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INSPIRING THE NEXT GENERATION

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CAREERING AHEAD

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CAREERING AHEAD

Between 2010-2018, less than two-thirds (63%) of students aged 15-16 reported having received any careers education and only half had undertaken work experience. This is one of the findings from a report published by academics working on ASPIRES 2, a mixed-methods research project that investigated young people's science and careers aspirations in England from ages 14 to 19.

"We found that careers education provision was patterned by social inequalities, with working-class, minority ethnic students, girls and lower-attaining students being significantly less likely to receive and benefit from high quality careers support," the report states.

High quality careers education is essential for encouraging and maintaining a diversified and flourishing workforce. It is for this very reason that Sir John Holman was commissioned by the Gatsby Foundation to devise a framework for world-class careers guidance in England (p 50). Happily, this framework, known as the Gatsby Benchmarks, is starting to take effect.

"We now know that, on average, for each benchmark a school achieves, that increases the number of students who are in employment, education or training by 1.4%," says John.

Then there is Jack Parsons, the UK's Chief Youth Officer, who is on a mission to help young people thrive (p 4). He founded The Youth Group, which aims to support young people and connect them with opportunities in the world of work. "With so many opportunities entering our doors every second, there is a huge amount of hope for young people," he says.

The researchers in this issue have collaborated with Futurum to produce careers and education resources that not only add to classroom practice but also meet Gatsby Benchmarks. They are passionate about supporting teachers and the next generation in any way they can. As linguistics expert Professor Nelya Koteyko says (p 34), "Do not be afraid to contact academic researchers about their work – they will be excited to hear that someone is interested, and happy to give their advice!"

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FOR EXAMPLE:

Animations for **Professor Peter Gammon** (p 70), **Dr Sam Rowe**, **Dr Víctor Gómez** and **Marcial Tapia** (p 78), **Professor Andrew Nunn** (p 92) and **Dr Erik Andersen** (p 96) will soon be available.

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HOW TO FIND CAREERS SUPPORT IN AN EVOLVING LANDSCAPE

JACK PARSONS GREW UP WITH BIG AMBITIONS, BECOMING CEO OF HIS OWN COMPANY WHEN HE WAS 25 YEARS OLD AND THE UK'S CHIEF YOUTH OFFICER. HE TELLS US MORE ABOUT THE YOUTH GROUP, ITS RESOURCES FOR YOUNG PEOPLE AND HOW HE MANAGED TO FIND CAREER SUCCESS DESPITE OTHERS' LOW EXPECTATIONS FOR HIS FUTURE

ABOUT JACK

© Jack Parsons

Jack, the UK Government's Chief Youth Officer, a global mental health ambassador and founder of The Youth Group, did not have the easiest start in life. He comes from a low income family, is dyslexic and had very little support from his school, but he did not let these challenges prevent him from being ambitious. Jack delivered newspapers in his early teens to fund judo classes and, after leaving school, took an apprenticeship with a local insurance broker. After the company folded, and a few months trying to find work without a degree, he was taken on by a recruitment firm. By the age of 21, Jack became top biller, made £700,000 in revenue for the company and won awards. And yet, he still found that there were fewer opportunities open to him without degree-level qualifications. This is when he founded The Youth Group, a social enterprise that helps connect young people with relevant opportunities and prepare them for the world of work.

IN A RECENT INTERVIEW FOR *CHILDREN & YOUNG PEOPLE NOW*, YOU SAID, "NO ONE AT SCHOOL HAD HIGH HOPES FOR ME". WHY WAS THIS SO?

With 32,028 schools in the UK and so many moving parts, there's bound to be challenges. In my case I was one of the unlucky ones. Teachers do such a good job with the resources they have, but I was missed. Those I looked up to, looked down at me. Far more progress has been made now, although there will be other young people like me still feeling like there's no one they can trust or confide in. One thing I've kept close to my chest is never letting feelings of despair tear me down because there is always a future that awaits.

YOU ALSO SAID THE SCHOOL SYSTEM WAS UNLIKELY TO HELP YOU GET THE RIGHT OPPORTUNITIES IN LIFE. WHAT OPPORTUNITIES ARE YOU REFERRING TO?

I have a curtain analogy. Everyone has the ability to open a curtain, and what lies behind the curtain is opportunity. One person may have the power to unveil a career curtain for you, or a curtain that expands your network, or help you connect to people who have two curtains instead of one. This is why aiming to open as many curtains as possible, regardless of the barriers others may place on you, is worthwhile.

Lots of young people will be experiencing the same things. In my case, after looking at my mock exam grades, the careers advisor said I should work on a building site because I wasn't going to reach my grades. When exams were over, I achieved 11 A* to C grades and I chose a different path to the one laid out for me. This is something that wasn't explained to me – the idea that you can say no to what you have been advised.

HOW DO YOU THINK YOUR LIFE WOULD HAVE BEEN DIFFERENT IF YOU HAD BEEN GIVEN SOLID CAREERS ADVICE AT SCHOOL?

There are an incredible number of careers entering the market now that didn't exist 20 years ago. Vlogging and digital marketing are just two examples that have absolutely erupted as a result of the booming technology

sector. Therefore, the question should not be: 'What does solid careers advice mean to you?' but 'How might the correct advice support me in an evolving landscape?'. This is a much more challenging question due to the uncertainty our futures hold – even if statistics can be used to predict growth areas.

What I can say is that I'm incredibly grateful to those who have opened curtains for me to now focus my attention on enabling young people to thrive across the UK.

AS THE UK'S CHIEF YOUTH OFFICER AND CEO OF YOUR OWN BUSINESS, YOU ARE PROOF THAT OPPORTUNITIES ARE OPEN TO PEOPLE FROM DISADVANTAGED BACKGROUNDS. AREN'T YOU?!

I absolutely agree. Opportunities are now far more accessible due to the internet providing us with increased access to individuals living thousands of miles away. The world of work has been sliced in half, with freelancing opportunities allowing people to get closer to being their own boss.

However, this then leads to a digital divide. Those who don't have access to technology that will enable them to make magic happen fall behind, which is why there needs to be a huge drive to ensure that those from disadvantaged backgrounds have access to the tools they need to fulfil their potential in today's world.

EARLIER IN THE YEAR, YOU MET UP WITH THE UK CHANCELLOR RISHI SUNAK AND HAVE MET OTHER UK MINISTERS. WHAT DOES YOUR ROLE AS UK'S CHIEF YOUTH OFFICER ENTAIL?

I'm very supportive of government officials who put their money where their mouth is when it comes to keeping two ears open to hear what the challenges are for young people.

To me, being the UK's Chief Youth Officer means enabling as many young people to thrive as possible across the nation. It's a public figure role that champions the interests of all young people across the country, getting them heard at the board table and officially in government. This is achieved in large part thanks to opportunities provided through The Youth Group, the 1.7 million young people in our community and the work my team does to support this role.

IN AN INTERVIEW WITH THE BBC, YOU ADVISED UNIVERSITY STUDENTS STRUGGLING TO FIND WORK PLACEMENTS TO RIP UP THEIR CVS. WHY?

Many may disagree with me, however, there's a feeling amongst young people that no matter how many CVs they send, little to no progress is made. Not to mention how difficult it is for recruiters to read and process CVs. This makes it an inefficient system, leading to shortcuts being made, which, in turn, means young people are inevitably left behind.

Recruiters spend on average six seconds looking at your CV before they decide to look into it further or reject it. The formatting in CVs also becomes distorted online, meaning that your CV can look very different on one device compared to another. A lot of space is wasted on additional lines and columns. There can be a boost of at least 25% which will enable the evidencing over more meaningful traits.

CVs need to be revised to reflect the many experiences young people do have rather than what they don't have, which many recruiters tend to focus on.

ARE YOU HOPEFUL THAT THINGS WILL CHANGE FOR THE BETTER FOR YOUNG PEOPLE?

Absolutely! With so many opportunities entering our doors every second, there is a huge amount of hope for young people. Never before could a young person have the flexibility many corporations and small companies are starting to offer. Everyone can be their own boss if they have a side-project that could turn into a business.

THE YOUTH GROUP

THE YOUTH GROUP IS A YOUTH-FIRST ORGANISATION THAT PROVIDES YOUNG PEOPLE WITH THE TOOLS THEY NEED TO GET AHEAD IN THE WORLD OF WORK. CEO AND FOUNDER **JACK PARSONS** EXPLAINS HOW THE YOUTH GROUP HAS HELPED OVER 90,000 YOUNG PEOPLE ALL OVER THE WORLD

WHAT BARRIERS DO YOUNG PEOPLE FACE IN THE WORLD OF WORK TODAY?

The main challenge for young people today is finding a reliable network of professionals and role models. Not having those essential contacts can really impact the confidence and mental health of those who are just starting out, leading them to miss out on valuable opportunities. This is especially true since the pandemic, which has increased a sense of isolation.

However, we are living in the best time to make important connections, with social media playing a key role in forming professional networks and developing a personal brand.

HOW DOES THE YOUTH GROUP HELP YOUNG PEOPLE TO OVERCOME SOME OF THOSE BARRIERS?

I founded The Youth Group because I was asked by young people to create a place for them to access opportunities. After researching this further, I knew young people were facing unique challenges in the workplace that were not being addressed.

There are many barriers facing young people today. However, it all starts with defining what a barrier is. Barriers could be parents, universities, The lack of opportunities, etc. The biggest barrier right now for young people is a lack of hope for their future. So now, the question is, how do we increase young people's hope for their future? Very simply, we connect the dots. This could be connecting the dots between mentors and young people, giving young people job opportunities or ensuring young people have that sense of confidence in companies they wish to go into – elements we are focusing at a grassroots level.

WHAT NEEDED TO HAPPEN TO SET THE YOUTH GROUP UP?

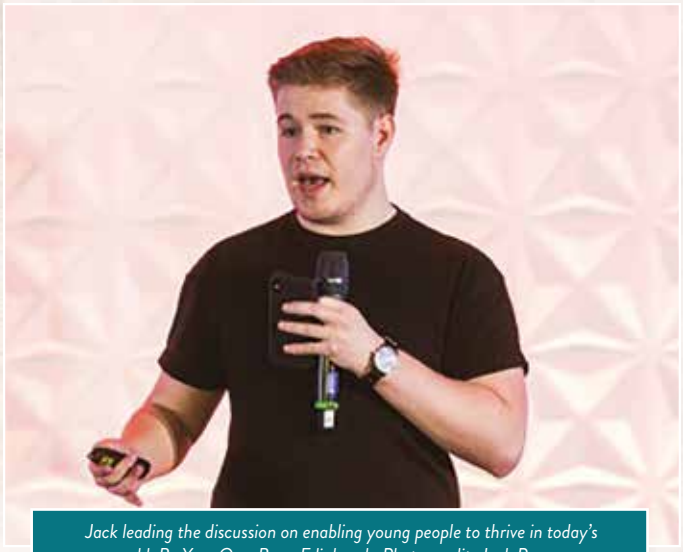
A mentor once said to me, "Surround yourself with smarter people than you". This is the first step I had to take to ensure a company, which meaningfully supports young people, was created. Everyone has the ability to find a mentor through the work we do at The Youth Group. We are opening doors for thousands of young people to enable them to be their own boss.

When you find yourself a mentor, what do you do with them? Listening and putting their advice into practice are the two next steps I had to take. If you're used to getting things done on your own, you learn to trust yourself, however, it's a double-edged sword because then it becomes very easy to get in the mindset you know best, when, in fact, there is always more and more to learn.

THROUGH THE YOUTH GROUP, YOUNG PEOPLE CAN ACCESS MENTORS. WHAT CAN THEY EXPECT FROM THE LIKES OF MARTIN MOLL, CHIEF MARKETING OFFICER AT HONDA, JESS BUTCHER (MBE), CO-FOUNDER OF TICK, OR RAKESH PATEL, DIRECTOR AT SPOTIFY?

Expert navigators. Navigating the job market without connections or guidance is a daunting task; our mentors can bridge that knowledge gap by giving mentees an essential insight into how to achieve self-realisation.

Regardless of whether a mentor is employed at an organisation that can offer that 'dream job', or has a recognisable name, young people can expect a variety of confident leaders dedicated to their personal and professional development.



Jack leading the discussion on enabling young people to thrive in today's world, Be Your Own Boss, Edinburgh. Photo credit: Jack Parsons

Jack hosting a panel in front of a large and engaged crowd of young people, The Youth Group Live Sessions, London. Photo credit: Jack Parsons

THE YOUTH GROUP ALSO HAS A JOBS BOARD, PROVIDING YOUNG PEOPLE WITH ACCESS TO APPRENTICESHIPS, WORK PLACEMENTS, GRADUATE PROGRAMMES AND MUCH MORE. HOW IS THE YOUTH GROUP ABLE TO OFFER ACCESS TO EXCLUSIVE JOBS THAT AREN'T AVAILABLE ONLINE?

Jobs boards are brilliant! What makes ours so special is the ringfenced opportunities we bring to the table, making it super tantalising for the young person joining because they will have access to a world of opportunity. Many of the amazing partners we have see this, which is why they sign up to meaningfully support the young people in our community.

ON THE JOBS PAGE, THE YOUTH GROUP PROMISES 'NO MORE LONG AND BORING APPLICATIONS'. HOW ARE YOUNG PEOPLE RECRUITED TO THE ROLES ON OFFER?

We simplify what we do to evidence what skills young people have over what they don't have, which, in effect, is a method to break the circle of 'no experience, therefore, no job, therefore, no experience'.

Instead, we have profiles dedicated to ensuring that the best possible pairings are made, between job roles and applicants. These profiles have been hugely popular with our youth applicants, which is why they're a bigger part of the process now.

SO FAR, 90,432 YOUNG PEOPLE HAVE BENEFITED FROM THE YOUTH GROUP, WHICH PLEDGES TO PUT TWO MILLION YOUNG PEOPLE INTO WORK ACROSS THE WORLD. WHAT WILL HAPPEN WHEN THIS PLEDGE HAS BEEN ACHIEVED?

A network is only as strong as its reach. Continuing to grow and adapt to a changing market will be essential to remain relevant, and to ensure that the challenges young people will face in five or ten years will always be addressed.

Diversity in backgrounds, experience and walks of life is and will continue to be a priority at The Youth Group, even when we reach our current goal.

ENGAGE WITH JACK AND THE YOUTH GROUP!

- JacksonRParsons
- Jack Parsons
- theyouthgrouphq
- The Youth Group
- The Youth Group Music List
- theyouthgroupuk

HOW TEXTS FROM THE PAST CAN SHAPE AND INFORM THE FUTURE

DR ALISON SEARLE, BASED AT **THE UNIVERSITY OF LEEDS** IN THE UK, IS ENGAGED IN A PROJECT THAT ANALYSES 17TH-CENTURY ARCHIVAL DOCUMENTS FROM THREE FAITH COMMUNITIES TO ADDRESS SOME OF THE CONTEXTS IN WHICH CAREGIVING HAS EMERGED. THE FINDINGS WILL HIGHLIGHT HOW HISTORICAL PRACTICES OF PASTORAL CARE AND HOLISTIC WELL-BEING INFORM THE PRESENT

GLOSSARY

ARCHIVAL – relating to an archive, a collection of historical documents

COLONIAL – relating to a colony, where settlers have taken control of/occupied another land

CATECHISE – instruct/teach Christian principles

MISSIONARY – a person sent to promote the Christian faith in a non-Christian country

NONCONFORMIST – a Christian of the Protestant Church who did not conform to the rule of the Church of England

PASTOR – a Christian minister or priest

PRESBYTERIAN – a type of Protestant Christian

In an age where emails clutter up inboxes around the world and we conduct conversations using instant messaging apps, such as Facebook Messenger and WhatsApp, letter writing has decreased in popularity.

However, this was not always the case – and let us be thankful for that, because the letter form can provide fascinating historical insights that shine a light on many aspects of life, society and the people who penned letters in bygone times.

Dr Alison Searle is an Associate Professor of Textual Studies at the University of Leeds in the UK who is acutely aware of the power of letters and other historical documents. One of the key things such texts reveal is context – by poring over archived materials, researchers gain a sense of how certain things were and how they may have shaped how things are now.

However, any textual studies come with a caveat – archival research is complex, in that it involves a history of suppression. We might ask whose documents get preserved, and who can access them? Are issues of survival and access simply about one's personal identity, or part of a broader social world?

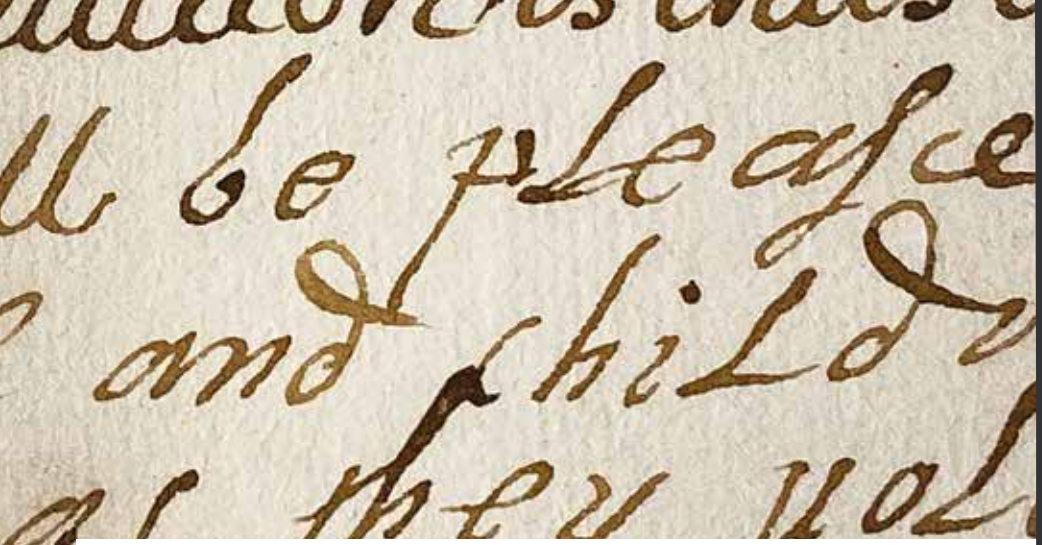
Alison is currently engaged in a project that is focused on the description and analysis of the concept of pastoral care within three faith communities that operated across the British Atlantic between 1630 and 1720. By analysing texts from this period, Alison hopes to understand how pre-modern care practices helped shape and inform those of today.

WHAT IS MEANT BY 'PASTORAL CARE'?

The focus of the project is on pastoral care in historical religious communities separated from one another, either due to oppression by the state, or because of new patterns of transatlantic travel resulting from commercial, colonial and missionary endeavours. In the context of the project, pastoral care describes attempts by these religious communities to provide for the well-being, health and flourishing of the souls, minds, and bodies of each of their members. Alison has partnered with a contemporary faith-based organisation called United Society Partners in the Gospel (USPG), which was founded in 1701, is still active today and forms an integral part of the project.

HOW HAS THE PANDEMIC HELPED CONTEXTUALISE THE RESEARCH PROJECT?

COVID-19 highlighted the importance of spiritual care as a critical component of public health provision. The significant increase in mortality in countries around the world helped bring local communities together and brought aspects of pastoral care into sharp focus, particularly how pastoral care is valued and how it is paid for. "Historically, (the forerunner of the USPG) The Society for the Propagation of the Gospel's caregiving across the Atlantic was resourced by enslaved labour on plantations



in the Caribbean. Legacies of enslavement involved an entanglement of (what some would have seen as) benevolence and violence in the provision of pastoral care that has implications for current thinking about mission, caregiving and global relationships," explains Alison. "Communication and its importance to human connection and caregiving has become more obvious as a result of the pandemic - just as letters operated as a technology for remote caregiving and relationship building in the past, so Zoom/texts/phones suddenly became critical as a means of reaching out to others."

As Alison highlights, communication and collaboration are also vital for her research. This project is seeing her work closely with the USPG's research and learning advisor, Dr Jo Sadgrove, alongside postdoctoral researchers, archivists, digital editors and software engineers.

WHICH THREE FAITH COMMUNITIES IS THE TEAM FOCUSED ON?

The first is Scottish Covenanters, who were a group of radical nonconformists in 17th-century Scotland. Samuel Rutherford was a presbyterian minister who was central to the Covenanters' oppositional practices and his letters of pastoral care to women and men who were part of this godly resistance network have survived in printed form.

The second faith community of interest is English nonconformists. Richard Baxter was a leader of this group because of his reputation as a godly minister, his prolific writings (which number more than 130 books) and his important networks of influence. Baxter could not preach much after 1660, so he wrote books and letters instead – letters to and from men, women and young people from a wide range of backgrounds survive.

The final faith community is The Society for the Propagation of the Gospel (the SPG, which has since evolved to become the USPG). It was founded in 1701, but it was focused outside of England – both to care for English nationals engaged in commerce in North America and the Caribbean, and to convert the indigenous peoples of the Americas and enslaved Africans. The letters that survive are an important record and archive of how the English state church tried to define its role beyond the borders of the nation state.

WHAT ROLE DID LETTERS PLAY WITHIN THESE COMMUNITIES?

It is important to consider the times and places in which these faith communities existed – after the British civil wars and Charles II's restoration to the throne, many of the more radical religious groups in England (often known as puritans) were unable to continue to practice within the state church due to its coercive authority structures. Many had to move away – and this persecution and distance required each of these communities to develop forms of ministry and pastoral care that could be exercised through the genre of the letter. This meant that questions about how one should live, or deal with complex situations, or process grief, were explored in a dialogic exchange via letter (remote caregiving rather than face-to-face). In this context, letter writing takes on major importance as a means by which pastors provide care.

WHAT DO THE LETTERS REVEAL ABOUT THE ROLE OF THE PASTOR?

The letters reveal that the pastor's caregiving role is both extensive and intensive. "They include dealing with cases of conscience, such as the responsibilities of a wife whose husband has contracted a sexually transmitted disease; the fate of a child dying at 17 weeks old; the challenges posed by melancholy, a combination of physical, mental, emotional and spiritual symptoms, which could lead to the real possibility of suicide; whether one should catechise an enslaved person for the sake of their eternal soul, despite the resistance of their master; and whether one could take communion kneeling," explains Alison. "For SPG missionaries, there were questions about how to run their ministry in their new environment, including how people could be ordained, and dealing with issues such as potential bigamy."

