure that everybody, including the losers, keeps faith in the electoral process," he says.

About *political science*

The field of political science involves studying systems of government, elections and other forms of political participation, public policies and international relations. It is a highly important field, given that elected (and non-elected) representatives and their governments make the decisions that shape our world for better or worse.

Approaches to political science

André often takes an observational approach to the study of political systems. "I am always curious to see the different rules that exist around the world," he says. "For instance, the outcomes of elections in smaller countries that I am unfamiliar with can often yield important lessons." Damien takes an analytical approach. "I see electoral systems and countries as data points that I use to test hypotheses," he explains. "My ultimate goal is to find ways to make the world a better place."

Variability between nations makes the study of electoral systems complex. "Correctly identifying the consequences of various electoral systems is the main challenge for me," says André. "I like to compare patterns before and after a given system has been modified." Damien adds that a combination of approaches can be especially fruitful. "If we use a variety of approaches and see they all point in the same direction, we can be confident that we're on to something important," he says.

Collaboration

"Unlike in natural sciences, teams of collaborators are usually smaller in political science," says Damien. "It's usually a handful of scholars who work on similar topics that decide to work together on a specific study." However, times are changing, and larger teams with set responsibilities are increasingly becoming the norm. "I see more large teams with a clear division of labour," says Damien. "Students are increasingly involved in these large teams, which is a great opportunity for them to acquire some hands-on experience." Damien says that working in teams is more fun and more motivating, and André agrees. "Working with great researchers, listening and learning from them and, sometimes, convincing them about a method, is pure delight," he says.

Additionally, the rise of the computer age has created big opportunities for political science. "Huge data banks are being created, which opens up all sorts of doors," says André. However, it can be difficult to know where to begin when faced with such vast volumes of data. "Being part of a large team, and having a specific role within that team, can really help a researcher, especially a student, to know how to handle data," says Damien. "I hope that universities will adjust their financial systems to this new reality, so professors have the resources to work directly with students and introduce them to this world."

"Working with great researchers, listening and learning from them and, sometimes, convincing them about a method, is pure delight."

Pathway from school to *political science*

- As well as political science, if it is available, Damien and André recommend taking economics, maths and psychology at school and post-16.
- Suitable undergraduate degrees can include political science, economics, public policy, psychology and sociology.

Explore careers in *political science*

- André recommends looking at *PS: Political Science & Politics*, a journal with many open-access articles that give an overview of the discipline: **www.cambridge.org/core/journals/ps-political-science-and-politics**
- Damien recommends finding political scientists who have done research that interests you. Reading their LinkedIn profile page or visiting their personal website could provide useful tips, links and further information about their work.
- According to Glassdoor, the average salary for a political scientist is around CAN $85,000 in Canada, and around £38,000 in the UK.

Meet *Damien*

I got really into politics as a teenager. I think my interest came from my dad and grandad who used to discuss politics around the dinner table. My high school history teacher was also passionate about the politics behind big historical developments like the American and Russian revolutions, which really fascinated me. That's why I decided to take a political science major at university.

Growing up in a relatively small country like Belgium, our media focused a lot on global politics. I consider this an advantage, compared to larger countries whose media tend to focus on their own politics. I was exposed to different political and electoral systems very early on, which triggered my interest in how differences between systems can shape nations.

I'm convinced of the power of democracy and try to defend it in my research. I aim to find ways to improve the democratic process, as keeping people engaged is essential for stability. I also like the process of research – from having an idea to data collection, to analysis and writing up the results. I love the feeling of finishing an academic paper that will, hopefully, advance our collective knowledge.

Attention to detail, self-discipline and creativity are all attributes that have helped me become a successful researcher. I'm also a 'people person' – I get along with people and love interacting with colleagues and listening to their ideas, goals and problems. Academia is full of people who are so much in their own head that they can seem cold to others; I believe my sociability has helped me reach leadership positions quite early in my career.