DR ALISON SEARLE

Associate Professor of Textual Studies, University of Leeds, UK

FIELD OF RESEARCH

Textual Studies

RESEARCH

Contributing to present-day thinking about well-being and caregiving by studying pastoral care in three faith communities between 1630 and 1720

FUNDER

Arts and Humanities Research Council (award number AH/T003197/1)

WHAT ARE THE LONG-TERM IMPACTS OF THE PROJECT?

Ultimately, any project that analyses historical documents provides a new perspective by looking at them through the lens of the present day. In this regard, the future will always make the past fascinating in different ways. Of course, there is the context of COVID-19, but the Black Lives Matter movement also foregrounds the importance of considering legacies of enslavement which was rife at the times these letters were written.

From a caregiving perspective (which is the chief focus of the project), being able to get a real sense of what constituted caregiving in the 17th century helps us think about what constitutes it now. "In a sense, the letters and exchanges from the early archive have fed into the discussion of how to provide care during the pandemic health crisis," says Alison. "Conversations with scholars working on selecting, transcribing and digitising the source material (and more specifically the enhanced visibility of the sources through the production of open-access digital surrogates) enabled USPG to explore what care in a global crisis might mean for an organisation positioned in the UK with a duty of care to people all around the world."

ABOUT TEXTUAL STUDIES

Because textual studies can involve the study and analysis of any written material from any period of history, it is difficult to summarise what you might be studying if you pursue a career in the field. Whether it is carefully turning the pages of a folio edition of William Shakespeare's plays, analysing the manuscripts of some of Emily Brontë's poems, poring over 17th-century letters from three faith communities, or more besides, the choice is yours.

Alison is unequivocal about the appeal of textual studies. "The opportunity to explore manuscripts written by a range of people and organisations from several centuries ago and to piece together the different kinds of stories they allow you to tell about the past, and how it intersects with the present, is intellectually challenging and rewarding," says Alison.

"Thinking about how best to contextualise documents such as letters and make them accessible for a variety of contemporary audiences in order to reflect on how these documents were created, preserved, curated and disseminated, and what this means for our understanding of history and the development of specific literary genres in the present…these are the rewards."

The relationship between historical manuscripts stored in archives and how they relate to present-day concerns will be an issue for future scholars, especially when we consider how these texts will be re-presented in new forms, such as digitally. "I think the Black Lives Matter movement will have a long-term impact on the field. In the course of my own research project, the iconic and iconoclastic toppling of Edward Colston's statue in Bristol has been a key moment," explains Alison. "A reminder that the presence of these histories casts a monumental shadow in public and urban spaces in very obvious ways and that the past is relevant to and has an impact on the modern day."

Alison also knows that her identity as a white, female, middle-class researcher offers her certain privileges as well as possible limitations. Does Alison have more or less access to texts than others? Will her reading of those texts be influenced by her own identity? Is this just a question of her 'identity' or does it also reflect the power structures of a broader social world? Textual studies of historical documents have a bearing on our present lives and perspectives, and poses many such fascinating questions.

EXPLORE A CAREER IN TEXTUAL STUDIES

- Alison recommends taking a look at *The Society for the History of Authorship, Reading and Publishing*, which contains lots of useful information on the study of book history: **www.sharpweb.org/main/**
- There is also *Early Printed Books* (**www.earlyprintedbooks.com/**), *Critical Race Conversations* (**www.folger.edu/critical-race-conversations**) and the *Early Modern Letters Online Exhibition* (**emlo-portal.bodleian.ox.ac.uk/exhibition/uspg/**), all of which should whet your appetite and give you an idea of some of what Alison and others in her field are involved with.

ALISON'S TOP TIPS

01 Follow what interests you, even if it is difficult to see how doing so will immediately lead to employability or a career. Skills in critical reading, interpretation and telling stories are valuable in many work environments.

02 Be open to learning new skills and take any opportunities that come your way. It is important to work with people rather than in competition with them!

03 If you're not visible, or someone else's voice is missing, write yourself in or provide a platform for that person to tell their story.

PATHWAY FROM SCHOOL TO TEXTUAL STUDIES

Alison says that there is no direct pathway to a career in textual studies – mainly because it is a broad term that embraces literary criticism, editing, and working with written texts in a variety of media forms. "An interest in the written word, different media forms (manuscripts, printed texts, digital technologies), interpretation, contextualisation and storytelling is central," explains Alison. "Any subject or activity that encourages digital literacy, or promotes an attentiveness to and engagement with other voices and focus on detail will help."

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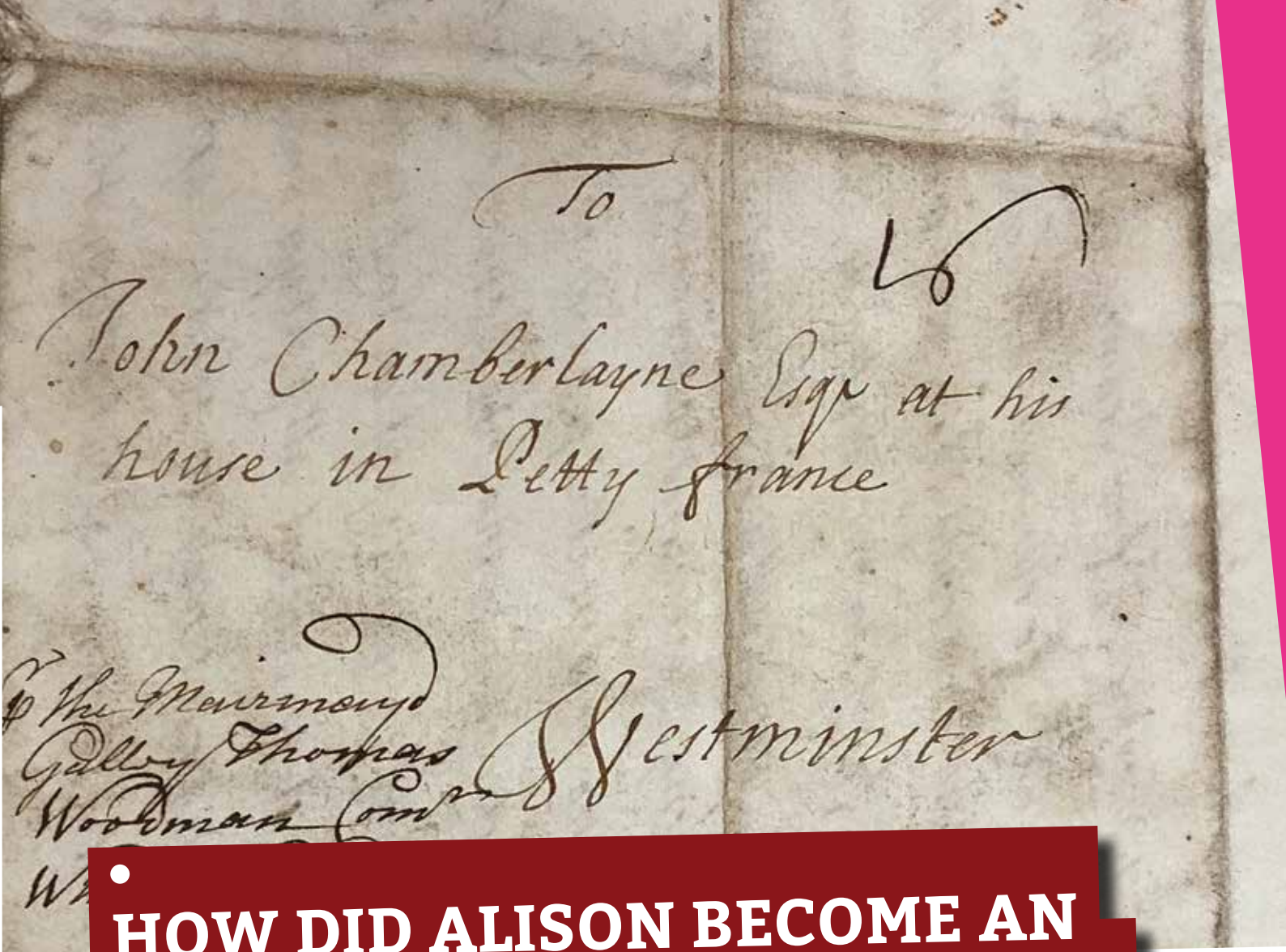


HOW DID ALISON BECOME AN EXPERT IN TEXTUAL STUDIES?

WHAT WERE YOUR INTERESTS WHEN YOU WERE GROWING UP?

I loved reading, writing, travelling and walking – especially by Sydney's beautiful harbour and beaches.

WHO OR WHAT INSPIRED YOU TO PURSUE TEXTUAL STUDIES?

I enjoyed English literature, ancient and modern history, and computing studies at school. I continued to pursue these interests in my BA (Hons) degree in English literature, and then in my PhD on the Bible and imagination. Two of my earliest jobs involved editing for an online literary reference work and working with handwritten letters from 17th-century England exploring Richard Baxter's correspondence with women. These experiences taught me the importance of attention to detail, the significance of the material form of a text, and the fascinating ways in which literary texts from the Renaissance and contemporary digital technologies intersect to allow new ways of reading, writing, thinking, imagining and contextualising. I was hooked.

WHAT ATTRIBUTES HAVE MADE YOU SUCCESSFUL AS A RESEARCHER?

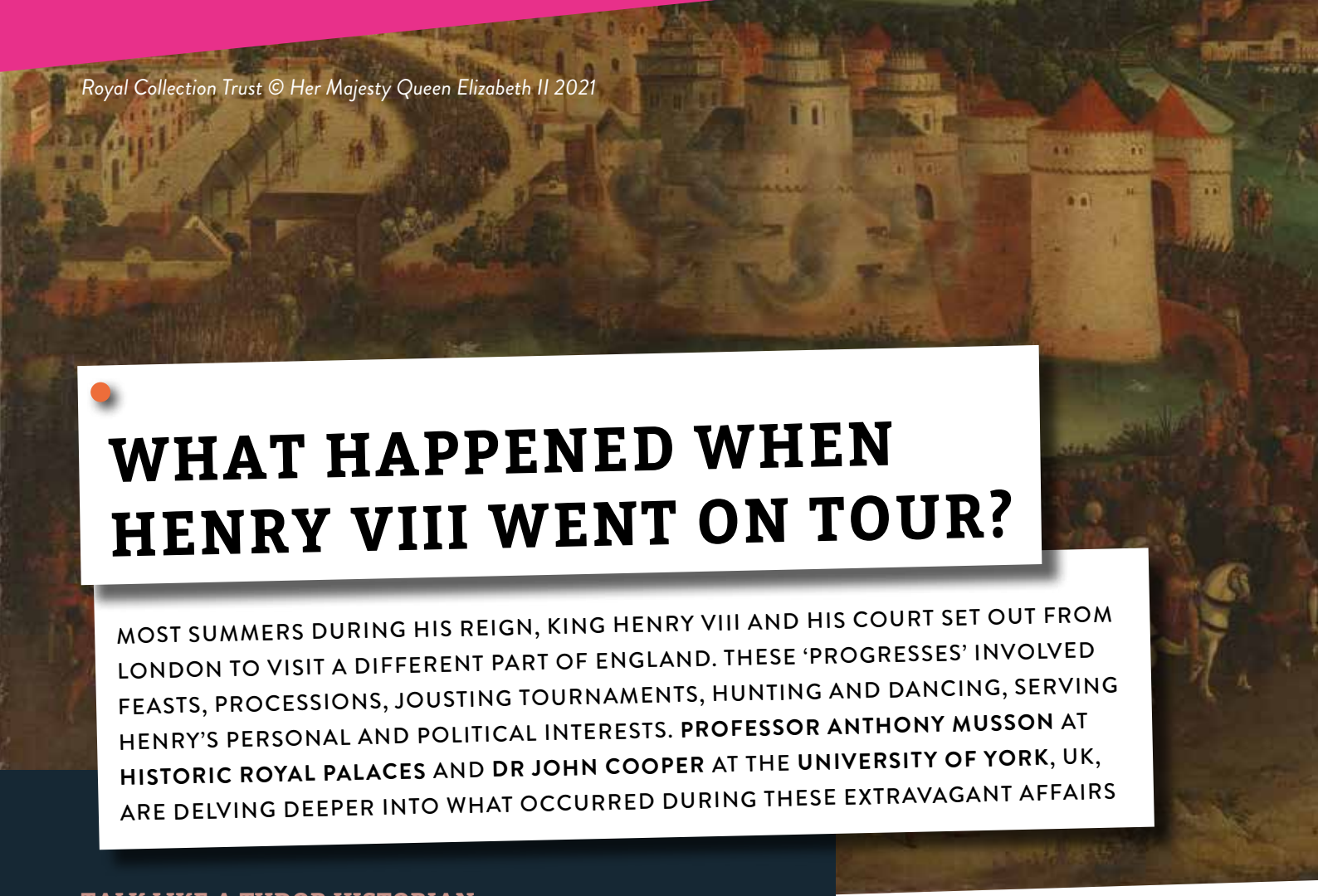
An irritating habit of asking question after question after question! A love of learning all I can about a particular piece of writing and its different contexts: how it was produced, how it was received and the ways in which it can be interpreted now. Doing a PhD can be a rather solitary process – it requires self-discipline and detailed commitment to becoming an expert on one particular topic within a discrete period of time (usually three years). However, the attributes that make one successful as a PhD student are not necessarily sufficient to make one successful in different kinds of research projects. In my current work, I am part of a team – the contributions of archivists, digital editors, other academic researchers, and learning partners in non-academic organisations are absolutely crucial to the success of the project. This means that a willingness to listen, to learn, to know my areas of expertise, and my areas of ignorance, are also essential to producing high-quality interdisciplinary research.

ARE YOU A KEEN LETTER WRITER YOURSELF?

I wrote letters to friends and family as a child and teenager. Now, it's more death by email, but I've been encouraging my 10-year-old son to write to family in Australia (all of our extended family are on the other side of the world, so it's a tangible way to stay in touch).

WHAT ARE YOUR PROUDEST CAREER ACHIEVEMENTS SO FAR?

Getting my PhD when I was 25 and being able to use the non-gendered professional title of doctor; publishing my first book, based on my PhD thesis, in 2008; and learning to work collaboratively with non-academic partners and heritage organisations in a way that brings my work on historical literary texts into direct dialogue and engagement with contemporary concerns of public health and legacies of enslavement.



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WHAT HAPPENED WHEN HENRY VIII WENT ON TOUR?

MOST SUMMERS DURING HIS REIGN, KING HENRY VIII AND HIS COURT SET OUT FROM LONDON TO VISIT A DIFFERENT PART OF ENGLAND. THESE 'PROGRESSES' INVOLVED FEASTS, PROCESSIONS, JOUSTING TOURNAMENTS, HUNTING AND DANCING, SERVING HENRY'S PERSONAL AND POLITICAL INTERESTS. **PROFESSOR ANTHONY MUSSON** AT **HISTORIC ROYAL PALACES** AND **DR JOHN COOPER** AT THE **UNIVERSITY OF YORK**, UK, ARE DELVING DEEPER INTO WHAT OCCURRED DURING THESE EXTRAVAGANT AFFAIRS

TALK LIKE A TUDOR HISTORIAN

CHIVALRY – a set of moral and social values first developed in the Middle Ages, instructing knights and nobles how to behave on and off the battlefield

GIESTS – the written schedules and instructions for the royal progresses

HENRY VIII – the second Tudor monarch, who ruled between 1509 and 1547

JOUSTING – a popular Tudor sport where horse riders would charge towards each other and aim to break their wooden lances on their opponents, showing off their bravery and skill

ROYAL COURT – the people who lived and worked with the king and queen, including nobles, royal guards, servants and musicians. Higher-ranking members of the court were called 'courtiers'

ROYAL PROGRESS – the summer tour taken by Tudor monarchs and their courts

TUDORS – a royal family which ruled England between 1485 and 1603. Many sweeping changes to England's culture, politics and religion took place during their reign

Known for chopping off the heads of his wives and for abolishing the Catholic church in England, Henry VIII is probably the country's most famous (or infamous) king. Owing to his extravagant lifestyle, including his series of six unfortunate wives, Henry VIII has captured the public's imagination for over 500 years. Yet despite being one of England's best-studied monarchs, historians still have many questions about some aspects of life during Henry's fascinating reign.

Most years, Henry and members of his court would travel to a different part of England in a series of grandiose tours named 'royal progresses'. "The progresses usually took place during the summer and could last up to three or four months," explains Professor Anthony Musson, Head of Research at Historic Royal Palaces. "Their emphasis was on splendour and ceremonial display, and the king was greeted with pageantry on approach to the gates of the city he was visiting."

Due to the scarcity of surviving historical records, there is much that we still do not know about the nature of these progresses and the organisational logistics required to host them. Anthony and his colleague, Dr John Cooper at the University of York, are hoping to discover what impact Henry's progresses had on England's culture and politics.

WHAT HAPPENED ON THE ROYAL PROGRESSES?

Formal ceremonies played an important role on the progresses. Henry would be welcomed into the hosting city with a series of stage-managed processions before being greeted by important nobles and courtiers. Gifts would be exchanged as a sign of friendship, and lavish banquets would be prepared.

The progresses allowed Henry to enjoy his two favourite hobbies, hunting and jousting. As well as providing personal entertainment, these activities had deeper political motives. Trusted courtiers were invited to participate in hunts and were rewarded with venison for their loyalty. Henry himself competed in jousting tournaments in the early years of his reign, displaying his strength and prowess to his watching subjects. These tournaments encouraged a competitive spirit among the knights of the realm and promoted the values of chivalry, which were highly important in Tudor society.

The purpose of the progresses was to display Henry's authority throughout the nation and beyond. But as John explains, these events did not always go to plan. "The City of York hosted Henry VIII in 1541, when the king travelled

north to meet his nephew King James V of Scotland," he says. "Unfortunately, James didn't show up!" Henry himself also caused disruption to the schedule of the progresses. "Henry was desperate to avoid the plague so he would often divert the route or cancel his visits," says Anthony. "And sometimes he just went 'off script' and did things spontaneously!"

One of the most successful progresses took place in 1520, when Henry travelled across the English Channel to meet with King François I of France. That trip was so magnificent that it became known as 'The Field of Cloth of Gold'.

WHY WERE THE PROGRESSES NECESSARY?

Monarchs had always journeyed around their realm. But by the mid-1530s, Henry VIII's actions as king had triggered enormous religious and political shifts in English society. There was an ever-present risk that his subjects would become dissatisfied, and possibly even rebel against him. In the face of this challenge, the royal progresses ensured that people all over England, from the nobles to the ordinary working folk, continued to comply with Henry's rule.

"In theory, progresses united the nation," Anthony explains. "Towns and cities pledged their loyalty to the king through stage-managed civic displays, and innkeepers, shopkeepers and craftworkers could take economic advantage of the large influx of visitors."

From a practical point of view, the progresses meant that Henry's London palaces, like Hampton Court, were empty for several months. This allowed repairs to be carried out, but more importantly provided an opportunity for servants to empty the lavatories!

WHAT WERE THE LOGISTICAL CHALLENGES OF THE PROGRESSES?

"The progresses were a logistical nightmare!" says Anthony. "Especially as Henry did not travel light and his entourage was considerable." Clearly, uprooting a large part of the royal court from London every year was an enormous undertaking. Instructions for the tours (known as 'giests') were published five months before the court set off, allowing organisers to plan every last detail.

All the supplies needed to keep Henry's entourage (including nobles, servants and even horses) fed and comfortable were secured well in advance of the progress's arrival in each town. "Royal purveyors and clerks would ride ahead securing provisions from towns, while local notables would provide gifts of food and wine for the royal court," Anthony says. "The costs of a royal visit were considerable and although the expense was supposed to be met from the royal coffers, Henry frequently relied on local generosity and the willingness of his subjects to please their king."

When the progress arrived at the house where they were staying, Henry and his queen would be given the finest accommodation available. Some courtiers built entire new wings to their houses, at vast personal expense, in the hope of impressing the king. But there was rarely enough space for the rest of his court. To provide the necessary sleeping quarters and reception areas, organisers often constructed grand and luxurious tents, dubbed 'portable palaces'.

WHAT DO ANTHONY AND JOHN HOPE TO DISCOVER?

The giests provide the best source of information about the itineraries, baggage and members of Henry's progresses, but not all of them have survived the centuries. To supplement these scarce records, Anthony and John are combing through other sources, including diplomatic reports, church registers, private letters between court officials and inventories of noble households.

They are hoping to build a fuller picture of what went on during Henry's lavish tours. Who went hunting with the king, and what political deals were struck? What role did the queen play on progress? What were the positive and negative impacts on the local community? Even, what were the acoustics like in the venues where performances and religious services were held? Alongside unravelling the many remaining mysteries surrounding the progresses, Anthony and John are also organising talks and workshops for historians, students and members of the public, including pitching a full-sized replica of a portable palace tent in York!

Ultimately, Anthony and John hope to improve our understanding of just how important Henry VIII's royal progresses were in shaping Tudor society, while bringing the full extravagance of the famous king's court to life.

PROFESSOR ANTHONY MUSSON

Historic Royal Palaces, UK

DR JOHN COOPER

University of York, UK

FIELD OF RESEARCH

Tudor History

RESEARCH PROJECT

Investigating the hidden details of Henry VIII's royal progresses

FUNDER

Arts and Humanities Research Council

ABOUT TUDOR HISTORY

WHY ARE WE STILL SO FASCINATED BY THE TUDORS?

Elizabeth I's reign ended in 1603, yet the Tudors continue to enthral us over 400 years later. Anthony believes there are many reasons for this. "The splendour and ceremony of the Tudor royal court, the love stories and tragedies surrounding Henry VIII's wives, the 'rags to riches' tales of courtiers and their eventual fall from grace, and the revolutionary changes in religion, politics and culture all capture our imagination," he says.

Much of this intriguing history lives on in beautiful buildings still found all over England, which you can visit to gain an insight into the lives of the people who once lived there. Tudor art, music and drama are still performed and enjoyed today, and have inspired many modern books and films.

WHAT ARE THE HIGHLIGHTS OF BEING A TUDOR HISTORIAN?

"There are lots of great things about being a professional historian," says John. "Reading original manuscripts in the British Library, corresponding with scholars around the world, talking with students who are just as excited about the past as you are..."

Both John and Anthony agree that the opportunity to spend time in historic locations is one of the best things about being a historian, allowing them to go behind the scenes and immerse themselves in the past. Anthony is based at Hampton Court Palace, one of Henry VIII's favourite London residences, where he oversees a variety of exciting research projects with Historic Royal Palaces. "I love walking through the grounds at Hampton Court when no tourists are about," he says. "It never ceases to amaze me how beautiful the setting is, and I have to pinch myself that Henry VIII and so many historical characters actually lived here!"

No two days are ever the same for Anthony and John. Their work involves visiting historical sites, examining ancient manuscripts, paintings and artefacts, and establishing new research projects. And they do not just collaborate with scholars, but with craftspeople, cooks and gardeners, who study Tudor sources to make furniture, feasts and flowerbeds that are as historically accurate as possible.

WHAT DO WE STILL NOT KNOW ABOUT THE TUDORS?

As the Tudors lived over 400 years ago, the surviving written records are scattered across many locations. Historians must piece together information from different sources to build a picture of Tudor life and society. They are constantly searching for new methods to understand how Tudor people experienced the historical events we read about, which often requires re-interpreting historical sources from different points of view.

While Tudor scribes recorded tales of kings and courtiers, we know much less about the experiences of ordinary people. Those living outside the lavish palaces and country estates (farm labourers, teachers, tradespeople...) were not considered worthy of having their lives recorded. Anthony and John are hoping to uncover the hidden experiences of the common people, allowing their stories to finally be shared with the modern world.

EXPLORE A CAREER AS A TUDOR HISTORIAN

- If you live in the UK, there could be a fascinating Tudor site near you. Visit Historic Royal Palaces (**www.hrp.org.uk**), the National Trust (**www.nationaltrust.org.uk**), English Heritage (**www.english-heritage.org.uk**) or Historic Houses (**www.historichouses.org**) to find out more.
- There are many great books, TV shows and online resources to explore the Tudors and other historical periods beyond your school history lessons. Anthony recommends the *Horrible Histories* series!
- Do you live near a museum or historical site? Ask about volunteering opportunities – it will be an excellent way to learn what historical work involves and will look great on your university application.
- Getting a job in a museum is competitive, but John believes that the destination is worth the journey.

PATHWAY FROM SCHOOL TO TUDOR HISTORY

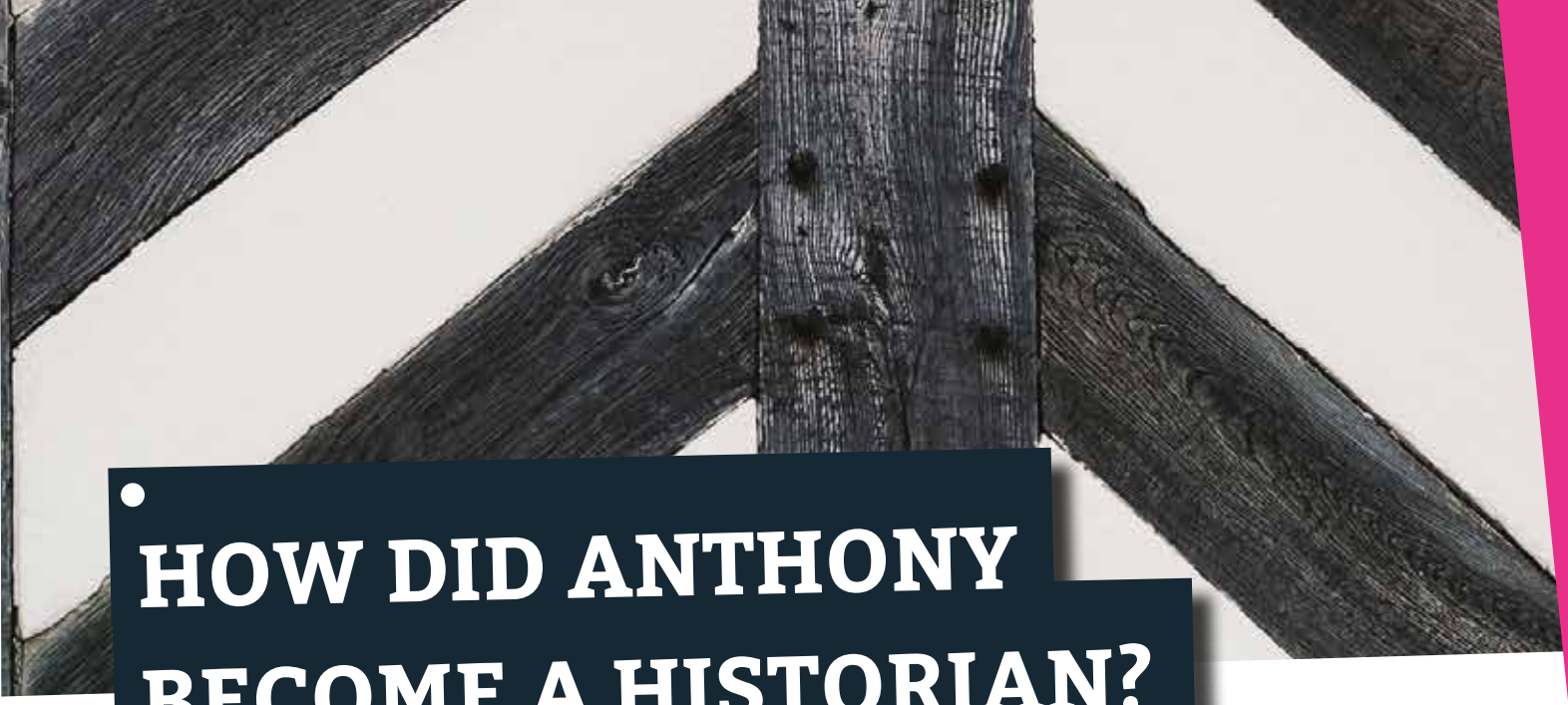
- Try to have an appreciation for all historical periods. Your school curriculum will only cover a tiny snapshot of the history of the world, so investigate other time periods in other cultures. Explore the aspects of the past that interest you.
- Never be afraid to ask your history teachers and tutors questions about what you see and read.
- Most universities offer history degrees. Look for courses taught by professors specialising in the Tudors.

ANTHONY AND JOHN'S TOP TIPS

01 Visit museums and historical sites. They will provide fascinating insights into past cultures.

02 Reading both fiction and non-fiction is a good way of exploring the past. It can be difficult to appreciate historical lives, but some novelists are very good at capturing the essence of historical periods and bringing them alive.

03 Think critically about what you read. Historians don't automatically accept each other's opinions, and there is no reason that you should either.



HOW DID ANTHONY BECOME A HISTORIAN?

I have been a musician for most of my life and enjoy composing, singing and playing the piano and organ. I was a chorister at Westminster Abbey from the age of 8 to 13. Singing in such historical surroundings at state occasions and famous memorial services definitely inspired my interest in history.

I was also very interested in churches. Exploring local parish churches or grand cathedrals is a great way to appreciate history. They are not just religious buildings, but microcosms of the concerns of past societies.

I didn't have an option to study the Tudors at A-level, so I first became fascinated with them at university. Some of my lecturers were dauntingly eminent, but usually very approachable. They encouraged me to be critical and to have my own opinions, important traits for a historian.

Working in Hampton Court Palace is an incredible privilege. I love my office as it overlooks the Chapel Royal and I can sometimes hear the organ or singing wafting up. There is also a secret passage that leads downstairs and comes out behind a tapestry just by the Great Hall. And I love the fantastic views from the roof of the palace, over the gardens to the parks and River Thames beyond.

My favourite fact about Henry VIII is that he was an accomplished musician, both playing and composing. It balances the military side to him!

HOW DID JOHN BECOME A HISTORIAN?

I've always been interested in the past. As a boy, I loved reading books about knights and castles and the unexplained mysteries of history. I was fascinated with the 'lost colony' of Roanoke Island, the first English people to try to settle in America. They disappeared, but left a strange message carved into a tree – what did it mean?

My inspiration as a historian was sparked by childhood visits to places like Pendennis Castle in Cornwall, built by Henry VIII to protect England from invasion. At school, I did a project on the Tudor warship the Mary Rose. It was amazing to watch it emerge from the bottom of the Solent live on TV, though there was a terrifying moment when the crane slipped and nearly dropped the ancient wreck back into the sea!

As a teenager I thought I might become an archaeologist, so I'm delighted now to be working alongside archaeologists on history projects like this one.

For me, the highlight of this project has been to get behind-the-scenes access to some of the palaces and houses owned by Henry VIII, particularly Hampton Court where we held one of our workshops. Henry VIII owned more than 50 royal palaces by the end of his reign!

I'm lucky to live in a Yorkshire village, with a garden which I have gradually transformed into a wildlife haven – a pond, shrubs chosen for bees and butterflies, a couple of native trees. It's been great to see how even a smallish space can be transformed into a home for wildlife.

I am motivated by a belief that we need to cherish what survives of the past and be prepared to defend it.

THE ART OF PROPAGANDA

ART AND DESIGN HAVE OFTEN HAD A MAJOR ROLE IN INFLUENCING THE ATTITUDES OF SOCIETY. **DR HARRIET ATKINSON**, FROM THE **UNIVERSITY OF BRIGHTON** IN THE UK, IS UNCOVERING THE ROLE OF MODERNIST ARTISTS BETWEEN 1933 AND 1953 IN BRITAIN – HOW THE INFLUENCES OF REFUGEES, THE OUTBREAK OF WORLD WAR II AND EVENTUAL VICTORY ALL AFFECTED EXHIBITIONS, AND HOW THESE IN TURN AFFECTED THE PEOPLE WHO SAW THEM

GLOSSARY

COMMUNISM – an ideology where property is publicly owned and common ownership removes class divides

FASCISM – a far-right ideology based on an authoritarian leader and the power of the state

LEFT-WING – believing in social equality and egalitarianism

MINISTRY OF INFORMATION – a British government department responsible for public information and propaganda (active during the world wars)

MODERNISM – a period from the early to the mid-20th century when art and design left behind their classical routes and became more experimental

NAZI GERMANY – Germany between 1933 and 1945, under the control of the Nazi party, which was defined by dictatorship and persecution of minorities, and was defeated during World War II

PICTOGRAM – a graphic symbol or picture used to represent a message, idea or information

PHOTOMONTAGE – a photographic image made of several different photographs edited or pieced together

PROPAGANDA – materials designed to promote a particular political perspective

RIGHT-WING – having conservative or capitalist views and believing in free enterprise and private ownership

SOVIET UNION – a socialist state that existed from 1922 to 1991, which at its height encompassed Russia and many other countries in eastern Europe and central Asia. It was defined by communist ideals such as centralised command, but also by suppression and corruption

WORLD WAR II – the global war from 1939 to 1945 between the Allies (such as Britain, the Soviet Union and the United States) and the Axis powers (such as Germany, Italy and Japan)

When was the last time you saw an image – maybe an Instagram post or a meme shared in a WhatsApp group – that portrayed a strong opinion? In our modern age of digital communication, chances are very recently! Now, think about the last time you saw an image that portrayed a strong political opinion or idea. What message was it conveying? Was it persuasive? Did you agree with the message? Did you trust the message and share it with others? Did you question whether the image – and the message it was conveying – was accurate or 'fake'? It is easy for us to link the concept of propaganda to the era of world wars, but it could be said that social media has made us all more politically active and, with the rise of misinformation, the use of propaganda more commonplace.

Dr Harriet Atkinson, Senior Lecturer at the University of Brighton in the UK, is a historian of art and design currently writing a history of political propaganda exhibitions that took place in Britain in the 1930s and 1940s. "For a long time, I've been interested in how governments use design to influence ideas about the nation, to persuade people of their point of view and to connect across national boundaries," says Harriet. The exhibitions she is looking at were aimed to provoke a particular response, such as national pride or anti-fascist feeling – not so different from some of the images we see today.

"This particular area of British Modernism has been overlooked until now – possibly because it bridges several different disciplines, and the evidence for the exhibitions is hard to come

by," says Harriet. These exhibitions tended to be short-lived and records of their existence can be scant and scattered. Moreover, researching their impact on society involves piecing together many seemingly unrelated pieces of evidence. Harriet spends her days poring over archive material to build the picture of how these exhibitions arose and what they represented.

A TIME OF WAR

When World War II broke out, the British government's Ministry of Information used exhibitions as a tool for generating particular emotions in the British public. "These exhibitions were designed to inspire audiences to live more efficiently, to take pride in the war effort, and to provoke anger against their enemies," says Harriet. The rise in photography meant that images of real people and situations could be incorporated into propaganda materials, helping create a directly relatable medium. Facts and statistics, using pictograms and diagrams to make them easier to understand, were also widely used to back up positive statements about how well Britain was coping with war.

"As well as provoking emotional responses, the Ministry of Information used exhibitions to teach new skills," says Harriet. "Many exhibitions focused on practical skills such as growing and preparing food, sewing and mending, and fuel efficiency. Displays often combined photographs and photomontages in clever ways, such as implying garden pests and Axis powers were a common enemy by adding Nazi insignia to images of slugs," she explains. "Images were often accompanied by lively instructional verses."

THE ROLE OF EXHIBITIONS

Not just consigned to art galleries, these exhibitions could be found in libraries, bomb sites, church halls, train stations and workers' canteens. They were meant to provide an accessible way of sharing messages and many exhibitions toured more rural areas, so they could reach a wider audience. "Historians often think of exhibitions as a portal into a particular issue," says Harriet. "In the case of the ones I'm looking at, they were being used to raise explicitly political points. But exhibitions can also help shed light on the development of artistic styles or show how a nation represented itself to the rest of the world."

Because they were accessible for viewers, these exhibitions could also be an effective way for marginalised people to broadcast their perspectives. "Many influential architects and designers from Czechoslovakia, Austria, Germany, Hungary and other parts of Europe took refuge in London during the 1930s," says Harriet. "They directly shaped the wider design cultures of Britain, through contributions to architecture, graphics and textiles." The early twentieth century marked a time when rising totalitarian regimes, in particular Fascists and Nazis, were becoming increasingly hostile to artistic expression that either directly or indirectly went against the leading political ideology. As a result, many artists moved to western Europe, including Britain, where they could express themselves more freely.

POLITICAL EXPRESSION

Harriet is investigating how different groups used exhibitions as platforms for expressing their political views. One group she is interested in is the Artists International Association (AIA), which was founded in 1933 by a collection of strongly left-wing artists, including some Communist Party members. "Some AIA members had spent time in the Soviet Union, where they were impressed by the central role of artists in imagining a new, utopian society," says Harriet. "However, the experiences of World War II changed their perspectives, and many ended up losing their radical edge." In fact, the post-war boom saw many artists and designers joining commercial practices.

Another significant group was the Free German League of Culture, founded in London in 1938 by refugees from Nazi Germany. Despite the relative liberality of Britain, they were still treated with caution by the government. "This group was also left-aligned and was closely monitored by MI5, who suspected that this organisation and their exhibitions were a front for a more seditious project," says Harriet.

LOOKING DEEPER

Some exhibitions were on a grand scale, and their impacts still resonate today. "Picasso's striking anti-war painting Guernica visited Britain in 1938 as part of a campaign to raise funds to support the anti-fascist grouping in the Spanish Civil War, and major wartime propaganda exhibitions such as The Army were very well-attended," says Harriet. "Other exhibitions were tiny and only seen by small audiences, in venues such as local shop windows." The task of deciphering the impacts of exhibitions large and small on the mentality of wider society is challenging, but through both factual reports – such as visitor numbers – and personal accounts or reviews of these exhibitions, Harriet can gradually build up an informative picture.

Studying history reveals fascinating insights into how society once was, but it also shines a light on how we are living now. Harriet's research reminds us of the importance of art and visual communication in reflecting and shaping societal values. The next time you look at an image online, think carefully about the message it is conveying and be a critical viewer. Do you trust the message? Is any photography used genuine? How have elements of art and design been used for a specific effect? Whether you feel the message is positive or not, ask yourself, are you being influenced through the 'art of propaganda'?

DR HARRIET ATKINSON

Senior Lecturer, School of Humanities and Applied Social Science, University of Brighton, UK

FIELD OF RESEARCH

History of Art and Design

RESEARCH PROJECT

Researching modernist exhibitions in Britain for propaganda and resistance, from 1933 to 1953

FUNDER

"'The Materialisation of Persuasion": Modernist Exhibitions in Britain for Propaganda and Resistance, 1933 to 1953', funded by the Arts and Humanities Research Council Leadership Fellowship, Project Reference: AH/S001883/1

ABOUT THE HISTORY OF ART AND DESIGN

Harriet is a historian of art and design, a discipline which gives key insights into everything from societal norms to radical ideas, and how they influenced art and design. Through examining the objects and artworks created by generations past, she is granted a window into the mentalities that shaped the world into what we see today. Harriet explains more about her work.

I enjoy thinking about images and objects, and they are the central focus of my research. I love working on my own and have been fortunate to travel to archives around the world – I've spent time in Washington and New York, for instance. I'm also lucky to work with and meet many fantastic people who share my interests. I love attending conferences in different places. Having conversations with the people I meet there is really stimulating.

My typical research day has changed significantly given the effects of the pandemic. Pre-COVID-19, I worked in the British Library every day, reading books and periodicals and visiting the library's extensive archives. Since the pandemic struck, I've transitioned to finding material online so I can work from home, with occasional visits to libraries and archives to gather new material. I'm very ritualistic about how I work – starting at a set time and having set periods within which to focus on my work.

Archive research is a slow and steady process. I begin by analysing drawings, photographs, plans, letters, interviews or minutes of meetings, depending on what evidence is available, and gradually build broader ideas around them. Little by little, the wider themes start to become apparent, and I can make connections between different pieces of evidence. Some days, I focus on small examples, whereas on other days I tackle the bigger ideas.

My academic work allows me to delve into many topics I find interesting. I have a new podcast underway called Graphic Interventions, where I interview contemporary artists, designers and collectives about how they make political comments through their graphic work. I am planning to combine what I learn from this podcast and the book on earlier exhibitions to create a documentary film about politically-engaged artists and designers in the early twentieth century.

I think that future historians will be interested in design's response to the pandemic and to climate change. We're only just starting to understand both of these at the moment. I also think that future historians will need to make sense of the impacts of so much of our everyday lives moving online during 2020.

EXPLORE A CAREER IN THE HISTORY OF ART AND DESIGN

- University is not the only pathway for a career in art and design. For instance, Artswork coordinates creative apprenticeships, such as in theatres or galleries, in southern England: **artswork.org.uk/our-work-with-young-people/creative-apprenticeships/**
- The University of Brighton has an extensive public outreach scheme for schools and young people in south-east England. For undergraduates, their Active Student programme helps students gain experience of relevant work and volunteering alongside their degrees: **www.brighton.ac.uk/careers/volunteering/index.aspx**
- Given the breadth of career paths within this subject area, salaries can vary widely. As a ballpark figure, the average historian salary in the UK is £37,000.

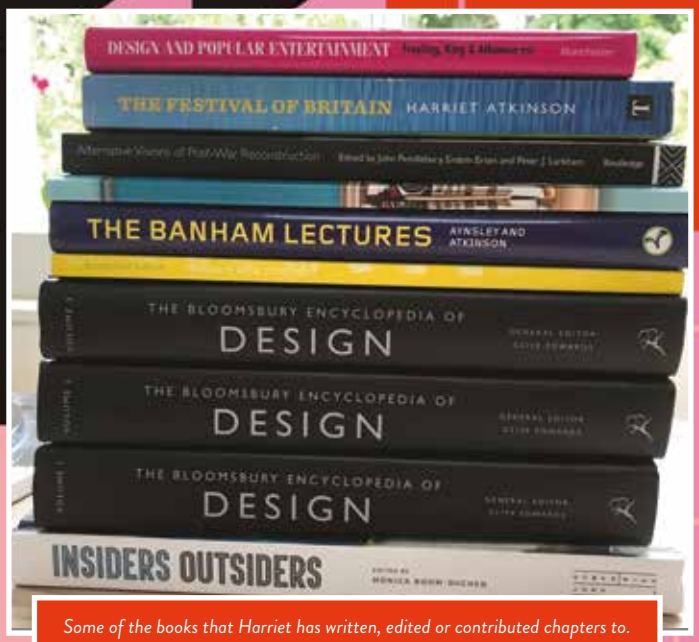
PATHWAY FROM SCHOOL TO A CAREER IN HISTORY OF ART AND DESIGN

Harriet says there are several academic routes to her research area. At school and at university, this can involve studying humanities subjects such as history or history of art, or creative subjects such as design and technology, art or graphic design. Harriet says that all these subjects offer a good grounding for entering the research field.

HARRIET'S TOP TIPS

01 Be actively interested in the subject. Go to exhibitions, read books about art and design, watch documentaries and films and go to free talks in person or online.

02 Volunteering or internships, such as with heritage organisations or museums, can be a really good way of getting a sense of the field and whether you might like to pursue a career in it.



Some of the books that Harriet has written, edited or contributed chapters to.

HOW DID HARRIET BECOME AN ART AND DESIGN HISTORIAN?

WHAT WERE YOUR INTERESTS AS A CHILD?

I was interested in art and design from a young age. At primary school, I was lucky enough to go on school trips to art galleries and found looking at the art there really exciting and inspiring. I also thought a lot about why the things we use every day – such as cutlery, chairs, traffic lights or road signs – look the way they do! As I got older, my interest grew into considering how governments use culture to bring people together, to improve well-being and to inspire national pride.