I was once told that I should be more selfish in the use of my time and energy. This doesn't work for me at all. I thrive through interactions with others and become miserable when I'm only working on my own projects.

I was the Director of the Quantitative Political Economy Group at King's College London for five years. I was able to really participate in shaping the group, through launching activities such as an annual workshop for PhD students in London that has the reputation of being one of the friendliest and most 'chilled' events in the field. Helping the group grow and increase its visibility and reputation was a huge achievement for me, and the gratitude of my colleagues meant the world.

I'm very excited to be moving to the Paris Institute of Political Sciences, known as Sciences Po. I hope to contribute to this terrific institution like I did at King's. As a native French speaker, I feel I'm also coming back to my 'roots', though I also hope to take over some things I learnt in the UK, such as a slightly different teaching style, which could bring another perspective to students there.

Damien's *top tip*

Pay attention to people around you. Everybody has something interesting to say; this is the best way to learn.

Elected (and non-elected) representatives and their governments make the decisions that shape our world for better or worse.
© Marko Aliaksandr/Shutterstock.com

Meet *André*

I grew up in a time of great optimism for solving collective problems. Political science seemed to be a great choice to take part in this 'quiet revolution'. I studied elections because of my great interest in ordinary citizens, and elections are the simplest way for citizens to engage in politics. I also like maths and quantitative analyses, and political science provides great data to use these skills.

I have a huge curiosity about how people behave. I want to understand how and why people do what they do in elections. I also have a deep scepticism for conventional wisdom – my motto is 'not convinced'! I find this helps a lot in challenging assumptions about the world.

I am proud to have supervised many great PhD students and postdocs. Seeing them go on to thrive in the field, while keeping in touch and even collaborating with them later on, is very rewarding.

André's *top tips*

1. Follow your passion, breed healthy scepticism, and collaborate with others.

2. When faced with a difficult project, work on the most challenging task first – for a researcher, that's usually writing!

Looking to the future with edge computing

Edge computing 'brings the cloud closer' – enabling small and simple technological devices to perform complex functions. **Professor Mahadev Satyanarayanan**, at **Carnegie Mellon University** in the US, and **Professor Nigel Davies**, at **Lancaster University** in the UK, are working on making this life-changing technology part of our everyday reality.

Professor Mahadev Satyanarayanan (Satya)

Computer Science Department, Carnegie Mellon University, Pittsburgh, USA

Professor Nigel Davies

School of Computing and Communications, Lancaster University, Lancaster, UK

Fields of research
Computer science, edge computing, mobile computing, pervasive computing

Research project
Working to make edge computing a reality, to fulfil life-improving functions through applications such as wearable cognitive assistance and technology-mediated serendipity

Funder
US National Science Foundation (NSF)

This research was supported by the NSF under grants CNS-1518865 and CNS-2106862.

PROFILES

Talk like a ...

computer scientist

Bandwidth — a measurement of the amount of information that can be sent between computers via a network connection

Cloud — in computer terms, a global network of servers that operate together to host software and infrastructure, which is accessed via the internet

Cognitive — related to conscious mental activities, such as thinking, reasoning and remembering

Edge computing — an emerging concept that describes a range of networks and devices in close proximity to the user

Internet of Things (IoT) — the network that connects everyday physical devices (which can include anything from traffic lights to washing machines), allowing them to send and receive data

Latency — the delay in network communication, defined by data delivery speeds

Millisecond (ms) — one thousandth of a second

Serendipity — something good happening by chance or 'luck'

Recent decades have seen a massive overhaul in how people live their daily lives, due in large part to increasingly sophisticated technologies. These changes affect everything from how we interact with each other to how we perform daily tasks. For instance, social media and video calls can connect us with people on the other side of the world; powerful search engines provide us with on-hand information on everything from recipes to health advice; and digital entertainment systems are more accessible than ever.