WHAT INSPIRED YOU TO PURSUE A CAREER IN YOUR FIELD?

I remember visiting the National Gallery with my school as a young child, and being bowled over by Titian's paintings of mythology. My interest in visual material was encouraged by my grandmother, who was an artist, and by my excellent secondary school art teacher, Mr Risoe. I loved the research process during my master's and although I hadn't planned on pursuing a career in academia, after nearly a decade working in arts policy and funding, I realised that my great passion was for research and writing.

WHAT ATTRIBUTES HAVE MADE YOU SUCCESSFUL AS A RESEARCHER?

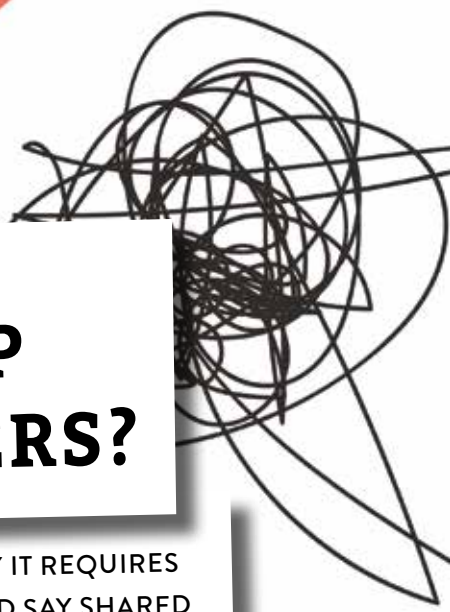
Single-mindedness, persistence, and the ability to motivate myself even when it feels like there's no end in sight. I genuinely love exploring archives, poring over dusty folders on my own! I also enjoy working collaboratively, editing books or planning conferences and workshops with others. Academia involves a lot of multi-tasking, and most academics find themselves juggling teaching, admin and research. There is also a lot of time spent filling in funding forms, which is a skill in itself.

HOW DO YOU SWITCH OFF FROM WORK?

Exercise is a very good way to switch off. I love running, walking, cycling and freshwater swimming. Spending time with my three children also naturally involves switching off from work.

WHAT ARE YOUR PROUDEST CAREER ACHIEVEMENTS SO FAR?

My current AHRC Fellowship has granted me the most extraordinary opportunity to investigate a whole series of ideas and interests I've held for a long time. The completion of my PhD, published in 2012, was another high point. Alongside my paid work as an academic, over the past 30 years I have always taken on voluntary positions in charities that make a contribution to my local community or to my communities of interest. This can be every bit as hard as paid work but is unremunerated and often unacknowledged. I'm proud to have kept this going.



HOW DOES EMPATHY HELP US TO UNDERSTAND OTHERS?

WHAT DOES IT MEAN TO UNDERSTAND SOMEONE ELSE? SOME WOULD SAY IT REQUIRES KNOWLEDGE OF WHAT THAT PERSON IS GOING THROUGH. OTHERS WOULD SAY SHARED PERSONAL EXPERIENCE IS NEEDED. ONE REQUIREMENT FOR UNDERSTANDING IS EMPATHY, THE SKILL OF SHARING ANOTHER PERSON'S PERSPECTIVE. AT THE **UNIVERSITY OF LIVERPOOL** IN THE UK, **PROFESSOR THOMAS SCHRAMME** IS INVESTIGATING THIS CONNECTION BETWEEN EMPATHY AND INTERPERSONAL UNDERSTANDING. WITH A TEAM OF RESEARCHERS, HE IS DEVELOPING A PHILOSOPHICAL THEORY TO EXPLAIN THE CONCEPTS BEHIND INTERPERSONAL UNDERSTANDING, AN ABILITY THAT IS INCREASINGLY IMPORTANT IN TODAY'S POLITICALLY AND CULTURALLY DIVIDED WORLD

TALK LIKE A PHILOSOPHER

EMPATHY – the ability to share the perspectives and feelings of another being

INTERPERSONAL UNDERSTANDING – to gain appreciative knowledge of thoughts and feelings of others

SYMPATHY – the feeling of pity or sorrow for someone else

PHILOSOPHY – the study of foundational questions regarding all aspects of human and natural being, including knowledge, the mind, ethics and existence

DEVELOPMENTAL PSYCHOLOGY – the scientific study of how human thought and behaviour change over a lifetime

EMOTION REGULATION – the ability to manage and respond to our emotions

Many of us find it hard to understand the decisions that other people make. We may be concerned that our actions are not understood by others, we get frustrated when our friends and family cannot see something from our point-of-view, and we struggle to comprehend how someone could commit an atrocious act like murder. But why is it so hard to understand each other, and what prevents us from putting ourselves in someone else's shoes?

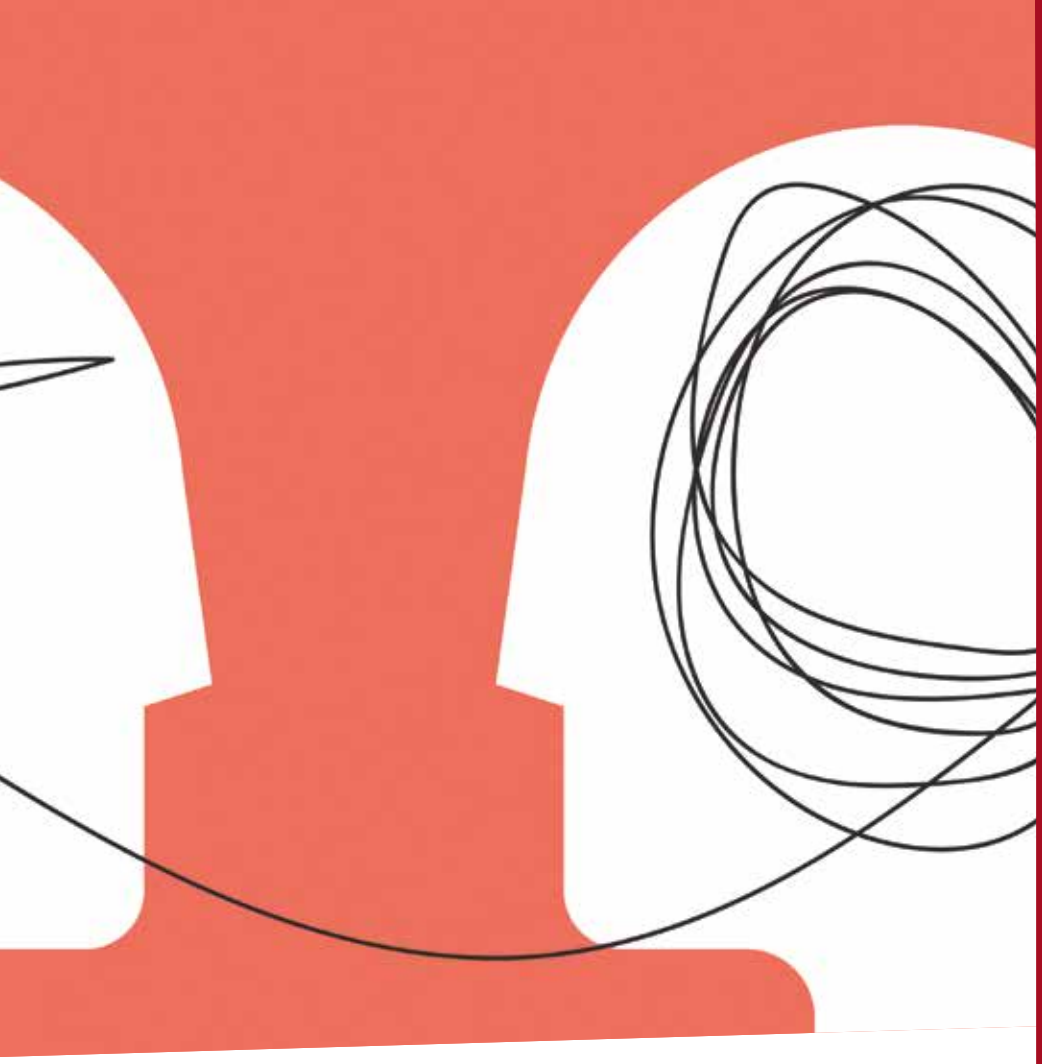
Empathy is a skill that enables us to take the perspective of other beings and feel what they feel. Professor Thomas Schramme, a philosopher at the University of Liverpool, is using philosophical discussion and psychological findings to develop a theory relating empathy to interpersonal understanding. In a world that is becoming increasingly politically and culturally divided, this theory will aid future discussions by increasing our knowledge of how we understand each other.

EMPATHY AND INTERPERSONAL UNDERSTANDING

"Empathy is not itself a moral skill," says Thomas, "but a mode of gaining understanding of another being." For example, some con artists are very good at 'getting into the heads of others', and so are good at empathy, but they are not caring or moral, rather they use their skill in empathy to cheat others. Empathy is also often confused with sympathy, which is the feeling of sadness or pity you may feel if someone else is sad, whereas empathy involves a broader understanding of others.

Like any other skill, to be used successfully, empathy needs to be practised and developed over time. When used correctly, empathy provides a way to access the minds of others, helping us to understand their thoughts and actions, and enabling us to interact with them.

Although empathy plays an important role in connecting with others, more seems to be needed for full understanding. To some people, 'understanding' means knowing why someone else is feeling a certain way, while for others, it requires a shared personal experience. "For example, we struggle to empathise with people who commit hideous crimes," explains Thomas. "In consequence, we can fail to understand them, even though we might know their motives." Empathy and understanding, therefore, appear to be heavily linked, but



PROFESSOR THOMAS SCHRAMME

University of Liverpool, UK

FIELD OF RESEARCH

Philosophy

RESEARCH PROJECT

Investigating the relationship between empathy and interpersonal understanding

FUNDER

Arts and Humanities Research Council

full understanding likely requires more than just empathy.

HOW DOES THOMAS STUDY EMPATHY?

Thomas is a member of a research group investigating this connection between empathy and interpersonal understanding. Philosophers research a topic by checking reality (known as 'phenomena') against a specific concept. "We are concerned with conceptual problems and try to develop terminology related to these topics that is clear and unambiguous," says Thomas. For example, Thomas may ask whether 'emotional contagion', such as our ability to pick up the mood of a room full of people, is really a form of empathy. "Does this phenomenon fall under the concept of empathy?"

Thomas is not only concerned with theoretical concepts. "We want to use findings from developmental psychology to reveal the reality of empathy," he says. Hopefully, this will lead him to an empirically informed theory of empathy in relation to interpersonal understanding. "We want to explain how empathy works."

THE LIMITS TO UNDERSTANDING OTHERS

In today's world, it often seems like we are getting worse at understanding each other. Thomas believes that psychological mechanisms such as biases and poor emotion regulation are hindering our performance of empathy. And our increasing interaction through technology is not helping, as we lose so many social cues such as tone of voice and body language when we do not communicate face-to-face. When no personal connection exists, it is hard to 'read' someone, and so therefore harder to empathise with them.

We also struggle to grasp what understanding actually means, and what a successful version of empathy looks like. We often fail to understand what is good for others, meaning empathic decisions might not lead us to morally sound conclusions. And barriers to fully understanding someone are always going to exist. "It is a common feature of empathy that we cannot ever fully succeed in empathising, because we cannot ever be the other person," says Thomas.

A common topic in philosophical discussions of empathy is whether we can empathise with people who have completely different backgrounds to us. Some theorists argue that to understand someone requires shared knowledge or experience with them, however Thomas sees limitations in this argument. "We can at least partly overcome different backgrounds," he says. "If we can accept there is always going to be a boundary to other minds, then cultural differences do not pose an insurmountable hurdle to successful understanding." With this viewpoint, he highlights the importance of successful understanding, rather than full understanding, when interacting with others.

BECOMING A BETTER EMPATHISER

If empathy is a skill, how we can improve our success at using it? As Thomas suggests, our capacity to empathise is not fixed or limited by personal or social identities. "Empathic skill can be improved by self-knowledge and imagination," he says. "If you know your weaknesses and biases, and can distance yourself from them, you have a good chance of improving your empathic abilities." Thomas believes an important requirement for empathy is to focus on the other person and not on yourself. "When we empathise, another person is the target of our efforts," he explains. "So we mustn't ask 'How would I feel in such a situation?' but 'How does this person feel?'"

Successful empathy is the ability to, as much as possible, understand the other person. And while it can be difficult to understand those with completely different life experiences, this is not a barrier to showing empathy. If we all developed our skills of empathy and used them to increase our interpersonal understanding, the world would likely be a much kinder and more compassionate place.

ABOUT PHILOSOPHY

Philosophy is the study of knowledge, the mind, ethics and our very existence. For thousands of years, we have been asking ourselves, 'Why are we here?' and 'How do we even know that we exist in the way we perceive ourselves in the world?' And today, philosophers are still trying to answer these questions.

Thomas specialises in moral and political philosophy, combined under the term 'practical philosophy' due to their concern with practices and actions. Humans behave in ways that have practical repercussions, for example someone's actions may harm others, and moral and political philosophy involves asking questions about how we should behave.

Thomas is also interested in the philosophy of medicine. "Pretty much all traditional areas of philosophy can be applied to medicine," he says. Ontology is the philosophical study of what exists and in what way. "This can be applied to the philosophical debate of whether mental disorders exist, or whether they are brain diseases," explains Thomas. Epistemology, the study of knowledge, can be used to investigate how medical conditions are diagnosed. "Are patients' illnesses diagnosed using certain rules and medical data?" asks Thomas. "Or do doctors use their intuition and experience to treat patients?"

WHAT ARE THE JOYS AND CHALLENGES OF BEING A PHILOSOPHER?

"I like the open nature of philosophy," says Thomas. "There is no topic that might not become the object of philosophical thinking." Thomas loves spending his working hours reading and thinking, allowing him to pursue his personal enjoyments as his job.

However, Thomas highlights this can also be a problem, as philosophy does not deliver products in a traditional way. "Philosophers don't invent new technology or identify life-saving treatments," he says. This can lead some people to think that philosophy is a superfluous activity, nice if you have the time for it, but not a serious economical pursuit. Thomas thinks it's important to fight this distorted image. "The benefits of philosophy are vast and they concern human thinking by offering new perspectives," he says. "This does not have a monetary value but is invaluable nonetheless."

WHAT IS THE FUTURE OF PHILOSOPHY?

Despite the challenges facing modern philosophers, Thomas thinks the field is an exciting one to work in. "You never know what philosophical issues will arise. That's the beauty of it!" he says. "Suddenly, new ideas are introduced, and they change how we perceive the world."

Philosophers address human issues, such as racism and climate change, and so they are vital for understanding how we can all live with each other and our planet. And new technological developments have philosophical implications. Modern philosophers ask questions about artificial intelligence and debate the concept of the 'extended mind'. This view argues that our mental realm is not just inside our head but is extended to things in the world. With so much of our existence now dependent upon, and contained within, our phones, why are our phones not considered part of our mind? "Philosophy opens a completely new avenue of thinking and a new way of perceiving the world," says Thomas.

EXPLORE A CAREER IN PHILOSOPHY

- The British Philosophical Association (**www.bpa.ac.uk**) contains resources for students (**www.bpa.ac.uk/resources**) and information for schools (**www.bpa.ac.uk/philosophy-in-schools**).
- The Royal Institute of Philosophy (**www.royalinstitutephilosophy.org**) organises public lectures and you can watch philosophers talk about philosophical issues through their YouTube channel (**www.youtube.com/user/RoyIntPhilosophy**).
- For an accessible introduction to philosophy, Thomas recommends *Think*, by Simon Blackburn, or any books by Julian Baggini.
- Visit the University of Liverpool's Philosophy Department (**www.liverpool.ac.uk/philosophy/outreach**) to find out more about the subject.
- Be aware that there is a lot of bad (pseudo-) philosophy information on the internet. Thomas says that you may need experience to distinguish between it and true philosophical work.

PATHWAY FROM SCHOOL TO PHILOSOPHY

• Reading and writing are essential skills for philosophers, and it is very useful if you enjoy them! Other necessary skills are the abilities to understand complicated debates, express your thoughts and form structured arguments.

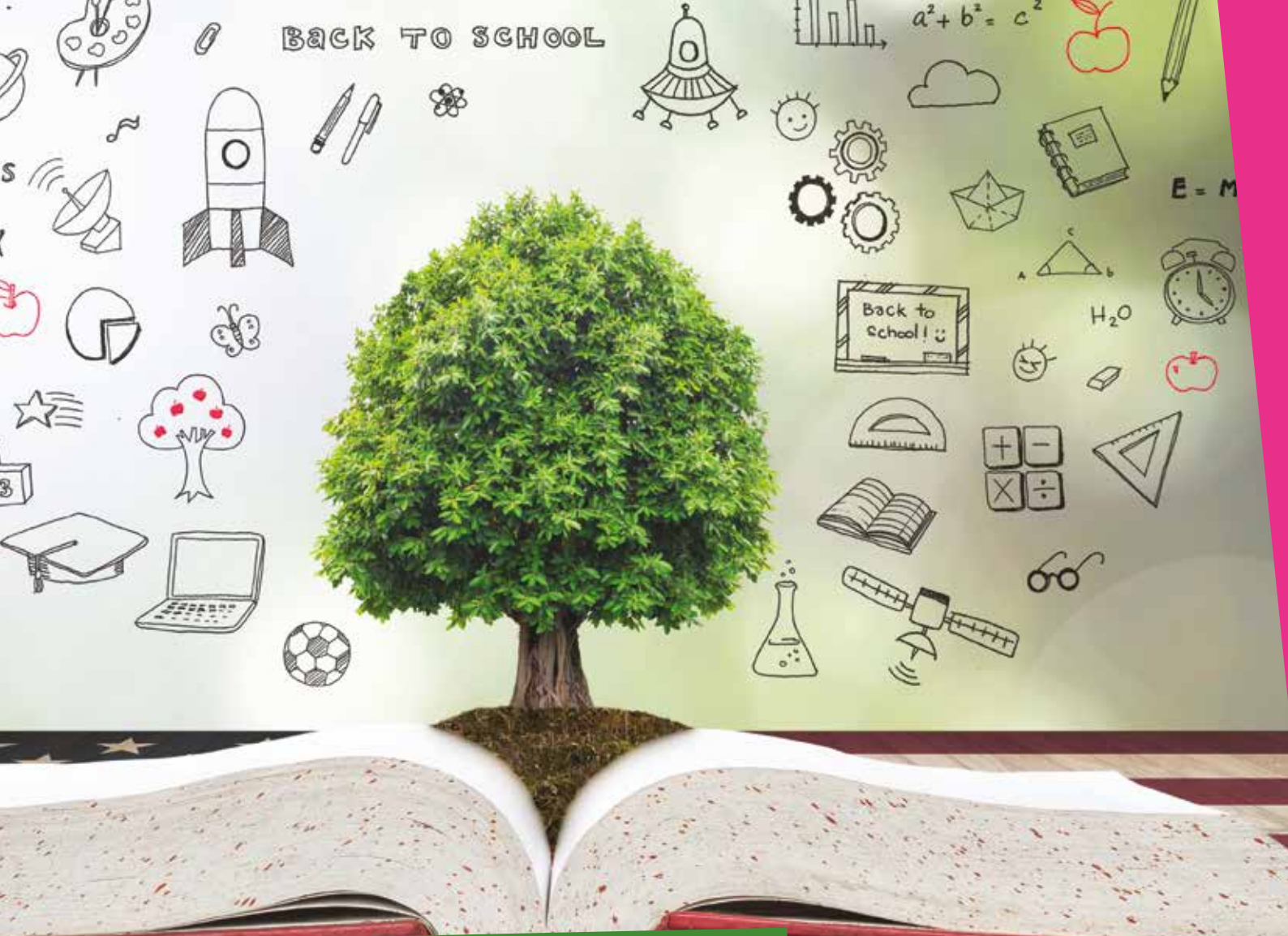
• "Philosophers need the analytical skill of 'logic'," says Thomas. "They need to be able to unpick arguments by ascertaining whether a given conclusion logically follows the statements provided."

• Many universities offer philosophy degrees. To become an academic philosopher like Thomas requires a lot of luck, so he advises against being single-minded about such a career path. But a degree in philosophy will teach you many skills of reasoning and logic, which will open doors to a wide range of careers outside academia.

THOMAS'S TOP TIPS

01 Anyone can read philosophy and philosophise! Philosophy is a democratic pursuit.

02 See philosophy as an interpersonal activity. You don't think alone, you are constantly in a conversation with others, even if they are not always present in person.



HOW DID THOMAS BECOME A PHILOSOPHER?

WHAT WERE YOUR INTERESTS WHEN YOU WERE YOUNGER?

For a long time, I was far more interested in activities than thinking. I wanted to become a chef when I was a young teenager, then an industrial designer when I was a young adult. In high school, I started developing some interest in ethical topics and politics, but only decided very late to enrol for a philosophy degree.

WHAT INSPIRED YOU TO BECOME A PHILOSOPHER?

I never planned to become an academic. It was down to luck and partly caused by the fact that I was running out of options after finishing my PhD! Initially, I tried to get into writing for newspapers, but I didn't have any contacts in journalism. Then, I got lucky and landed my first academic job in philosophy, which started my career.

HOW WOULD YOU DESCRIBE YOURSELF? ARE THESE USEFUL CHARACTERISTICS FOR A PHILOSOPHER?