Yet there is still a lot of room to go further – and to go smaller. "Today, the designers of mobile hardware face a difficult choice," says Professor Mahadev Satyanarayanan (Satya), a professor of computer science at Carnegie Mellon University. "They can make their devices very powerful, at the cost of making them heavy, bulky and with short battery life. Or, they can make them extremely light and small, with long battery life, but only able to run simple applications." At least, that is the current situation. Satya believes he has found the answer to sidestepping this trade-off. With his collaborator and fellow

computer scientist Professor Nigel Davies, from Lancaster University, Satya is pushing the frontiers of technological possibility.

Edge computing

"Edge computing makes cloud-like computing resources available to simple devices," says Satya. "It enables them to perform near-real-time tasks that they could not perform with only their own computing resources." The cloud is a distributed collection of servers accessed via the internet, and these servers can be very powerful. Theoretically, we can already access the cloud from any device with an internet connection, but that connection may involve many network hops that each add a small delay. The cumulative effect of these delays may be significant, and may vary unpredictably.

Small, wearable devices, such as smart watches, move around a lot, so to ensure they remain close to the cloud, an in-between step is needed. Satya and Nigel suggest the concept of 'cloudlets', which would mediate access between the cloud and Internet of Things (IoT) devices. This moves processing closer to the user, keeping latency low and bandwidth high – in other words, keeping the system speedy *and* capable of complex tasks.

Technology-mediated serendipity could prompt spontaneous interactions between people.

> **"Edge computing makes cloud-like computing resources available to simple devices."**

Wearable cognitive assistance

To understand why speed is so important, first we need to understand the intended purposes of edge computing. One such purpose is cognitive assistance. "Wearable cognitive assistance is a new class of applications that we describe as 'an angel on your shoulder'," says Satya. "It can help you in your day-to-day tasks and catch errors before they become major issues." Satya envisages such assistance being especially useful for older people, who may suffer from poorer memory and find certain cognitive tasks more difficult. "The possibilities are endless," says Satya. "For example, if you are visually impaired, such a system could guide you as a human assistant might."

For this assistance to work, it needs to be fast. "Humans are remarkably fast and accurate on cognitive tasks, and acutely sensitive to delays in interactions," says Satya. "We see this in virtual reality applications that use head-tracked systems that need latencies of less than 16 ms to achieve perceptual stability – otherwise the latency is noticeable and causes problems." Other cognitive tasks are also breathtakingly fast. Face recognition takes between 370 and 620 ms, depending on familiarity, while speech recognition takes between 300 to 450 ms for short phrases. Only 4 ms are needed to recognise a human voice. "For cognitive assistance technologies to work, they need to exceed humans' cognitive abilities, while being just as fast, or faster," says Satya. "Currently, cloud computing cannot achieve these speeds for most areas, simply because the servers in the cloud are too far away."

Technology-mediated serendipity

Another exciting potential application of edge computing is one which would aid meaningful human interactions. It is well-known that many of the world's best innovations began life as a casual conversation or a chance meeting between colleagues. A transition to an increasingly digital world potentially threatens this wellspring for creativity, as such spontaneous encounters do not really happen in the digital space. Nigel thinks that edge computing could help prevent this risk. "Technology-mediated serendipity seeks to leverage IoT technologies, edge computing, high-resolution video, and a whole host of other elements of computer science to recreate serendipitous interactions without the need for people to be in the same physical space," he says.

Satya and Nigel have invented an imaginary system called 'Pomme' to illustrate this potential. For instance, when a remote worker is having a coffee break, they may set their watch to 'opt-in' for Pomme. A chime alerts them to another colleague similarly away from their desk – maybe somebody in the office having lunch. The two are automatically connected via a video call and begin chatting about their work; they may realise that their projects have a lot of synergy and potential for deeper collaboration.

"Technology-mediated serendipity requires very fast establishment of video and audio connections," says Nigel. "However, as these are unprompted, there are privacy concerns, so the technology must acknowledge these and offer options for filtering video and audio feeds." For instance, if other people are visible, they would need to be obscured by a filter to maintain their privacy. "Determining the appropriateness of connections and performing the relevant filtering is best done as close to the user as possible, to ensure sensitive data doesn't leave their location," says Nigel. "By using cloudlets, edge computing could provide this security."

About *computer science*

"In today's world, computer programming is arguably as fundamental a skill as reading, writing and arithmetic," says Satya. "Software and programming have become indispensable tools in science." Advances in computer science can lead to advances in every other area of science, because they provide powerful data collection and manipulation tools. "Computing and programming are providing scientists with the tools to realise our collective visions of the future," says Nigel. "Software provides almost limitless potential for creativity."

An important aspect of computer science is its application – how it can be used in real society. "Computer science is often creating systems that must operate within existing social and organisational structures, not to mention legal and ethical considerations," says Nigel. "It's important that computer scientists are able to consider these broad issues in their work." Furthermore, like all sciences, computer science is becoming increasingly collaborative. "Modern computer systems are of such a scale and complexity that no one person can create them," says Nigel. "The ability to work as a team is a critical skill for the modern computer scientist."

Recognised as an academic field in the 1960s, computer science is still a relatively young discipline. "Really, we are only getting started!" says Nigel. "The next generation of computer scientists will be involved in creating revolutionary new systems and applications – be it quantum technology or human augmentation."

Pathway from school to *computer science*

- Nigel emphasises how computer science intersects with many other subjects. For example, hardware aspects relate to electronics and engineering, while human-computer interactions relate to psychology and sociology.
- At school and post-16, studying mathematics (and further mathematics in the UK) will give you the widest possible range of options at university. In the UK, you can still study computing without mathematics, but you will have a far smaller set of universities to choose from.
- Additional subjects could include computing itself, if available, along with other sciences or some of the complementary subjects mentioned above.

Explore careers in *computer science*

- Nigel recommends looking at the websites of the British Computer Society (**www.bcs.org**) and the Association for Computing Machinery (**www.acm.org**) to read case studies and interviews and learn more about careers in computer science.
- There are vast amounts of free online resources for computer programming, which can be a useful way to see if you enjoy the topic. For example, W3Schools provides a tutorial in Python: **www.w3schools.com/python**
- According to Indeed, the average computer scientist salary is around $108,000 in the US and £54,000 in the UK.

Meet *Nigel*

My uncle was a research scientist with British Telecom. He had a Commodore PET computer at home that I learned to program on. This is what kick-started my interest in computer science.

My careers advisor at school told me not to bother applying to university! Computers were fairly new at the time, and I think they didn't see their potential. Fortunately, I ignored their advice and applied anyway – definitely the right choice.

When I encounter obstacles, I go for a stroll. Often the answer comes to me while I'm out walking. Outside of work, I relax by playing music with friends and colleagues.

I am very proud of my former PhD students who have gone on to have great careers. In technical terms, I'm most proud of a really early mobile tour guide system we created back in the late 1990s. It provided a glimpse of the future, with many features that are now seen in modern apps.

I'm now focusing on creating some new cutting-edge laboratories for teaching cyber security and computer science. Once I've completed that project, I'm looking forward to carrying out new research into memory augmentation.

Nigel's *top tips*

1. Work on something that you are passionate about. I love what I do, so going into work is a daily joy.
2. If you want an academic career, remember it involves both sharing your knowledge through teaching, and creating new knowledge through research. To be successful you need to be good at – and enjoy – both these elements.

Meet *Satya*

From my very first experience with computers in 1973, I was hooked. I was an undergraduate student in India, and the university received its very first computer that year – one operated using punched cards. I attended an introductory programming course in FORTRAN (a programming language), taught by the inspiring Professor H.N. Mahabala. The experience of being able to get a machine to do complex intellectual tasks perfectly and reproducibly was totally awesome.