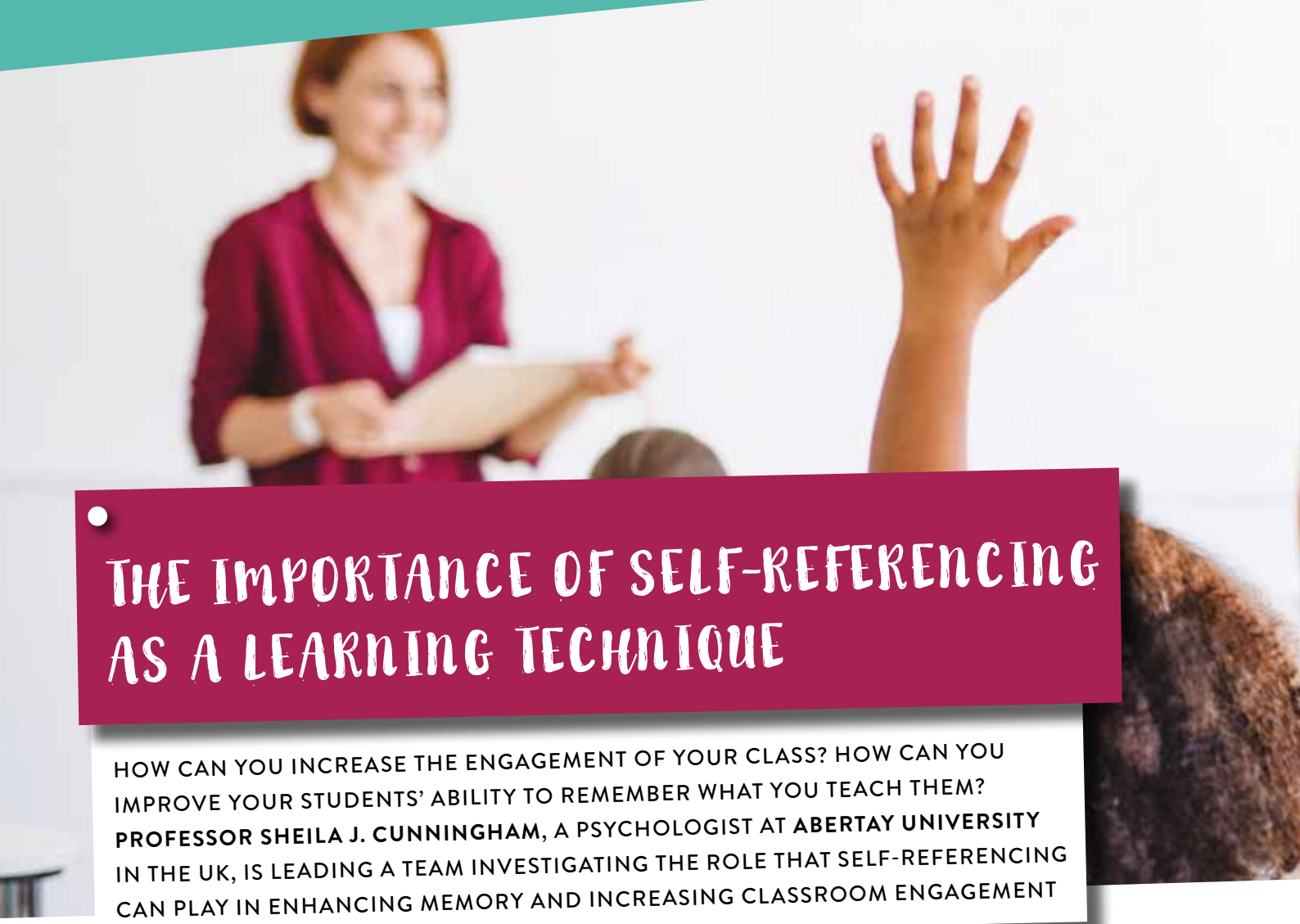
I'd say I'm diligent and conscientious. I always try and give my best. This also makes me competitive, although I do support my colleagues and enjoy their achievements. I certainly believe these characteristics are helpful, but they are not required to become a successful philosopher.

WHAT IS YOUR FAVOURITE FACT ABOUT A FAMOUS PHILOSOPHER?

I have to say that most of them are quite boring people! For instance, Ludwig Wittgenstein, a famous philosopher who taught at Cambridge, is reported to have said that it did not matter to him what he ate, as long as it was the same every time. Apparently, he always ate the same meal! I don't know if that's really true, but I would say that indicates a character flaw, a kind of dietary narrow-mindedness. Still, we don't admire famous philosophers for their character, but for their thoughts.

WHAT DO YOU ENJOY DOING OUTSIDE OF WORK?

My main passion outside of work is football. I play for a vet's team and try to squeeze in regular 5-a-side games with colleagues. I'm also interested in movies.



THE IMPORTANCE OF SELF-REFERENCING AS A LEARNING TECHNIQUE

HOW CAN YOU INCREASE THE ENGAGEMENT OF YOUR CLASS? HOW CAN YOU IMPROVE YOUR STUDENTS' ABILITY TO REMEMBER WHAT YOU TEACH THEM? **PROFESSOR SHEILA J. CUNNINGHAM**, A PSYCHOLOGIST AT **ABERTAY UNIVERSITY** IN THE UK, IS LEADING A TEAM INVESTIGATING THE ROLE THAT SELF-REFERENCING CAN PLAY IN ENHANCING MEMORY AND INCREASING CLASSROOM ENGAGEMENT

How is it that we remember something? And why do we remember some things better than others? Memory plays a hugely important role in our learning. Learning can be defined as acquiring knowledge or new skills, but we also need to maintain access to this new information, so that we can retrieve and apply what we have learned in the future. For this reason, memory is pivotal to learning.

Rhymes and mnemonics are common tools for helping us to remember information. During maths classes, do your students hum along to the to the tune of 'Pop! Goes the weasel'?

Half the sum of the parallel sides,
Times the differences between them,
That's the way you calculate,
The area of a trapezium!

Or do they remember the order of the planets from the sun using My Very Easy Method Just Speeds Up Naming Planets – Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune (prior to the banishment of Pluto)?

Adding to these well-known methods of supporting memory, Professor Sheila J. Cunningham of Abertay University, a psychologist specialising in social cognition, is investigating a method known as 'self-referencing'. Sheila is leading an ESRC-funded project exploring how self-referencing can have a positive impact on memory and learning, with colleagues Dr Janet Mclean (Abertay University) and Dr Josephine Ross (University of Dundee), and research staff Dr Joshua March and Karen Golden. The project is based on findings that self-referencing, self-knowledge and self-cues can easily be applied in the classroom, providing simple ways of increasing student engagement and knowledge retention.

WHAT ARE SELF-REFERENCING, SELF-KNOWLEDGE AND SELF-CUES?

"Self-referencing is simply the process of linking information with yourself," says Sheila. This is a useful tool for improving memory, because if you process information while associating it with yourself, you are more likely to remember the information than if you process it in relation to someone else.

"Self-knowledge is the term used to describe the network of information about ourselves that we hold in our memory," says Sheila. This includes knowledge about our character traits, facts about ourselves and the autobiographical memories we hold. "And self-cues are things we encounter that link to our self-knowledge." This could be our own name, an image of our own face or belongings, or even words like our pet's name. When we perceive a self-cue, that activates our self-knowledge and attracts our attention.

HOW DO SELF-KNOWLEDGE AND SELF-CUES IMPACT ON MEMORY?

Both self-knowledge and self-cues have a strengthening effect on our memory. "There is over forty years of research showing that when self-cues are encountered or self-knowledge is activated, a strong memory trace is produced," explains Sheila. "This research consistently shows that if participants are asked to think about a list of trait words (e.g., kind, tidy, calm) in relation to themselves ("Does this word describe you?"), in relation to another person ("Does this word describe Beyoncé?"), or in a non-social way ("Is this a positive word?"), words considered in relation to the self are remembered better. This is known as the 'self-reference effect' on memory."

Sheila and her team have built on these early findings, showing that to produce a self-reference effect on memory, it is not even necessary to evaluate the trait words. "Our research shows that simply presenting the

word alongside the participant's own name or face onscreen results in better memory for that word," explains Sheila. Studies like these show that self-knowledge and self-cues produce a robust memory advantage.

WHY DO WE REMEMBER INFORMATION BETTER IF IT RELATES TO US?

Put simply, the more relevant a cue is to you, the more it will attract your attention. Think about when you overhear someone using your name in conversation – your ears are instantly pricked. From a psychological point of view, this system ensures we keep track of information that is potentially important to us, thereby increasing the likelihood that a reliable memory trace for that information will be encoded and stored.

Once encoded, self-referenced memories can be linked to existing self-knowledge. Our long-term memory is organised categorically, with all the information linked to a central construct stored as a network. When one part of that network is activated, it increases the activation of the other associated memory (e.g., when the word 'doctor' is activated, associated constructs like 'nurse', 'medicine' and 'hospital' would also increase in activation). "Because we have such a vast and frequently accessed store of self-knowledge, this category is particularly rich and easily accessed," says Sheila. "This means that incoming information that is related to us has an accessible framework to slot into, linking it to other self-related information."

HOW CAN SELF-REFERENCING BE USED IN THE CLASSROOM TO HELP LEARNING, AND HOW DOES IT DIFFER FROM PERSONALISATION?

Personalisation is a reasonably well-established teaching method, where engagement is encouraged by making teaching materials relevant to the interests of children. Maths problems may be based around popular hobbies like football, or students may be asked to write about a well-known celebrity. While this is a great encouragement tool, not every child has the same interests. This means that materials used in the classroom can only be 'personalised' around generic themes. To create truly personalised materials would necessitate individual resources tailored for each child, requiring additional time and money to provide these.

"The good thing about using self-referencing is that we know every child is interested in themselves!" says Sheila. This means that simple self-referencing techniques can result in generic teaching materials that are nevertheless personal to each child, encouraging every student to engage. "Simply adding the pronoun 'you' creates a self-referent version of a task, problem or worksheet," Sheila explains.

WHAT HAS SHEILA OBSERVED WHEN SELF-REFERENCING IS USED IN THE CLASSROOM?

Sheila and her team are working with teacher focus groups from Scottish primary schools to develop their understanding of how self-referencing can be applied within common educational practices. They have been testing children's performances on classroom tasks to examine the impact of self-referencing on different types of attention and memory. So far, their work has focused on exploring the use of personal pronouns to activate self-referencing in numeracy (problem solving) and literacy (close reading) tasks.

"There is evidence that including personal pronouns in maths problem solving tasks can improve the speed and accuracy of responses," says Sheila. "For example, in word problems with multiple characters (Sally has three balls and Johnny has four balls. How many balls are there altogether?), speed and accuracy are improved by replacing one of the characters with the pronoun 'you' (You have three balls and Johnny has four balls. How many balls are there altogether?)." Children engage more with the activity when they are included within the task itself and by altering the task to include the pronoun 'you', it becomes self-referent.

In other research Sheila has been involved with, it was observed that children wrote longer and more accurate sentences if they began the sentence with the word 'I'. One week, children were asked to write self-referent sentences, starting each with the word 'I'. The next week, they were asked to write sentences about Harry Potter, beginning every sentence with 'Harry'. "The children wrote sentences that were around 10% longer in the self-referent week, suggesting they were more engaged in the task," says Sheila. "And when later tested on the spelling of the words used in their sentences, we found significantly better performance of words from the self-referent sentences. Words from the self-referent sentences produced test scores around 13% higher than words from other-referent sentences."

"What was nice about this study is that the change in instruction to make the sentences self-referent required no materials, no investment and no extra effort from the teachers, but produced a measurable impact on the children's learning," says Sheila. She is keen to highlight the importance and effectiveness of self-referencing as a technique that educators can use in the classroom. Ultimately, this will help teachers impart their knowledge in better ways to the benefit of all students.

PROFESSOR SHEILA J. CUNNINGHAM

Abertay University, UK

FIELD OF RESEARCH

Social Cognition

RESEARCH PROJECT

Investigating the effect of self-referencing on memory and how this can be used in the classroom

FUNDER

Economic and Social Research Council

The support of the Economic and Social Research Council (ESRC) UK is gratefully acknowledged. Our current project is supported by ESRC research grant ES/T000465/1.

SOCIAL COGNITION IN EDUCATION

Sheila is a professor of social cognition, the branch of psychology that studies how we process social information such as facts about ourselves and other people. This involves systems like short-term and long-term memory, attention and perception. Social cognition is biased by heuristics (taking mental short-cuts to quickly solve a problem or make a judgment) that skew how we notice, encode and remember information.

Social cognition research has revealed a lot about the ways in which people remember information, which is relevant to much existing educational theory and practice. We organise information categorically in our memory, such that when a category is activated, the activation of all the other information associated with that category is increased. This means that if you present new information to your students in categorised chunks, they are more likely to remember it successfully.

Cognitive studies have also shown that information is easier to remember and organise if it is consistent with what we expect. If new information is different from expected, it can only be easily remembered if the learner has enough attentional capacity to process the unexpected information properly. "This can be applied in learning," says Sheila. "If a lesson is built on effective scaffolding so that new information is consistent with existing knowledge, this is likely to result in easier encoding and improve subsequent recall."

USING SELF-REFERENCING WITH OLDER STUDENTS

Although Sheila's research has centred on children at primary school, self-referencing can just as easily be applied to older students across a range of subjects. "The memory advantages associated with self-referencing are robust across childhood, adolescence and adulthood," says Sheila, "so are just as applicable to secondary and university students as they are to primary children." In fact, as older children encounter more complex information, self-referencing might help them better relate to the material, thereby engaging their attention and supporting their memory. "Any tasks that involve learning or organising information can benefit from self-referencing techniques," explains Sheila.

The benefits of self-referencing for older students are evident to Sheila in her professional life while teaching psychology at university. Her subject covers complex cognitive models about a range of topics such as working memory, child development and prejudice. By asking her students to consider how these mechanisms might have influenced their own experiences, Sheila is asking her students to apply self-referencing to the topics she is teaching, and she finds that this makes a big difference in their engagement in the class.

"When discussing attentional capacity, I might ask my students to list times when they have experienced dual-tasking issues, like trying to remember a phone number while looking for a pen to write it down," she says. "Or when discussing prejudice, I ask them to think about when their own impression of a stranger may have been unfairly influenced."

Any topic in any subject – science, maths, languages, humanities, arts – can be made more engaging by asking students to stop and think about how this particular topic relates to them and their own experiences. In addition, if students are aware of the value of self-referencing, then they can apply it to their own personal study techniques. Encourage your students to think of ways to relate any new information to themselves, allowing them to take advantage of this simple but effective tool to improve memory.

APPLYING SELF-REFERENCING IN THE CLASSROOM

As discussed, there are a variety of ways in which self-referencing can be applied in the classroom. Sheila and her team have used different techniques to create a self-reference effect on memory, with one of the most reliable methods being self-ownership. "We developed an ownership game in which two players have different coloured shopping baskets. They are given pictures of objects with a coloured sticker, and the player whose basket matches the colour of the sticker 'owns' that object," explains Sheila. "Later, when we test players' memory for all the objects presented, we find a much higher recall of the 'self-owned' items that were in the player's own basket, compared to those 'owned' by the other player."

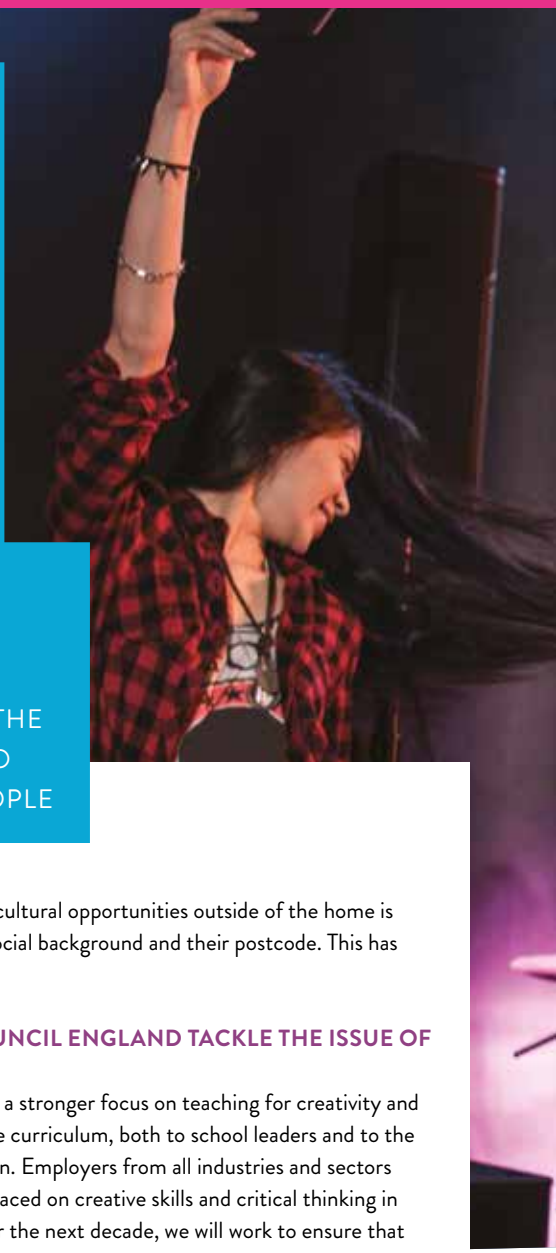
Interestingly, Sheila's research has shown that the self-ownership effect exists in both children and adults, and works even when players are presented with dozens of objects for just a couple of seconds each. Even though the ownership is not real (the players understand that they are not really going home with the items in their basket), the suggestion of self-ownership appears to be enough to help them remember the objects.

Such findings can be extrapolated and applied in the classroom. "The memory advantage for self-owned items is also found when the belongings are not objects but are things to learn, like facts written on flashcards," explains Sheila. "This makes the ownership game a useful learning aid, taking self-referencing into the classroom."

Sheila encourages all educators to apply self-referencing techniques in your own lessons. Ask your students to relate the topics you are teaching to their own personal experiences. Include the pronoun 'you' in instructions for any tasks. Create your own version of the ownership game when introducing new facts to your class.

How will you include self-referencing in your classroom?

LET'S CREATE: WHAT ART COUNCIL ENGLAND'S 10-YEAR STRATEGY MEANS FOR SCHOOLS AND YOUNG PEOPLE



IN 2020, **ARTS COUNCIL ENGLAND**, ENGLAND'S NATIONAL DEVELOPMENT AGENCY FOR CREATIVITY AND CULTURE, SET OUT ITS 10-YEAR STRATEGY AND, OVER THE COURSE OF THIS YEAR, IS PUBLISHING ITS DELIVERY PLAN FOR 2021-24. WE READ THROUGH THE STRATEGY, KNOWN AS **LET'S CREATE**, AND SELECT KEY ELEMENTS TO UNDERSTAND WHAT IT WILL MEAN FOR SCHOOLS AND YOUNG PEOPLE

WHAT IS ART COUNCIL ENGLAND'S VISION?

By 2030, we want England to be a country in which the creativity of each of us is valued and given the chance to flourish, and where every one of us has access to a remarkable range of high-quality cultural experiences.

Recognition of the part that creativity and culture can play in supporting local economies and talent, health and wellbeing, and children and young people, has flourished over recent years, strengthening our partnerships with local and national government, opening up new avenues for all who work in museums, libraries and arts organisations, and improving the lives of people everywhere.

WHERE DO SCHOOLS AND YOUNG PEOPLE SIT WITHIN THE 10-YEAR STRATEGY?

Children and young people were at the heart of our first Strategy and it was clear from our consultation that the public places tremendous value on our support for them. So, over the next 10 years, we will focus a large part of our development role on ensuring that children and young people are able to fulfil their creative potential, and access the highest-quality cultural experiences where they live, where they go to school and where they spend their free time.

Our partnership with the Department for Education will remain central to our work in this area. We will continue to advocate – to the Department for Education, and to the public and teachers – for the value of creativity in education as well as the importance of a rich curriculum that includes art and design, dance, drama and music. Securing the creative and cultural lives of all our children and young people is critical to realising this Strategy's vision for 2030.

WHAT ARE THE ISSUES FACING SCHOOLS AND YOUNG PEOPLE?

Children and young people talk passionately about the pleasure they get from creative activities (many of which they undertake in their own time, and often online) and how they use them to express themselves and develop their skills and confidence. They also talk about the important role that creative activities can play in helping them deal with anxiety, stress and social isolation. However, for most young people, access to high quality creative and cultural opportunities outside of the home is too dependent on their social background and their postcode. This has to change.

HOW WILL ARTS COUNCIL ENGLAND TACKLE THE ISSUE OF INEQUALITY?

We will make the case for a stronger focus on teaching for creativity and critical thinking across the curriculum, both to school leaders and to the Department for Education. Employers from all industries and sectors spoke of the value they placed on creative skills and critical thinking in their workforces, and over the next decade, we will work to ensure that those skills are developed more effectively in young people.

In addition, we are committed to ensuring that a broad and vital arts curriculum is taught in all schools. We will also encourage the Department for Education to build on its current investment in Music Education Hubs, National Youth Music and Dance organisations, In Harmony and Saturday Clubs, so that all children and young people in this country can develop their creative potential, inside and outside of school. Finally, we will create clearer, more accessible pathways for children and young people who are interested in pursuing careers in the creative industries.

We will publish a set of named priority places in which cultural engagement and our current investment are too low, and where, as a result, opportunities for creative and cultural engagement are underdeveloped. We will particularly focus on supporting programmes that improve opportunities for children and young people in these places to access high-quality culture and realise their creative potential. We will support this work with a range of investment and capacity-building programmes, including via the National Portfolio, ring-fenced Place Partnership Funds within NLPG, Developing Your Creative Practice, and Creative People and Places.

HOW WILL ARTS COUNCIL ENGLAND SUPPORT CAREERS IN THE ARTS?

Given the very visible impact of the pandemic on the creative industries, there is a real danger that many young people will abandon their aspirations for a career in our sector. We will work with others to rebuild

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twitter.com/ace_national

www.linkedin.com/company/arts-council-england/

www.instagram.com/aceagrams/

confidence, especially among children and young people, in the viability of a career in the creative industries. We will work with partners to ensure that new pathways into the creative industries are opened up for young people everywhere, but especially Black, Asian, ethnically diverse and disabled creative practitioners, as well as those from lower socio-economic backgrounds.

HOW WILL ARTS COUNCIL ENGLAND WORK WITH CULTURAL ORGANISATIONS?

We believe that cooperation between cultural organisations and local partners is particularly effective when it is aimed at supporting children and young people. We will encourage cultural organisations to work in partnership with local education providers to plan, resource and deliver a joined-up cultural education programme that ensures every child in their area can access high-quality culture and realise their creative potential.