> ***The experiences and insights that I gained were priceless and gave me the opportunity to work with some extremely talented and wonderful people.***

From 1983 to 1986, I worked on the Andrew Project (en.wikipedia.org/wiki/Andrew_Project) at Carnegie Mellon University – a transformative experience. We knew very little about distributed systems then, but we learnt as we went! We were trying to build a system for use at scale, rather than a pure research system. The experiences and insights that I gained were priceless and gave me the opportunity to work with some extremely talented and wonderful people.

Creating the Andrew File System and the Coda File System back in the 1980s and 1990s are some of my proudest career achievements. Later, I worked on mobile computing, which brings with it unique challenges. Addressing these mobility-related challenges eventually led to the technical insights that form the basis of edge computing today. I'm excited to see where this development leads next.

Satya's *top tip*

Building systems that really work is challenging. A simple concept may involve weeks of hard work to reach a smoothly functioning system, but the effort is well worth it, and all the troubleshooting and dead ends along the way are the best way to gain deep insights into the system you are building. Most importantly, it is extremely satisfying to see your code work!

Cyber security for the AI age

As the digital world grows in power and complexity, so do the threats it faces. There is a constant arms race between cyber security and cyber criminals, both rushing to outcompete the other in sophistication. This means that the field of cyber security is rapidly growing and hungry for new talent that can understand the evolving threat landscape and respond accordingly by embracing new technologies, says **Dr Burcu Bulgurcu** at **Toronto Metropolitan University** in Canada.

Dr Burcu Bulgurcu

Assistant Professor, Department of Information Technology Management, Toronto Metropolitan University, Canada

Rogers Cybersecure Catalyst Research Fellow, Toronto Metropolitan University, Canada

PROFILE

Fields of research
Cyber security, information privacy

Research project
Understanding human behaviour to promote cyber security and privacy practices

Funder
Canadian Social Sciences and Humanities Research Council (SSHRC)

This work is supported by the SSHRC of Canada, under Insight Development Grant number 430-2021-01150. The contents are solely the responsibility of the authors and do not necessarily represent the official views of the SSHRC.

Talk like a ...

cyber security expert

Cyber security — the protections and measures taken against digital threats, namely cyber criminals

Generative AI — artificial intelligence that is capable of generating media (such as text or images). Generative AI uses models that learn from training data to generate new data with similar characteristics

Malware — software specifically designed to damage or criminally exploit a computer system

Threat landscape — the collective potential cyber security risks and dangers faced by a sector or individual

Today, more companies than ever are operating in the digital space. As organisations become increasingly dependent on online resources, they run the risk of being targeted by cyber criminals aiming to steal their assets, blackmail employees, or damage their business with malware, ransomware or other types of attacks. "Digitalisation is helping organisations to enhance communication and collaboration efforts, to innovate, and to stay competitive," says Dr Burcu Bulgurcu, a cyber security researcher at Toronto Metropolitan University. "However, without robust IT infrastructure and proper investments in security efforts, organisations lack the necessary backbone for security, leading to serious business vulnerabilities."

Burcu studies cyber security, but not in the way that involves delving deep into computer code. Instead, she studies how people's decisions affect their online security and privacy, and whether their behaviour can be nudged towards adopting stronger safeguards online. "I am interested in human-computer interaction and interface design," she says. "For instance, I designed app interfaces with different levels of privacy controls, to understand how availability of these controls affects user perception and concerns around privacy."

Cyber security breaches are rarely due to issues with the cyber security technology itself. Instead, they are caused by human error due to a lack of understanding and awareness of cyber security risks. Burcu's research findings are helping policymakers and educators incorporate the behaviours and motivations of technology users into their work.

The threat landscape

Cyber security professionals refer to the cyber 'threat landscape', which describes the scope of identified and potential threats affecting a particular context, such as a sector or group of users. "The threat landscape evolves rapidly and constantly," says Burcu. Cyber security company BlackBerry reports that the healthcare and financial services are those most frequently targeted, as both hold large volumes of sensitive personal information that can be hijacked by criminals

© thinkhubstudio/Shutterstock.com

to hold these services at ransom. Additionally, financial services also provide access to large sums of money, which criminals try to access through mobile banking malware.

There is evidence that cyber attacks have been increasing in recent years. "Every year, the numbers get worse and show that we are far from being able to mitigate and contain the numerous cyber threats that target both industry and government," says Burcu. "Organisations are increasingly under pressure to protect themselves, but many security professionals report that their organisations are not sufficiently prepared." Between March and May 2023, BlackBerry saw a 13% increase in cyber attacks involving new malware from the previous 90-day period. "This demonstrates that attackers are diversifying their toolkit to try and bypass defences," says Burcu.

An emerging and especially damaging form of attack involves targeting digital supply chains. Many organisations buy software from suppliers, which is then downloaded onto company computers. "Supply chain attacks happen when a cyber criminal compromises this software before the product reaches customers," says Burcu. "This provides an opportunity for the malware to reach several organisations at once, creating a ripple effect and potentially impacting thousands of victims." It is estimated that software supply chain attacks hit 60% of companies in 2021.

The rise of AI

Artificial intelligence (AI) is a game-changer, and nowhere more so than within cyber security. "Both cyber attacks and our responses will become more intelligent due to generative AI," says Burcu. "In recent years, malicious actors have been employing AI to compromise corporate networks and interfere with business activities." AI can exploit a whole range of weaknesses – many human in origin – that previously were not available. "A generative tool, such as ChatGPT, can be used to generate a personalised phishing message based on a company's information and staff," says Burcu. "For instance, an AI bot can call an employee, using a deepfake voice that sounds like their boss, to ask them to transfer funds to a certain account."

> **"It's important to educate people on cyber security to raise awareness and establish responsible digital behaviour as a norm."**

Responding to these threats requires not only advanced technologies, but also training people to be aware of risks that previously did not exist. "It's important to educate people on cyber security to raise awareness and establish responsible digital behaviour as a norm," says Burcu. "Most people will easily trade a long-term goal, such as protecting their security, with a short-term goal, such as immediately accessing a digital resource." Most people readily accept the default privacy settings and security policies for apps or programmes without reading them. While people might say they are concerned about their privacy or security, their behaviour rarely reflects this priority.

A holistic approach

"For the next generation of cyber security professionals, I believe that the most crucial skill to develop will be critical thinking," says Burcu. "This should be coupled with the ability to approach issues holistically, and to work collaboratively within an interdisciplinary team. Today's sophisticated attacks cannot be addressed with a one-dimensional approach." Burcu believes that it is vital for tomorrow's cyber security professionals to understand not only the technical side of the challenge, but also human behaviour and social sciences.

In Burcu's research, she uses both qualitative methods, which include interviewing people and analysing their responses, and quantitative methods, such as gathering data via surveys and social media and statistically analysing them. She conducts experiments to explore how people interact with different digital interfaces and what this means for their online privacy. She also analyses organisations' enterprise social media data by using advanced analysis techniques such as machine learning and natural language processing. This is to show that selected privacy settings of teams (and therefore whether organisational communications are private or transparent) can affect their performance, creativity and innovative output.

Achieving this breadth of knowledge is challenging, especially when the field is changing all the time, but Burcu says that is what makes cyber security and information systems so interesting. She enjoys understanding users' backgrounds and cultures, and unpicking the complex systems that govern our interactions with technology. "It's not just within cyber security that this holistic approach is needed," says Burcu. "Other professionals, such as doctors, will need to understand how to use digital technologies to support their patients and protect their sensitive personal information."

By ensuring that digital information and resources are kept secure and confidential, the next generation of cyber security professionals will be responsible for keeping us safe from cyber threats.

Explore careers in *cyber security*

"Career options in cyber security are limitless!" says Burcu. Entry-level positions include IT or network support specialist, cyber security analyst or system administrator. With some experience, these roles can evolve into higher level positions, such as penetration tester, vulnerability analyst or cyber security supervisor. Other careers in the field include incident responder, security operations analyst, network security specialist, security architect, cyber security researcher or digital forensic analyst.