- **NATIONAL YOUTH MUSIC ORGANISATIONS**
  Organisations that operate across the country and provide progression routes and pathways for talented young musicians to develop, across a range of musical genres. They are jointly supported by Arts Council England and the Department for Education.

- **MUSIC EDUCATION HUBS**
  Groups of organisations – such as local authorities, schools, cultural organisations, and community or voluntary organisations – working together to create joined-up music education provision. They respond to local need and fulfil the objectives of the National Plan for Music Education. Arts Council England manages funding for Music Education Hubs on behalf of the Department for Education.

- **SATURDAY CLUBS**
  A national programme developed in 2009 with a vision to create regular opportunities for young people to be inspired by and develop within the creative industries. The programme is open to anyone between the ages of 13-16 and is delivered in colleges and universities across the UK. It is jointly supported by Arts Council England and the Department for Education

WHAT CAN WE EXPECT FROM ARTS COUNCIL ENGLAND IN THE NEXT TEN YEARS?

The next decade, in our national role, we will strive to be relevant and responsive to the public, the cultural sector and the places that we are here to serve, by listening and giving voice to a wide a range of people, including young people.

This text is an abridged version of Art Council England's 2020-2030 Let's Create Strategy. To read more about Let's Create, visit: **www.artscouncil.org.uk/letscreate** and **www.artscouncil.org.uk/lets-create/our-delivery-plan-2021-2024**

CAN MENTORING HELP POETS THRIVE?

HOW IMPORTANT HAS MENTORING BEEN IN THE CREATIVE INDUSTRIES? THIS IS WHAT **PROFESSOR WILL MAY** FROM THE **UNIVERSITY OF SOUTHAMPTON** IN THE UK IS TRYING TO DETERMINE. HE HAS USED HIS FINDINGS TO ESTABLISH POETRY AMBASSADORS, A MENTORING PROGRAMME TO SUPPORT YOUNG POETS AND HELP THEM TO DEVELOP THEIR CREATIVE ABILITIES

TALK LIKE A LITERATURE RESEARCHER

ANTHOLOGY – a collection of poetry

CREATIVE INDUSTRIES – industries based in individual creativity, skill and talent, such as arts, writing, music, fashion, advertising, computer gaming, television and film

MENTOR – an advisor who helps train and guide a more novice colleague

MENTEE – the recipient of a mentor's advice and guidance

The romantic image of the lone poet is not true to life, says Professor Will May of the University of Southampton, as writers and poets are supported by a network of mentors who devote time and energy to encourage each other in their creative endeavours. Will is exploring the role of mentoring in the creative industries and has uncovered how both public initiatives and informal mentoring have shaped contemporary British literary communities. But Will's work is about more than just appreciating literary history – he has also put his findings into practice by creating a mentoring programme for young poets, allowing them to develop their talents under the guidance of experienced writers.

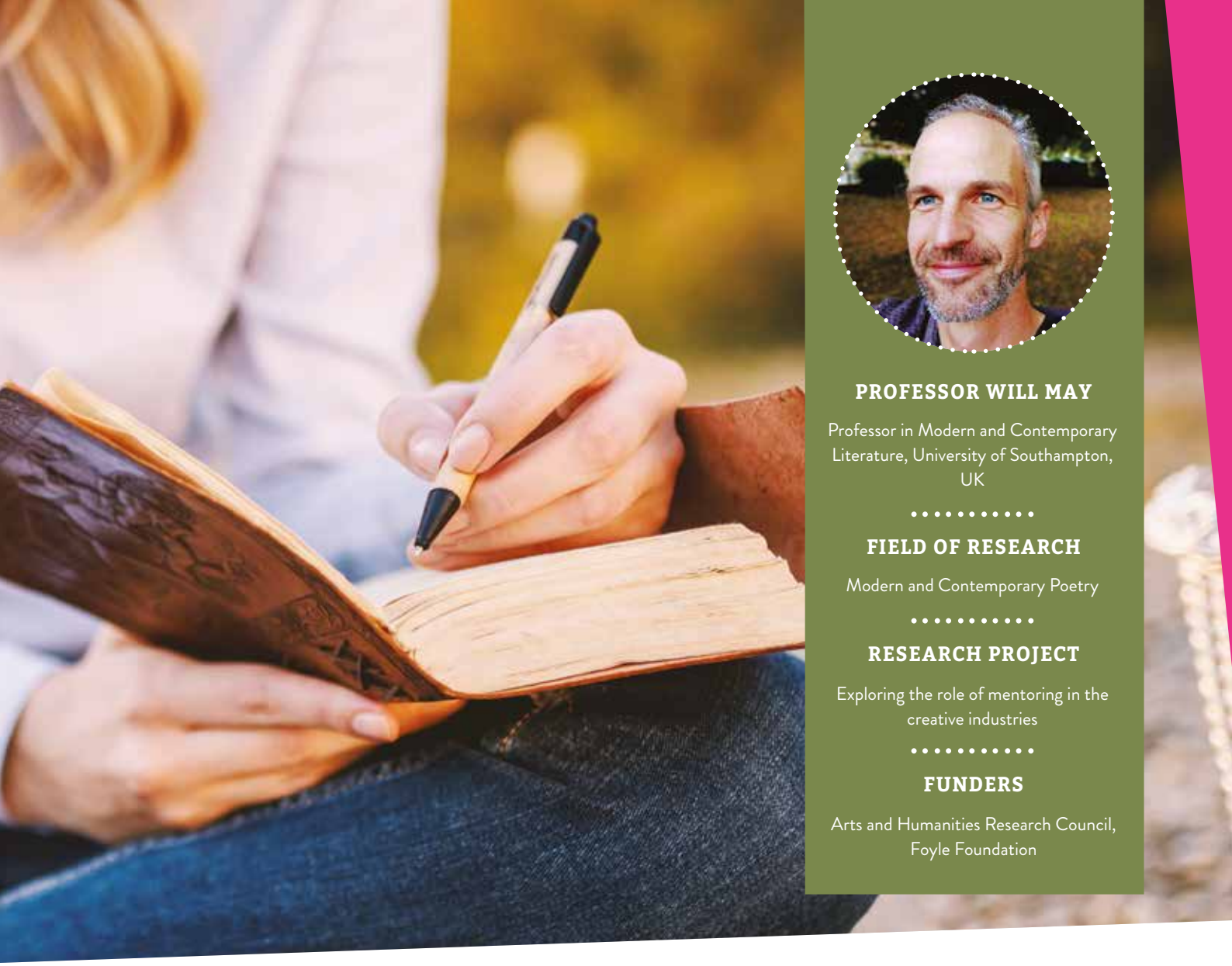
WHAT NETWORKS HAVE SUPPORTED CONTEMPORARY BRITISH POETS?

Contemporary British writers and poets have had access to both public and informal mentoring and support. The UK has nurtured literary expression through initiatives run in local libraries, community organisations, like Centerprise in Hackney, and formal schemes, like the Ledbury Emerging Critics Programme. We can also trace its history by looking at correspondence between poets, publishers and editors across the country.

Equally (or perhaps even more) important are informal mentoring and networking groups. Will cites the example of poets Malika Booker and Roger Robinson, who founded a writer's collective that met weekly in Malika's kitchen. "It grew organically, creating a space for marginalised writers to hone their craft," he says, "and now Malika's Kitchen has not only become a regular scheme run by the Poetry Society, shaping the work of some of our best contemporary writers, but has satellite groups across the world." During his research, Will has discovered that many poets create their own mentoring communities with other poets, joined by their mutual love of writing.

Unlike other sectors, the creative industries are often funded on a project basis, with little support for professional development or training. Groups like Malika's Kitchen have played a vital role in helping writers grow through a shared exploration of their writing. Will is exploring this role by collecting stories from mentors and mentees who participated in these informal networks, to discover how their mentoring experience shaped them as artists.

Will's research is more than just retrospective. He believes mentoring in poetry can act as a model for the creative industries. "People tend to read, write and publish poetry to enrich their lives rather than fill their



PROFESSOR WILL MAY

Professor in Modern and Contemporary Literature, University of Southampton, UK

FIELD OF RESEARCH

Modern and Contemporary Poetry

RESEARCH PROJECT

Exploring the role of mentoring in the creative industries

FUNDERS

Arts and Humanities Research Council, Foyle Foundation

pockets," he explains. "This insulates poetry from creative sectors more dependent on market trends and means it has been able to develop sustained knowledge and expertise about mentoring that hasn't yet crossed into other creative industries." The poetry community is an excellent case study for mentoring in the creative industries and a model for other artistic and literary communities.

WHAT IS THE POETRY AMBASSADORS SCHEME?

In partnership with the Winchester Poetry Festival and the literature development organisation Artful Scribe, Will launched the Poetry Ambassadors scheme to connect experienced poets like Romalyn Ante with young poets like Eve Wright. "Formal mentoring schemes can act as lightning rods of change for the mentors and mentees involved," says Will. Mentees gain confidence in their ability and develop greater ambitions for their writing. Mentors in turn benefit from the opportunity to work with a younger generation of writers and contribute to the future of the literary community.

"I'd really like to just feel a little bit more asserted in my writer self, so to speak," says Eve, of their hopes for the Poetry Ambassadors. "Writing is a very isolated craft, especially when you're just starting, so I've really appreciated the support with discovering my poems with another poet." Eve's mentor, Romalyn, helps them with both the technical and psychological elements of the craft. "It's hard for anyone to believe they'll get attached to words until you've put your heart into putting them in a certain order and suddenly giving them the cut feels like you're losing them forever," Eve explains. "My mentoring partnership with Romalyn has helped me learn to let go when I edit my poems."

Eve's experience is familiar to Romalyn. She herself was mentored in the past and knows what it's like to be taking the first steps to being a poet and how important it is to have a guide. "The poetry world is both big and small, but if you're just starting out, especially as a young person, then it can seem quite daunting and overwhelming," Romalyn explains. This can be especially true if a would-be poet lacks role models. "I didn't come from a literary background," she says, "so I really appreciated having a mentor as I began my poetry journey. It really was a tremendous help to have someone to guide me. I want to support young poets like Eve, and I want to learn from the experience myself."

Poetry Ambassadors is launching its first anthology of poetry with Broken Sleep Press in October 2021. Beyond helping mentees and mentors, the mentoring scheme has helped transform the organisations that run it, deepening the collaborations between the University of Southampton, the Winchester Poetry Festival and Artful Scribe, broadening their horizons and making them more outward-looking. "It is helping us work together to better support young people across the region," Will says. Will's research shows that the study of literature is far from an ivory tower endeavour – poetry and writing create communities, give a voice to young or marginalised groups, and allow them to shape their culture and society through their creative works.

ABOUT MODERN AND CONTEMPORARY LITERATURE

"I love the breadth and restlessness of research in English literature," says Will. In his work, he has studied the relationship between music and poetry, 'whimsy' as a literary mode, and the connections between solitary poets and their wider networks and communities. To do this, he has interviewed poets about their practice, dug through literary archives and made connections across disciplines to find new approaches in critical and creative thinking. Literature research often is interdisciplinary, drawing on texts from history, philosophy and economics to frame questions and construct arguments.

WHAT PRACTICAL IMPACT CAN WRITING HAVE?

"To write is to find a voice, and to write better is to draw on those around you to develop it," says Will. "Writing can be used to build and support communities." His research has taught him ways to support writers and writing, a subject he is deeply passionate about. Understanding how writers have succeeded in the past gives us a blueprint for building organisations and institutions to support them and their communities in the future.

EXPLORE A CAREER IN LITERATURE RESEARCH

The University of Southampton offers the Access to Southampton programme (**www.southampton.ac.uk/schools-colleges/access-to-southampton.page**) to help students apply to university.

Verse Mentors (**www.poetryandmentoring.com/podcast**), Will's four-part podcast series about poetry and mentoring, explores the crucial role of mentoring for poets.

The English Department at the University of Southampton has created a series of podcasts discussing texts and study tips to support GCSE and A-level students: **www.southampton.ac.uk/english/about/english-podcasts.page**

PATHWAY FROM SCHOOL TO LITERATURE

Will recommends studying English and other languages in school to, "train your ear, eye, and brain to attend to the power and possibility of literature," before a university degree in English or English literature.

An English or literature undergraduate degree is often the starting point for literature research, and a PhD or extensive professional writing experience is required for an academic career.

But the study of literature is interdisciplinary, so the most important skill to develop is your ability to analyse texts. Will's colleagues in the English Department at the University of Southampton have degrees in history, philosophy and law, showing that a range of subjects could lead to a career in literature research.

MEET MEMBERS OF THE POETRY AMBASSADORS SCHEME

ROMALYN ANTE
POETRY AMBASSADOR MENTOR

WHAT INSPIRES YOU IN YOUR POETRY WRITING?

I've been working as a nurse for almost 10 years and my writing focuses on nursing, especially migrant nurses, as I come from a community of migrant Filipino nurses. I wanted to shed light on the narrative of migrants, and I'm lucky that I wanted to write about something that is already deeply embedded in my own person.

Even though I didn't have any literary experience, my nursing background has taught me to write. In nursing, you're taught to pay attention and to observe. You relate with other people and foster empathy. And these techniques I've learnt through nursing are the same techniques that we use as writers.

WHAT IS YOUR PROUDEST POETRY ACHIEVEMENT?

I would say that it would be the publication of my first poetry book, *Antiemetic for Homesickness*. I'm proud that this book allows readers to come to poetry. I have readers who are doctors, nurses, carers. I have readers who are migrants themselves. I think that's what poetry should be about – poetry should open doors wider. I'm really proud that my work speaks with different readers from different backgrounds.

WHAT DO YOU ENJOY, APART FROM WRITING POETRY?

As well as being a nurse, I also run a Filipino grocery shop with my husband. I enjoy managing it as I get to communicate more with my community, and I enjoy being around food – I love cooking. I also walk my dogs every day, and I like drawing and any other kind of arts and crafts.

WHAT ADVICE WOULD YOU GIVE TO OTHERS WHO WANT TO WRITE POETRY?

Find a mentor to guide you and be open to being taught – it will enhance your own creative practice. I've had three mentors and they have been really helpful. I wouldn't be where I am now if not for their support. A good mentor will guide you and will help you chose what path to take. But, at the end of the day, it is your path, and only you can walk it. Remember, your poetry is yours. It is between you and your work, so think about why you are writing.

HOW DID WILL BECOME A LITERATURE RESEARCHER?

I've always loved singing and music of all kinds – from pop, jazz, and folk to classical song cycles. But the more I learnt about songs, the more my attention turned to the words.

I think it was a sibling who inspired my interest in studying literature. I'm the youngest of four, and I remember reading my eldest sister's English essays and being very confused but intrigued!

I did my PhD on the extraordinary British poet Stevie Smith and I adore her writing. I love the way she stubbornly makes room for all the feelings and encounters of everyday life we didn't realise we could make into poems: frogs, hedges, newspaper clippings, rainy parks. Her scratchy drawings and strange half-sung performances really expanded my sense of what a poem could be, as well as what it could be about.

I'm a great believer in creative writing as a way of keeping your thinking creative too. I enjoy writing myself, as well as studying other people's work. Even if I am teaching an undergraduate course on critical reading, we will often use writing activities to find new ways of thinking about the texts we're studying.

Writing is a conversation with the world, not a formal exam or a private diary. The more you read and think through what other people are writing, and talk to other people about it, the more freedom you will give yourself to experiment, learn and grow.

Beekeeping and acrobatics are both hobbies I've taken up in the last few years and hugely enjoy. Acrobatics is a wonderful (and very undigital) way to think about humans – we leave our worries at the door and become vessels for energy and movement. Beekeeping is fascinating – bees tend to know what they are doing much more than beekeepers do, so it's mostly a chance to look on in awe at a superorganism doing its dazzling work.

WILL'S TOP TIP

Writing is a rewarding journey but should also be a companionable one – find structures that can help support you, whether that's a local writing group, or a national network.

EVE WRIGHT
POETRY AMBASSADOR MENTEE

WHAT INSPIRES YOU IN YOUR POETRY WRITING?

Oftentimes, it's me reading into innocuous, or not so innocuous, events or things and trying to juice the poetry out of them. I'm a strong believer that you can make poetry out of anything. I'm a big music listener, so that is a major influence.

WHAT DO YOU ENJOY, APART FROM WRITING POETRY?

I'm a massive science nerd – I'll have you know my human body, Kevin, with squishy organs is a good writing companion! I'm so much of a science nerd that I'm studying Biomedical Science at university this October.

WHAT IS YOUR PROUDEST POETRY ACHIEVEMENT SO FAR?

I'm getting published in *Ambit* this July. This is my first publication in a major poetry magazine, and I am still pinching myself. I am probably still pinching myself as you this!

WHAT ARE YOUR AMBITIONS FOR THE FUTURE?

It would be nice to have a poetry collection with my name on it one day. As an autistic person, I often believed I would never be as worthy of a place in the writing world as my neurotypical counterparts. If I can make just one person feel capable of writing, it would mean the world to me.

WHAT ADVICE WOULD YOU GIVE TO OTHERS WHO WANT TO WRITE POETRY?

Just keep on jamming your foot in all the writing doors (metaphorically) that get shut on you – eventually you will manage to get both feet through. Take every opportunity you can. Of course, never jam your feet in doors at the expense of your mental health. If you aren't ready for it yet, it is okay to keep some doors closed.

Also, if you have nothing to write, you likely do. Even if it is just "I don't know what to write". If you're ever stuck, just write anything that comes to mind for five minutes. You never know, you may just strike gold.

HOW CAN WE DESIGN SOCIAL MEDIA TO BE INCLUSIVE?

DIGITAL INTERACTIONS ARE BECOMING AN EVER-LARGER PART OF OUR LIVES. AT **QUEEN MARY UNIVERSITY OF LONDON** IN THE UK, **PROFESSOR NELYA KOTEYKO** AND **DR MARTINE VAN DRIEL** ARE USING LINGUISTICS TO UNDERSTAND HOW AUTISTIC PEOPLE USE SOCIAL MEDIA, AND HOW MORE INCLUSIVE ONLINE PLATFORMS CAN BE BUILT FOR THE FUTURE

GLOSSARY

AUTISM – a developmental difference which affects how people communicate and interact with the world

GIF (GRAPHICS INTERCHANGE FORMAT) – a short, animated image commonly used online

LINGUISTIC ETHNOGRAPHY – the interpretation of human interactions within the specific social contexts and structures in which they occur

SOCIAL MEDIA/SOCIAL NETWORKING SITES – online platforms where people can connect, communicate and share information

The coronavirus pandemic has changed some of the ways we communicate, with virtual interactions replacing many of our face-to-face conversations. While online communication has been a challenge for many, autistic people encountered barriers in communication before the pandemic.

At Queen Mary University of London, linguists Professor Nelya Koteyko and Dr Martine van Driel are investigating how autistic people interact with and through social media, and how changes in the design of digital platforms might benefit autistic users.

WHAT'S IN AN EMOJI?

"When we communicate online, we are missing a large part of in-person communication, for instance body language, eye contact and gestures," explain Nelya and Martine. As we now live large parts of our lives in an online environment, we are having to learn how to adapt to these missing gestures. Since the advent of text messaging, we have been replacing these physical cues to our moods and feelings, first with emoticons such as :-), then emojis such as 😊, and finally with GIFs and memes on social media.

As we increasingly use these online displays of emotion, we also become more sensitive to their meanings. And it's not just about emojis and GIFs. Punctuation can also change the tone of a non-verbal message, as can the use of capital letters.

Imagine you are late to meet your friend in the park. They have already arrived and so send you a message to let you know. How would you feel receiving these three different messages?

How does their choice of punctuation change how you feel about their message? Perhaps message 1 with no punctuation is just a statement, simply letting you know that they have arrived at your meeting point. An exclamation mark generally indicates excitement, so the sender of message 2 is probably excited to see you when you arrive. But adding a full-stop to the end of a short online message? This is often considered passive aggressive or angry. If you receive message 3, take the hint that your friend is fed up with your lateness!

AND WHAT DOES THIS HAVE TO DO WITH LINGUISTICS?

Linguistics is not about speaking lots of different languages. It is about the structures

and patterns of human communication, and in the case of applied linguistics, the contexts in which these structures and patterns arise.

The rise of social media provides a new area of research for applied linguists, as the contexts in which we use language to communicate online are different from face-to-face communication. As applied linguists, Nelya and Martine are interested in how people use language as well as emojis, GIFs and images to communicate and connect with others through social networking sites and digital platforms.

WHY MIGHT AUTISTIC PEOPLE PREFER ONLINE COMMUNICATION?

In the UK around 700,000 children and adults are autistic, a developmental difference which affects how people interact with others and their environment. Nelya and Martine are collaborating with the autism charity Autistica to examine how autistic adults communicate via social networking sites.

Some autistic people have different ways and preferences for using body language; for example, not relying on eye contact during conversation as much as non-autistic people do. In face-to-face interactions with non-autistic people, this may lead to misunderstandings. Social media environments come with different forms of communication, where eye contact no longer plays a central role, and where we can choose to use only text or to supplement text with still or moving images (e.g. GIFs) "In addition, communicating online means autistic people can avoid things that may be overwhelming, such as travel to physical meetings, background noise and interacting with strangers," explains Martine.

For these reasons, some autistic people may prefer to communicate online rather than face-to-face, making social media an important environment for autistic users. However, most social media platforms have been designed by and for non-autistic users, meaning some features may still not be inclusive.

WHAT CAN TWEETS AND HASHTAGS TELL US?

Nelya and Martine have a step-by-step plan of how to investigate this issue. First, they are observing how autistic participants interact on social media platforms by studying their posts on Facebook and Twitter. "We observe what features of the platform they use, and look for patterns in what they post and how they post it. For example, do they tag people or use hashtags?" says Nelya. "Or do participants include emojis?" adds Martine. "If so, we ask what the emojis do in each specific post. Do they clarify the emotion in the text, or do they turn the text into a joke?" Hashtags and emojis are useful for people to find others online and to relate to each other. Nelya and Martine use special linguistics software to analyse the language in the posts to see how specific words or word combinations are used, enabling them to look into patterns across the thousands of social media posts they have collected. They also note the types of social media features used, for instance 'sharing', 'replying' or posting 'status updates'.