"There is a significant talent shortage in both technical and non-technical roles in the field of cyber security," says Burcu, which means cyber security professionals are in high demand. "In fact, they are in such demand that this might be one of the few scientific fields where a young person with a keen interest could secure employment without a traditional university degree." If you are passionate about cyber security, you could gain work experience and certification that could lead to a direct job in the field.

The skills needed for a career in cyber security are changing at an incredible pace. Creativity, critical thinking and communication skills are becoming more important than ever. "It's important that we, and future generations, leverage the latest advances, such as AI and other emerging technologies," says Burcu.

Cyber security encompasses many different fields, including non-technical roles. For example, for organisations to comply with the growing list of cyber security laws and regulations, they need lawyers and policymakers who understand the implications of cybersecurity and information privacy. "If you aspire to become a computer scientist or cyber security professional, it is still essential to understand the fundamentals of human behaviour and social sciences in our hyper-connected digital world," says Burcu. "In my work, for example, I investigate human behaviour and design user friendly interfaces that encourage people to adopt more protective behaviours."

Pathway from school to *cyber security*

- At school, Burcu recommends studying computer science, information technologies (IT), mathematics, and programming. She also suggests finding courses that introduce you to networking, operation systems, risk management, information privacy, big data and ethics.
- At university, degrees in computer science and IT could lead to a career in cyber security. However, cyber security careers can also be obtained through non-technical programmes, such as business administration, management information systems or law. Most of these degrees have started to offer programmes related to cyber security, privacy, data protection, governance, criminology, digital forensics, legal research and compliance to prepare students for non-technical roles in cyber security.
- "You don't need to be highly technical to work in the field," says Burcu. "If you are interested in technology and willing to learn the fundamentals, you can find a way to integrate your background or interests into the field of cyber security."
- Currently, the talent gap is so big in the industry that you may secure a job in cyber security without a university degree. There are many official bodies with which you can gain qualifications and certification in cyber security, including ISC2 (**www.isc2.org**), CertNexus (**www.certnexus.com**), Global Information Assurance Certification (**www.giac.org**) and ISACA (**www.isaca.org**). "Toronto Metropolitan University offers a great security programme to qualify you to take the Certified Information Systems Security Professional (CISSP) exam (**www.isc2.org/certifications/cissp**) and other similar examinations, focusing on technical and managerial aspects of cyber security," says Burcu.

Burcu's top tips *for staying safe online*

- Think before sharing something online. Rationally assess what you would gain or lose by releasing that information to strangers. Being conscious of your actions is the first step towards long-term safety.
- Take time to review and adjust the privacy settings on your social media accounts and electronic devices.
- Use strong passwords. Avoid using the same password on multiple platforms. Use a password manager to help you remember your passwords.
- Be aware of phishing attacks, including unsolicited emails, messages or links.
- Be cautious when downloading files from the internet.
- If you encounter any inappropriate or harmful content or behaviour online, report it to someone you trust, such as a parent, teacher or the police, and do not engage with it.

Meet *Burcu*

When I was younger, I enjoyed science and mathematics. I was surprised when a high school teacher advised me to study something related to technology at university, because at the time (in 1998), the internet wasn't commonplace. I remember him saying, "Even kitchens will be equipped with computers in the future," and today, you can get a fridge that connects to your phone!

At the age of 25, fresh from completing my education in Turkey, I took the bold step of applying for PhD programmes abroad. I lacked academic connections to reach out to for guidance, but I was determined to make my dreams materialise. I was offered a PhD with full scholarship in Vancouver, Canada, and emigrated solo, leaving behind my family, friends and support system. Looking back, I reflect on the magnitude of that decision. For me, the courage I showed is my proudest accomplishment. This was a time when expressing myself in a foreign language and adapting to an unfamiliar culture were still uncharted territories, and leaving my homeland was a new experience.