Next, Nelya and Martine conduct interviews with the participants, asking about their experience of using social media. They analyse interview transcripts to identify themes and topics that participants talk about when discussing their social media use. They are already starting to get some important feedback. "Autistic users of these platforms said they liked the ability to easily step away from an interaction when they need a break or need a bit more time to think about what to say," Martine reports.

WHAT NEXT?

In the final part of the plan, Nelya and Martine will be working with Professor John Vines at the University of Edinburgh and autistic social media users to put their knowledge into practice. John is interested in how people interact with computers and uses this knowledge to improve software design. "Once we understand how autistic people use language, images and technical features such as 'likes' on social media platforms, this knowledge can be used by software designers to create digital networking environments that take autistic user preferences into account," explains Nelya.

Nelya and Martine emphasise that their project is not about imposing solutions from academic theory. "It is crucial to work with autistic participants directly so we can learn from their experiences and understand why they use social media in the ways that they do." If you have a passion for inclusion and a curiosity about language, a career in applied linguistics could be for you!

PROFESSOR NELYA KOTEYKO

Professor of Language and Communication, Queen Mary University of London, UK

DR MARTINE VAN DRIEL

Postdoctoral researcher in Applied Linguistics, Queen Mary University of London, UK

FIELD OF RESEARCH

Applied Linguistics

RESEARCH PROJECT

Analysing autistic user experiences of online social networking and improving social networking platforms

FUNDER

Economic and Social Research Council

ABOUT LINGUISTICS

As the study of language and communication, linguistics is a broad field covering many subdisciplines. Applied linguistics is often concerned with how language is used in the everyday, by individuals or specific groups and institutions. "When we look at patterns in language, we can aim to examine why some word choices seem to be more successful than others at conveying particular meanings in specific contexts, while others may result in misunderstanding," says Nelya.

Martine sees linguistics as playing an important role in our culture and society. "We can draw attention to all the different ways people communicate, with the hope that everyone will become more aware of the diversity that we have," she explains. "The most challenging aspect is that we can never know how someone intended their words or text to be understood."

HOW CAN LINGUISTICS HELP WITH PUBLIC HEALTH COMMUNICATION?

"How patients, doctors or political leaders talk face-to-face or online can tell us about how people experience and understand particular illnesses, as well as their treatment and prevention," explains Nelya. Since the start of the pandemic, we have all been overwhelmed by media statements and press conferences, and the value of science communication has become more obvious than ever. Nelya is passionate about using linguistic analysis to understand how knowledge about health and illness is communicated by different groups in society, and how people talk about their experiences of living with illness.

WHAT ISSUES WILL BE FACING THE NEXT GENERATION OF LINGUISTS?

"The current objects of applied linguistics research still often come from Anglo-American or European cultures," says Nelya. "This means that 'real world' issues tend to be limited to mostly Western, affluent societies." However, she is optimistic that this is starting to change, particularly in the field of linguistic ethnography. "There is a growing interest in how we talk and write about issues such as inequality, war and climate change in a variety of cultures and societies."

Although Martine spends much of her time researching online communication, she still believes that "as the ways we communicate continue to evolve, it will be important to remember that often we can connect how we communicate online to how we speak in person".

EXPLORE A CAREER IN APPLIED LINGUISTICS

- With a background in linguistics, you could explore academic roles in research or teaching, medical roles such as speech therapy, or use your skills for a broader range of media-focused careers.
- Keep up to date with linguistics research by reading magazines and listening to podcasts. Nelya recommends:
  - Babel: **babelzine.co.uk**
  - ULAB: **www.ulab.org.uk/about-ulab**
  - Lingthusiasm: **www.lingthusiasm.com**
  - BBC Word of Mouth: **www.bbc.co.uk/programmes/b006qtnz**
  - En Clair (using linguistics to solve crime!): **wp.lancs.ac.uk/enclair**
- Visit the British Association of Applied Linguistics (**www.baal.org.uk**) or the International Association of Applied Linguistics (**www.aila.info**) to learn more about the field.
- Learn about the importance of linguistics for health and science communication and find out about upcoming talks and events: **baalhealthsci.wordpress.com**
- Find out about linguistics and language events for schools run by Queen Mary University of London: **www.qmul.ac.uk/sllf/outreach**

FIND OUT MORE ABOUT THE PROJECT

www.autisticadultsonline.com

www.twitter.com/Online_Autistic

PATHWAY FROM SCHOOL TO APPLIED LINGUISTICS

"Try to take courses that teach you about grammar (in any language)," advise Nelya and Martine, "as well as courses where you will learn about different people and cultures, such as sociology and anthropology."

Many universities will offer linguistics degrees. You will be able to specialise in applied linguistics as you progress through your studies.

NELYA AND MARTINE'S TOP TIPS

01 Try to figure out what interests you most, whilst also remaining open to the different opportunities that life can offer you.

02 Do not be afraid to contact academic researchers about their work – they will be excited to hear that someone is interested, and happy to give their advice!

03 When you receive criticism on your work you should read it through once, but then take some time to 'cool off' before responding. This will help you to be more objective and learn from the criticism – which is what criticism is all about!

HOW DID NELYA BECOME A LINGUIST?

I initially wanted to become a botanist, keen to classify plant species. But in the final years of school I turned my attention to patterns and classifications in language – first in translation and later becoming interested in English on its own.

I found myself really enjoying writing a linguistics dissertation for my undergraduate degree, having expected it to be more like completing a final chore. Working 'with' a research supervisor rather than simply listening to lectures was a big part of that. Collaborative and interdisciplinary research is still important to me now.

I have not followed any well-defined plan to become a linguist. I have previously worked in departments of sociology and media studies, although linguistic analysis has always been key to my research.

Immigrating to the UK as a young adult has sharpened my interest in how meaning is communicated and negotiated across difference, whether it is between different cultural groups using the same language or between people who have different communicative abilities and preferences. I am proud to have contributed to the development of linguistic tools that help us examine and understand such communication.

Technology (such as mobile phones) is now firmly part of our everyday lives. I strive to highlight the important contributions linguists can make to multidisciplinary projects that want to understand the role of communication technology in 'big' societal questions about inclusion and/or health and well-being.

Out of work I enjoy playing volleyball, although in the last five years it is more about playing with my young daughter!

HOW DID MARTINE BECOME A LINGUIST?

I was always a big reader when I was younger, mainly reading fiction. When I went to university, I discovered my interest in language, both through extracurricular activities like debating and through classes in linguistics.

I've always been curious – I would ask a lot of questions as a child! When it comes to language, I think it is fascinating how much the way we say something can affect what people think about us, the topic, and the world at large.

Finding a job during a global pandemic is something I am very proud of as very few universities were hiring so competition was fierce. I also have a book contract for a personal research project of mine, which is amazing.

I'm hoping that in a few years I will be able to move to a permanent lectureship, where I would get to teach and do research.

In my free time, I love to swim, it really clears my mind. I also have a dog called Pippa who I like to take on walks or just cuddle with. I also love reality TV shows! Sometimes your mind needs a little break after a day of deep thinking.

CAN IMMERSION IN VIRTUAL REALITY HELP COMBAT OPIOID ADDICTION?

OPIOID ADDICTION IS A CRISIS IN THE USA, WHERE TENS OF THOUSANDS OF PEOPLE DIE FROM OPIOID-RELATED OVERDOSES EVERY YEAR. **NOAH ROBINSON**, A CLINICAL PSYCHOLOGY PHD CANDIDATE AT **VANDERBILT UNIVERSITY** IN THE USA, IS INVESTIGATING HOW COGNITIVE BEHAVIOURAL THERAPY TECHNIQUES CAN BE DELIVERED THROUGH VIRTUAL REALITY ENVIRONMENTS, BY NON-PROFESSIONAL COACHES, TO HELP PEOPLE OVERCOME THEIR ADDICTION TO OPIOIDS

TALK LIKE A CLINICAL PSYCHOLOGIST

ADDICTION – dependency on a substance (e.g. a drug) that results in negative consequences for the user and withdrawal if they try to stop. People may also be dependent on a behaviour (e.g. playing video games or gambling)

COGNITIVE BEHAVIOURAL THERAPY – a type of psychological therapy focusing on how people's thoughts, emotions, behaviours and body are connected to one another within their environment

OPIOIDS – a group of drugs including prescription painkillers, such as morphine, and illegal drugs, such as heroin

OVERDOSE – when too much of a drug is taken at one time, either accidentally or intentionally, potentially causing death

RANDOMISED CONTROLLED TRIAL – a type of scientific study, commonly used in medical or clinical science, to test the effectiveness of an intervention

VIRTUAL REALITY (VR) – a computer simulation of a 3D environment that a person can interact with

Tens of thousands of people die from opioid-related overdoses every year in the USA. They may misuse prescription medications or take illegal opioids such as heroin. Opioids are highly addictive, so once someone starts taking them, it is very hard to stop. Noah Robinson, a PhD candidate at Vanderbilt University in the USA, believes that virtual reality (VR) may have the power to help those who are affected. Not only is Noah investigating how VR can combat opioid addiction, but he has also founded his own company, Very Real Help, to enable him to put his research into practice.

HOW DOES ADDICTION BEGIN?

Many prescription painkillers contain opioids. Doctors prescribe medicines such as morphine or codeine to patients to reduce their physical pain. But the addictive nature of opioids means that patients may become dependent on their medication, resulting in cravings for the substance and withdrawal symptoms when they stop taking them. This may be because the opioids are not only removing the patient's physical pain, but also their psychological pain. "This means that the relief the patient is experiencing becomes very enticing," explains Noah, "which is when dependency on the opioid starts to occur. Then when the painkiller prescription runs out, some people switch to heroin. Painkillers are very expensive, but heroin is a lot cheaper."

Noah has first-hand experience of the impacts of dependency from his own life. As a teenager, he was dependent on an online video game, playing 80,000 hours of the game throughout his teenage years. "That's as if I had a full-time job, 40 hours a week, for five years!" Noah describes his 'addiction' to the video game as a coping mechanism. When he was 13, he realised that he was gay. He worried about how the world would perceive him, which made him feel ashamed and depressed. But the video game helped him escape from his negative emotions, in the same way opioids decrease the negative emotions of substance users.

NOAH ROBINSON

PhD candidate, Hollon Research Group, Vanderbilt University, USA
CEO of Very Real Help

FIELD OF RESEARCH

Clinical Psychology

RESEARCH PROJECT

Combatting the opioid crisis in the USA by combining virtual reality and cognitive behavioural therapy techniques

FUNDERS

National Science Foundation, National Institute of Health

HOW CAN VIRTUAL REALITY COMBAT OPIOID ADDICTION?

Noah's own experiences of dependency on a video game and a need to escape reality inspired his research into combating opioid addiction. "What if there was something that people could escape into, that could actually help them confront the underlying reasons of why they're escaping in the first place?" he asked himself.

He became excited by the potential of VR technology when he first tried it, as virtual reality has the unique ability to completely replace someone's environment with positive experiences and social connection. "I saw that VR was really powerful when I started working at an inpatient treatment centre and I brought VR headsets with me," he says. "I started seeing huge changes in the mood of patients when they went into virtual reality. They were saying things like, 'all my anxiety is gone' or, 'I don't have any cravings'." Noah has developed an approach he calls Cognitive Behavioral Immersion™, where he uses virtual reality as an immersive environment in which to deliver cognitive behavioural therapy.

THE HELP CLUB

Through his company, Very Real Help, Noah created the Help Club, a VR experience aiming to help people overcome opioid addiction. Like the video game Noah was once dependent upon, Help Club has been designed by psychologists. But unlike video games, which are designed to be as 'addictive' as possible, Help Club is designed so that while people are escaping into the virtual reality environment, they can learn coping strategies for their real-life problems. People join Help Club anonymously (represented as avatars in the virtual environment) and can take part in peer support sessions there, led by a trained peer coach. The coach teaches cognitive behavioural tools, which include techniques related to examining thought patterns and changing behaviours to cope with mental health problems. People can then apply these techniques in their real life when they need them.

Noah is clear that Help Club is not a replacement for rehab from a health care provider. But, he thinks that Help Club can offer affordable and accessible help for people with addiction. People can access it whenever they need to, rather than having to wait for their next therapy appointment. "If someone's having a craving at home, they can put on a virtual reality headset, escape their own environment (which has all the cues for using substances) and go into this world of social connection, support and safety where they can talk to other people and potentially experience positive emotions," explains Noah. Help Club can offer support at the moment it is needed most. Typically, cravings only last 15-20 minutes, but in that moment they seem really, really intense and powerful. "If someone can get through the craving, they can avoid relapse," says Noah.

IS COGNITIVE BEHAVIORAL IMMERSION™ EFFECTIVE?

Individual patients report that Cognitive Behavioral Immersion™ helps them to feel better, and Noah's early research indicates that his methods could be effective. His research involves mood surveys which patients fill out themselves and initial results suggest that the VR environment both reduces negative emotions and increases positive emotions. Most medicines only work to reduce negative emotions, so this could be a real benefit to Cognitive Behavioral Immersion™.

However, Noah's research is still in its early days. To scientifically evaluate whether Cognitive Behavioral Immersion™ helps those with opioid addiction, he will run randomised control trials aiming to answer the question "Does the virtual reality help improve outcomes above and beyond standard treatment?" Noah will randomly assign some patients to receive his VR intervention, while a control group will receive standard opioid addiction treatment. By comparing the outcomes of the two randomised groups, Noah can test the effectiveness of his Cognitive Behavioral Immersion™.

LOOKING TO THE FUTURE

The future for Cognitive Behavioral Immersion™ depends on the outcomes of these trials. "At the moment, we have people who are enthusiastic and excited about what we're doing," says Noah. "But until we do a randomised control trial, tracking outcomes under controlled experimental conditions, we can't know that VR intervention is actually helping people. So that's the vital next step."

ABOUT CLINICAL PSYCHOLOGY

Clinical psychology is the branch of psychology concerned with the assessment and treatment of mental health issues. Clinical psychologists deal with a range of conditions including addiction, depression, anxiety, eating disorders and learning disabilities. They work in various health and social care settings such as hospitals, clinics, social services, schools and prisons. Clinical psychologists never stop learning!

Noah says that clinical psychology is unlike most other subjects because it involves research as well as interaction with patients, which he finds very rewarding, although it comes with challenges.

WHAT ARE THE REWARDS OF CLINICAL PSYCHOLOGY RESEARCH?

Noah thinks that being involved in both research and patient care is fascinating and helps to build a broad set of skills. The research part of his work has opened up opportunities to help more people than a role in patient care alone would allow. "The most rewarding thing is helping people by building an intervention," he says. "This is the most exciting thing I've ever done in my life!"

AND WHAT ARE THE CHALLENGES?

Any field of research comes with big challenges and ground-breaking findings are not guaranteed – research is often characterised by incremental progress rather than pioneering work. Noah says psychology research presents its own particular challenges because lots of the concepts are difficult to measure. "They're all very abstract," he says. "What is emotion? What are thoughts? As my undergraduate professor said, 'research in psychology is like trying to measure the weight of smoke'!"

Noah has the additional challenge of running a company at the same time as completing a PhD. "I've had to learn how to create a business and how to do my research at the same time," he says. "But the business is enabling me to do my research and the research is enabling the business to exist."

Noah believes collaborations between industry and research are really important for developing new psychology interventions. In the USA, you need a company (often a pharmaceutical company, but in this case a technology company) to deliver an intervention to people.

WHAT WILL CLINICAL PSYCHOLOGY LOOK LIKE IN THE FUTURE?

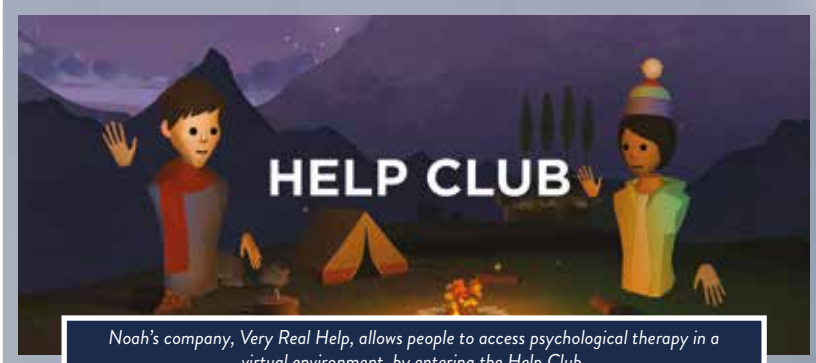
Human interaction will always be really important in clinical psychology, but the next generation of clinical psychologists will need to be technology-literate too. "Technology and artificial intelligence are going to become an increasingly important part of how interventions are delivered," Noah predicts. "It will be super valuable to have programming skills, and computer science is going to be important in psychology." Psychologists like Noah are increasingly using VR to deliver treatments and to conduct research because virtual environments allow them to carefully control their experiments.

EXPLORE A CAREER IN CLINICAL PSYCHOLOGY

- Noah recommends getting exposure to both research (it does not have to be psychology research) and patient interaction (e.g. volunteering at a clinic) to see if you like both aspects of clinical psychology.
- Vanderbilt University (**www.vanderbilt.edu/psychological_sciences**), where Noah studies, has volunteering opportunities for people aged 18+ to learn clinical psychology skills in the lab.
- Help Club also has volunteer opportunities for anyone aged 18+ who is interested in becoming a coach. You can contact hello@veryrealhelp.com if you are interested.
- In the USA, guidance on how to find a psychology internship can be found at: **www.psychology.org/resources/how-to-find-an-internship** and psychology students can be matched to an internship here: **www.natmatch.com/psychint**
- Technology will likely be a big part of the future of clinical psychology. Noah advocates learning how to build VR environments using Unity (**learn.unity.com**). "It's really fun – you can build worlds, put on the VR headset and go into the world that you just built."
- Salaries vary, but the careers website **www.indeed.com** reports that the average salary for a clinical psychologist in the USA is nearly $100,000.

PATHWAY FROM SCHOOL TO CLINICAL PSYCHOLOGY

- You will typically need at least one science subject (e.g. psychology, biology, chemistry, computer science) or maths to be eligible for a psychology degree.
- With a degree in psychology, you can then specialise in clinical psychology at postgraduate level.
- To work as a professional clinical psychologist, it is important that your degrees are accredited i.e. approved by a national organisation like the American Psychological Association in the USA. It is worth researching career pathways in the country you want to work in, because requirements can vary between places.



Noah's company, Very Real Help, allows people to access psychological therapy in a virtual environment, by entering the Help Club.

NOAH'S TOP TIPS

01 Stick with your passion, and go with what your gut tells you, even when your approach seems unconventional.

02 Be willing to try something new and ignore those who discourage you – it's often unconventional approaches that make a huge impact on the world!

HOW DID NOAH BECOME A CLINICAL PSYCHOLOGIST?

WHAT WERE YOUR INTERESTS WHEN YOU WERE YOUNGER?

I loved reading fantasy books, sailing and playing music (trumpet and trombone). And playing video games, obviously, was a big thing!

WHAT INSPIRED YOU TO BECOME SCIENTIST?

I've always been really curious. In elementary school I was limited to two questions a day, because I asked too many questions! I was always interested in psychology and I got really excited when I started doing research and realised its potential to help other people.

WHAT ATTRIBUTES HAVE MADE YOU SUCCESSFUL AS A SCIENTIST?

I think curiosity is important. Humility – understanding that we don't know everything. And then a willingness to push boundaries.

WHAT DO YOU ENJOY OUTSIDE OF WORK?

I love sailing, reading and playing music, so basically the same things as when I was younger. I do still play video games occasionally. But now that I am not escaping from an underlying problem, I play in more moderation than as a teenager.

WHAT ARE YOUR PROUDEST CAREER ACHIEVEMENTS SO FAR?

Getting a grant, becoming a PhD candidate, and starting a company while doing my PhD (which many people advised me not to do!). It's definitely been the hardest thing I've ever done in my life.

YOU ARE CURRENTLY COMPLETING YOUR PHD – WHAT DO YOU HOPE ARE THE NEXT STEPS FOR YOUR CAREER?

I'm hoping to build what we're doing into a clinical research platform. I hope to do a career's-worth of research to understand how we can build scalable, affordable interventions and measure their efficacy within virtual environments.

Playing video games is not a problem, but like most other things it is important to do it in moderation. If you are worried that your gaming is excessive, try following Noah's advice:

"If you have a dependency on gaming, it's important to explore other components of your life," he says. "I believe that excessive gaming is a symptom of an underlying problem. Some questions to explore include: Why are you playing video games? What might be missing in your life (e.g., social interaction outside of the game)? Are you avoiding or escaping something negative in the real world, as I was?"

Once the underlying issue can be identified, then healthy coping strategies can be explored that are alternatives to gaming.

If you want to continue gaming but cut down the time you spend on it, Noah suggests thinking about what you want to achieve in the game, rather than setting time limits. "Instead of trying to restrict yourself by thinking 'I'll only play for one hour today', set goals such as 'I'll complete two raids with my clan'," he advises.

BLOOD, SECT AND FEARS

WHY DO PEOPLE DONATE BLOOD TO STRANGERS? **PROFESSOR JACOB COPEMAN**, A SOCIAL ANTHROPOLOGIST AT THE **UNIVERSITY OF SANTIAGO DE COMPOSTELA** IN SPAIN, HAS DISCOVERED THAT RELIGION, CULTURE AND POLITICS ALL PLAY THEIR PART

TALK LIKE A SOCIAL ANTHROPOLOGIST

RELIGIOUS GURU – a teacher or master of spiritual and religious knowledge

DEVOTEE – a strong believer in a religion who follows the teachings of a guru

If a member of your family was ill and needed blood, would you give up some of your own to save them? What if the person was not a family member, but a stranger? The idea of giving your own blood to somebody you have never met before might seem strange, but this is what millions of people around the world do every year.