I decided to study cyber security and privacy at graduate school. I realised how impactful rapid digitalisation could be, and how vulnerable it could make individual technology users, given technological advancements are always far ahead of policy, regulation and legislation.

To my astonishment, my studies took me into the social sciences. During my PhD studies in information systems, I found myself focusing on understanding human and organisational behaviours. It is fascinating to look into how technology affects our behaviour, and what underpins our motives. This involves not only conscious motivations but also the covert realm of unconscious beliefs and biases. This leads me to draw insights from disciplines such as business, psychology, neuroscience and organisational behaviour, as well as computer science.

> ***I lacked academic connections to reach out to for guidance, but I was determined to make my dreams materialise.***

I quickly learnt the problem of cyber security is not just technical. It also relies on social science, depending on awareness and training, so people understand the possible consequences of leaving digital footprints online by engaging with different technologies. By studying human behaviour, we can look into crafting user interfaces that help users make more informed choices. I'm fascinated by how we can design digital technologies to nudge users towards safer online actions, to protect them in the long term.

These days, spending time with my two young children is my biggest enjoyment. We like to be active and travel together as a family. I also enjoy yoga and painting for relaxation.

Burcu's *top tips*

1. Embrace life's tests. You will inevitably encounter challenges and failures, but these can be rich with lessons that contribute to your growth and resilience.

2. Balance aspirations and flexibility. While it's important to set goals, it's equally vital to avoid them becoming rigid and unyielding. Being adaptable and flexible is indispensable for making the most of opportunities as they arise.

3. Embrace the rapidly changing technological landscape. Technology is reshaping our lives and opening new doors. AI is helping us tackle intricate challenges. Grasping this transformative power is essential for the next generation.

How to use our education and career resources

You will find a great range of free, inspiring research articles at **futurumcareers.com/articles**

Learn key terminology relating to the field

Meet the people behind the research

Read about fascinating research projects that are happening right now

Explore fields of research, and learn about future career opportunities

Consider different educational options

Find out how the researchers got to be where they are today

Read advice from inspiring people

Many of our articles are accompanied by an animation, PowerPoint and/or podcast:
futurumcareers.com/education-resources

POWERPOINTS
Our career PowerPoints summarise research projects, highlight researchers' careers guidance and prompt you to reflect on your own skills:
futurumcareers.com/ppts

ANIMATIONS
Our animations bring the research project to life and include a downloadable script with suggested activities:
futurumcareers.com/animations

PODCASTS
Listen to researchers recount their own experiences and career pathways, and be inspired!
futurumcareers.com/stem-shape-podcasts

ACTIVITY SHEETS
Check your understanding, develop your knowledge, think critically, evaluate and continue your learning:
futurumcarees.com/activity-sheets

Keep in touch.

Thanks for reading Futurum. Did you know that all our articles and accompanying activity sheets, PowerPoints and animations are available online?

Visit our website: **www.futurumcareers.com**

We regularly publish new articles, activity sheets, PowerPoints and animations. Keep up to date by signing up to our monthly newsletter: **www.futurumcareers.com/sign-up**

Contact the researchers in the articles

Go to futurumcareers.com/articles

Select the article and scroll to the bottom

Type your question in the comments field

Click 'Notify me of follow-up comments via email'

Click 'Submit Comment'

Follow us

for updates on new instant articles, blogs and events:

Tell us what you think

We would LOVE to hear from you: send us a message through social media, comment on our articles or blogs, or send us an email: **info@futurumcareers.com**

futurum
Inspiring the next generation

The work presented in this document has received funding from the European Union's H2020 research and innovation programme – project Scientix 4 (Grant agreement N. 101000063), coordinated by European Schoolnet (EUN). The content of the document is the sole responsibility of the organizer and it does not represent the opinion of the European Commission (EC), and the EC is not responsible for any use that might be made of information contained.