Professor Jacob Copeman is a social anthropologist at the University of Santiago de Compostela in Spain. He has been trying to understand why people are motivated to donate their blood, and how this fits into the fabric of our societies. He has discovered that there is far more to donating than medical facts. Giving blood is also about politics, religion and social influencers.

WHAT IS VOLUNTARY BLOOD DONATION?

There are some medical conditions such as anaemia and leukaemia that affect the health of a person's blood. These can be treated by giving the patient healthy blood from someone else and injecting it into a blood vessel. This process is known as a blood transfusion, and it is also used to help people who have lost blood during surgery, childbirth or an accident. Blood transfusions save millions of lives around the world, but they would be impossible without blood donations.

Voluntary blood donation is where somebody gives their blood to be used by whoever might need it, without getting any payment in return. Alternatively, a donor might give their blood to a central blood bank because they have a relative who needs a blood transfusion. This is known as a replacement donation. A third type of donation is a commercial one, where the donor receives a payment. However, voluntary donation is considered the safest method for patients, and is strongly encouraged by the World Health Organization (WHO).

WHAT HAS BLOOD DONATION GOT TO DO WITH ANTHROPOLOGY?

In your biology classes you will have learned that blood is a bodily fluid made up of plasma, red blood cells, white blood cells and platelets. But is this the first thing that comes to mind when you hear the word blood? Depending on your beliefs and culture, you might associate blood with family connections, Christ on the cross, halal meat, war, sacrifice, or any number of other things. Blood donation, therefore, means different things to different people, and this is what anthropologists such as Jacob are interested in.

Jacob has covered attitudes towards blood donation around the world, in countries that include Brazil, China, India, the Navajo Nation, Papua New Guinea, Sri Lanka and the United States. He says it is an "extraordinary emotive force for some communities, and often the source of controversies". Jacob has looked at how non-governmental organisations (NGOs) teach the science of blood regeneration to help allay people's fears about donating, how blood banks work, how people link blood donation to ancient Indian ideas of gift-giving,

PROFESSOR JACOB COPEMAN

Research Professor, University of Santiago de Compostela, Spain; Distinguished Investigator, Galician Innovation Agency (GAIN)

FIELD OF RESEARCH

Social Anthropology

RESEARCH PROJECT

Investigating the political and religious elements of voluntary blood donation, particularly in India

FUNDER

The Economic and Social Research Council

how blood is used in political activism, the use of human blood in art, and the relationship between blood donation and time (encapsulated in the motivational slogan: 'Donate blood. It means only a few minutes to you...but a lifetime for somebody else'). Here we will concentrate on the part of his work investigating what motivates people to give blood in India.

HOW DID BLOOD DONATION BECOME A RELIGIOUS PRACTICE IN INDIA?

In all cultures, there are some people who are particularly respected, and can influence the decisions of other people. For example, in the UK these people include celebrities, sportspeople or social media influencers. In India, some of the most influential people are Hindu and Sikh gurus, and it was thanks to them that voluntary blood donation became popular in the 1980s.

Before the gurus became involved, many people in India were sceptical about giving blood. They had their own cultural understanding of medicine and blood, and many were suspicious of new western medicine. Many believed that giving blood would lead to permanent weakness (in fact, your body regenerates completely in 4-8 weeks). As a result, few people came forward.

Doctors realised that gurus had the power to change the attitudes of their devotees. If a guru endorsed blood donation, their devotees then saw it as a way of expressing their religion and showing their respect for the guru. For many devotees, giving blood was transformed from a strange new medical practice into a sacred ritual, and donations sky-rocketed. As they did so, questions started to arise about the structure of Indian society itself.

HOW DID BLOOD DONATION CHALLENGE THE INDIAN CASTE SYSTEM?

The Indian caste system is a traditional division of society, in which people in the upper castes are considered superior to those in lower castes. Often, the differences between castes are thought to be biological in nature. Many people might believe that there is something contained in a person's blood that indicates which caste they belong to.

However, blood donation has shown people that this is not the case. In reality, there are different types of blood (called A, B and O), but people from different castes can have the same blood type. This means that blood donations cross the boundaries of caste, and help Indian people feel more connected as a country. In fact, the idea that donating blood is a way of contributing to the nation has found its way into Indian politics.

WHY DO POLITICAL PARTIES IN INDIA HOLD BLOOD DONATION EVENTS?

Blood donation is seen as patriotic due to India's history. When people fought to become independent from British colonial rule, they spilt their blood for the sake of their country. India became a free country in 1947, but was later invaded in 1962 by China. During the war, many who were not fighting donated their blood to treat injured soldiers. These memories, in addition to the way blood crosses the caste boundaries, make giving blood a symbol of national pride.

As a result, political campaigns often involve blood donation events. Jacob has observed many such events, and remembers vividly the atmosphere at the first one he attended. "As they donated their blood beneath a colourful marriage tent, activists signed an anti-corruption pledge, joined hands and chanted 'Long live Sonia Gandhi', who is the leader of the Indian National Congress political party." Sometimes, political parties even compete to donate the most blood, as a display of political rivalry.

WHAT CAN WE LEARN FROM THE ANTHROPOLOGY OF BLOOD DONATION?

A key message of Jacob's work is that if we want to change people's behaviour, then we must first understand their culture. In the case of Indian blood donation, people often were not persuaded by doctors; many, instead, put their trust in religious gurus. In order to encourage people to give blood, the gurus first had to be convinced that it fitted with their beliefs. If this had not happened, Indian blood banks might still be trying, unsuccessfully, to persuade large swathes of the population that donating blood is safe and effective.

One important facet of anthropology is that it helps us to understand what motivates groups of people, and who the influencers are in different societies. You may be a voluntary blood donor one day, if – that is – the blood bank understands who or what motivates you!

ABOUT SOCIAL ANTHROPOLOGY

How do social structures and practices differ, and how are they the same? What defines culture, and what is universally human? These are the questions that anthropologists try to answer. They do so by studying peoples' lives in detail, often by living alongside communities for extended periods of time.

DO ANTHROPOLOGISTS STUDY REMOTE TRIBES?

Social anthropology is often associated with the study of small, isolated communities. While this is sometimes the case, anthropologists are interested in much more. Ultimately, any community, from any part of the world, has its own unique features and could be the subject of anthropological research.

WHY IS SOCIAL ANTHROPOLOGY IMPORTANT IN MEDICINE?

Advances in medicine are useless unless they are accepted by a society. The last time you swallowed a pill, did you stop to check the ingredients and find out how it works? Probably not, because you trust the pharmacy or doctor who gave you the pill. Building that trust between medicine and society is vital, and that is where anthropology can help.

Medical anthropologists explore belief systems, power structures and motivations in different medical contexts. This can help the medical profession to communicate effectively with different populations. Jacob's work on blood donation in India is just one example of this type of anthropology.

EXPLORE A CAREER IN SOCIAL ANTHROPOLOGY

- Anthropology is global in its reach, and gives you the tools to research the nature of societies, communities and organisations. Learn more about the subject at **www.discoveranthropology.org.uk**.
- The American Anthropology Association has a YouTube playlist showcasing anthropologists in a wide range of specialities: **www.youtube.com/playlist?list=PL0OchlJ85m4f_2--kdkxQlt9ozy9CQc2K**
- You could work in academia, policy, development, social work, business and in many other sectors. Salaries for academic anthropologists in the UK range from £32,000 to £82,000.

JACOB'S TOP TIPS

01 Develop your curiosity for how different cultures, organisations and societies work. Read newspapers, follow relevant media channels, watch relevant TV programmes. Be curious when travelling, both in your home country and abroad.

02 Only a small number of social anthropologists follow an academic career. Explore other sectors where your degree will be valuable, including education, human resources (HR), public relations (PR), social work, museum work, charity and international development, policy work, market research, film or business. Gain practical experience during your studies to help you decide which sectors interest you most.

03 Remember that many people will not fully understand what social anthropology is about, and you may need to explain it concisely to future employers. Be ready to talk about the valuable skillset you will develop through your studies.

PATHWAY FROM SCHOOL TO SOCIAL ANTHROPOLOGY

- To study anthropology at university, you will need to show an interest in how different societies work, and the people who make up these different societies.
- English literature, religious studies and history will all stand you in good stead as an anthropologist. However, most universities do not require specific subjects.
- Some anthropologists come to the field after studying another arts or humanities subjects. Jacob, for example, studied English for his first degree.

A photo taken by Jacob of the University of Santiago de Compostela at night. Imagine this being your place of work!

HOW DID JACOB BECOME A SOCIAL ANTHROPOLOGIST?

WHAT DID YOU KNOW ABOUT ANTHROPOLOGY WHEN YOU WERE GROWING UP?

Nothing! I first encountered social anthropology when I was at university. Out of interest, I took a course in the anthropology of emotions and personhood. This sparked an interest in both anthropology and India which, having completed my BA in English Literature, led to me taking a conversion Master's course in social anthropology at the University of Cambridge, and choosing a dissertation project based in India.

HOW DID YOU REALISE ANTHROPOLOGY WAS SOMETHING YOU WANTED TO GET INVOLVED WITH?

I was unaware of anthropology as a subject until I was in my late teens, so I certainly didn't grow up thinking I'd be an anthropologist – I don't think many people do! However, in my early teens, I developed keen interests in politics, religion and culture. When I discovered anthropology as a discipline, I realised these interests were an excellent basis for anthropology. In my time, I've also wanted to run an independent arts venue, and be a writer on music and sport.

HOW DID YOU COME TO STUDY BLOOD AND BLOOD DONATION?

I came to this topic by doing a PhD on the social aspects of blood donation in India. In particular, it explored the transition from a system of commercial donation to a voluntary donation system. By accident, this became a study of religion and religious change. What I hadn't realised before I got to Delhi to do the research was that a key strategy of blood banks was to enthuse religious gurus, whose support of voluntary blood donation motivated their devotees to take part. In this way, the study of blood and blood donation lead on to other themes, all of which I continue to research. You just never know where your research will take you.

WHAT QUALITIES DO YOU HAVE THAT MAKE YOU A GOOD ANTHROPOLOGIST?

I get excited by ideas – that helps; a love of reading, too; plus an interest in the interconnectedness of disciplines and ideas; and keenness to interact with people. I like – and have been reasonably successful in – collaborating with others: both the people whom I meet while undertaking fieldwork in India, and also other scholars.

For one of my books on blood in India (*Hematologies: The Political Life of Blood in India*) I collaborated with Professor Dwaipayan Banerjee, who is in the science studies programme at MIT in the US. Working with Dwai was stimulating and inspiring. We never actually met during the writing process; everything was done via email.

WHAT DO YOU LOVE ABOUT THE WORK YOU DO?

I have always been curious about how societies work, and the differences and similarities between different societies and cultures. I love the fact that I can follow my curiosities and explore these in such depth. I meet interesting people all over the world, and have the opportunity to be part of events I would otherwise know nothing about, from mass blood donation camps in India to spectacular religious ceremonies.

I also love the global reach of being an academic researcher. Academia is an international community, and I benefit hugely from the cross-fertilisation of ideas that comes from collaborating with academics around the world.

HOW DOES THE TYPE OF PAYMENT YOU RECEIVE IMPACT YOUR HEALTH?

BY COMBINING THE EXPERTISE OF ECONOMISTS AND PSYCHOLOGISTS AT **THE UNIVERSITY OF ABERDEEN** IN THE UK, **PROFESSOR KEITH BENDER** AND **DR NICOLE ANDELIC**, ALONG WITH COLLEAGUES **DR JULIA ALLAN, DR DAN POWELL** AND **PROFESSOR IOANNIS THEODOSSIOU**, ARE INVESTIGATING THE NEGATIVE IMPACTS OF PERFORMANCE-RELATED PAY JOBS ON THE HEALTH OF WORKERS

How can you earn more money? If your job is to pick apples in an orchard, then you will probably be paid per bucket of apples that you collect. The more apples you pick, the more money you make. If you cycle around town with takeaways for a food delivery company, you will only be paid when you hand food over to a customer. The more meals you deliver, the more money you make. If you work in car sales, then you are likely to earn 'commission', so on top of your salary you will be paid a bonus for every sale you make. The more cars you sell, the more money you make.

This type of payment is known as performance-related pay (PRP), where your pay is determined by how much you produce. About 25% of UK jobs have PRP contracts, from simple agricultural labour to complex wealth management jobs. While PRP has clear advantages for employers (they only have to pay workers for the services they actually provide or the goods they produce) and employees (it's easy to make more money – just do more work), some social scientists believe that the system could be having severe negative impacts on the health of workers.

To investigate this issue, a group of economists (Professor Keith Bender and Professor Ioannis Theodossiou) and psychologists (Dr Nicole Andelic, Dr Julia Allan and Dr Dan Powell) at the University of Aberdeen, have teamed up in a unique collaboration.

WHAT ARE THE NEGATIVE CONSEQUENCES OF PRP JOBS?

Many employers like PRP contracts. "They give workers an incentive to produce more," says Keith, "and they allow the employer to vary the number of workers. If demand decreases (e.g. fewer people order takeaways) then they do not have to pay as many workers."

But there are also harmful impacts of PRP contracts. In an effort to earn more money, workers may be less careful, increasing their risk of injury. PRP employees often spend more time working, instead of doing healthy activities like socialising, exercising or resting. And PRP income is not certain or stable as it commonly depends on factors outside of the workers' control. If no one orders a takeaway, the delivery cyclist has no opportunity to earn money.

"These factors cause extra stress for workers," says Keith, "and medical research shows that persistent stress is a key factor in bad health outcomes like heart disease and strokes." So far, there has been very little research into how PRP jobs are affecting employees' health. By combining the expertise of economists and psychologists, Keith, Nicole and the team hope to understand what impacts PRP contracts are having on health.

THE EFFECTS OF STRESS

Dangerous or unpredictable situations will

THE TEAM'S TOP TIPS

1 Give in to your curiosity! Be guided by whatever sparks a genuine interest in you.

2 It's okay to not know what you want to do when you finish school. And it is okay to change your mind during your career!

3 At university, speak to your lecturers about their careers and ask if they have opportunities for you to assist with any projects that they have. It's a great way to try research and gain some experience.

trigger a 'fight-or-flight' response – our heart rate increases to pump more oxygen to our muscles, and we shut down our attention to other activities until the threat has passed. While this response can be useful, and even essential to survival in some situations, constant stress is detrimental to our health.

A key driver of this response is cortisol. "Cortisol is a hormone with many functions and is always present in the body," Nicole explains. "But during stressful episodes, the brain signals to the adrenal glands to release even more cortisol as part of the body's fight-or-flight response. Constant stress will result in consistently high levels of cortisol, which eventually compromises the immune system."

Keith and Nicole's team are conducting experiments to study whether PRP systems increase the levels of cortisol in the body. They ask groups of participants to solve a series of maths questions and then either pay them with a fixed amount (provided they meet a minimum standard) to complete the whole task, or pay them for every question they get right (PRP). "Like most other research in this area, we ask participants to rate how stressed they feel before and after the study," says Nicole. "What is very different about this experiment is that we also measure the amount of cortisol in the participants' saliva."

DO PRP JOBS INCREASE CORTISOL LEVELS?

Yes! The team's experiments have clearly shown that social scientists' predictions about the negative health impacts of PRP jobs were correct. "We have discovered that if we randomly put people into different payment groups, even a brief 10-minute work task is enough to be more stressful as measured by cortisol if you are paid by PRP rather than a fixed salary," says Nicole.

In follow-up experiments, the team are also exploring the influence of other payment policies often used in PRP jobs. For example, some participants risk losing money when they answer questions incorrectly, just as some employees will be docked pay if they fail to produce a particular good or service, such as missing a food delivery or bruising the apples they are harvesting. Preliminary results suggest that an additional penalty makes PRP jobs even more stressful.

WHAT DOES THIS MEAN FOR EMPLOYERS AND EMPLOYEES?

Social scientists are only just beginning to identify the link between stress and how people are paid, which has important implications for how companies can operate effectively.

THE PERFORMANCE-RELATED PAY AND HEALTH TEAM, UNIVERSITY OF ABERDEEN, UK

PROFESSOR KEITH BENDER
Labour Economics

DR NICOLE ANDELIC
Psychology

DR JULIA ALLAN
Health Psychology

DR DAN POWELL
Health Psychology

PROFESSOR IOANNIS THEODOSSIOU
Labour Economics

RESEARCH PROJECT

Investigating the impact of performance-related pay on stress and health

PROJECT WEBSITE

www.abdn.ac.uk/business/research/PRPH.php

FUNDER

Economic and Social Research Council (Grant number ES/R01163X/1)

Many employers, employees and public health officials do not know about the negative impacts of PRP jobs and this gap in knowledge is likely to have a significant negative impact on workers' health. "The important thing is that these groups need to understand the potentially negative effects of PRP," says Keith. "At the very least, PRP workers should know that PRP can negatively impact their health and so should take measures to look after their wellbeing." Ultimately, the team's research could help to reduce the levels of stress that many people experience in the workplace, helping them to lead happier and healthier lives.

ABOUT ECONOMICS

Economics is a social science that examines how and why people, companies and governments make decisions, and what restricts them from enacting those decisions. It is a highly diverse and dynamic field that combines many different elements – theory, statistics, maths, history, politics, etc. You might think that economics is just about the stock market and oil prices, but it plays a role in a huge range of occupations. Any job that requires an analytical mindset and fitting together different pieces of a problem can benefit from an understanding of economics.

ABOUT HEALTH PSYCHOLOGY

Health psychology is the study of the psychological processes that underlie health and illness. This can involve promoting healthy lifestyles by supporting those trying to quit smoking or by encouraging exercise and healthy diets. It can involve helping people to cope with health conditions, through managing chronic pain or dealing with disabilities. And it can support the delivery of efficient healthcare by developing ways to reduce medical errors or to relieve stress and fatigue in healthcare workers. As health psychology deals with some of the biggest problems facing our society, it is an incredibly exciting and satisfying field to work in.

MEET KEITH

Economics is fun and exciting! Everything is about economics – as long as decisions are involved, economics can be a framework to think about them.

As a student, I loved how economics combines so many things like discourse, maths, history and statistics. I had some wonderful lecturers who both inspired and pushed me to learn as much as I could about economics. I loved both research and telling people about my research, so an academic job seemed the best fit for me.

My own subfield of economics is labour economics. The wonderful thing about this is that everyone is a labour economist – if they want a job, that is! The labour market is fascinating to me – it is fundamental to nearly everything that we do as a modern society and affects so many other aspects of life. It is exciting and rewarding that I can research topics that are relevant to people and firms and can cause them to think about things anew.

It is always great to work with people from another discipline as you can learn a lot about how they think about the world. Being able to rely on the expertise of psychologists who use health measures in their own research helps me from making silly mistakes when designing experiments and collecting data.

When not working, I enjoy a nice walk with my family and my dog, Rory, and I try to do a bit of gardening. Before the pandemic, I sang in our University Choral Society and am very much looking forward to re-joining when we are allowed to sing in groups again.

MEET IOANNIS

I have been always interested in politics and economics. In my early years, I was mainly interested in history, and the topic of economic history inspired me to become an economist.

Studying economics provides a toolkit of skills, approaches and ways of thinking that can be applied to a wide range of economic and social problems.

My field of economics involves thinking in terms of models and then developing their ability to study complex real-world problems. This is a fascinating procedure and requires some detective work when solving the riddles relating to economic issues. My research applies to important issues relating to the welfare of the population. This partly involves studying the impact of the economy on factors including mental health, job satisfaction and working conditions.

Psychology underpins many of the founding principles of economics, including individuals' motives, expectations and their reaction to future uncertainties. This collaboration between economists and psychologists has enriched my understanding and knowledge of human psychology.

In my free time I enjoy hillwalking, sailing, motorbiking and gardening. I relax by reading Keynes' writings and other similar literature, but also classics from Victor Hugo to Fyodor Dostoevsky, and from Epicurus to William Shakespeare.

MEET NICOLE

I didn't know that I wanted to become a psychologist before I started university. I just decided to study psychology because it seemed interesting!

I am a very curious person (nosy, some might say!), so one of my favourite things is finding out the results of my research. I love that my job involves learning new things and that much of my work has implications for others and can make a difference in people's lives.

I think that I am a better psychologist after working with economists! I had done previous research on financial decision making and on physiological stress, so in many ways this collaboration has finally allowed me to combine my two interests. Working with people outside of your discipline means having to push yourself to learn new things and consider your research from new perspectives.

I loved reading and writing while I was growing up. I thought I was terrible at maths and wanted nothing to do with numbers. Now, I work with numbers every day and I love it!

MEET JULIA

When I was younger, I was interested in everything but had no real idea of what I wanted to do. I wanted to be a vet until I realised that I was too soft to deal with animals in pain. I wanted to be a graphic designer until I realised that I wasn't that great at art. I eventually stumbled across psychology when I read a university brochure that my older brother brought home. I'm naturally inquisitive and like to know why people do what they do, so psychology sounded perfect!

My psychology degree didn't contain any health psychology. But then, when I met two health psychologists, everything they were working on sounded interesting to me – the links between stress and heart attacks, why different people who'd had identical operations experienced different outcomes, how to support people to change their lifestyle behaviour... I realised I would like to do something with real-world relevance, so I took a chance, applied for a job with them, got it, and have never looked back!

I love that the research I do is really varied and that it is useful in the real world. I've worked on projects recently that have ranged from helping to detect skin cancer earlier to improving children's dental health. No two projects are the same, but they all have results with the potential to make a positive difference in the world.

Working with experts from other fields is always great as you pick up loads of interesting things you would never have come across in your own field. As a psychologist, I know a lot about stress and the impact of different aspects of stress on health. The economists know all about different working practices and payment schemes. By combining our knowledge and interests, we can start to understand why jobs with certain characteristics might be damaging to health and help employers keep their workforces healthy.

MEET DAN

What we do, say and feel can have a profound influence over our own health and wellbeing, and that of others. So, changing behaviour can be a route to improving health, but this is often not easy. It's crucial to find ways to make healthy behaviours more appealing to everyone and find ways to help people make changes when they want to.

I enjoy exploring how and why our health and wellbeing changes from day-to-day or place-to-place. This usually involves repeated (and relatively intense) observations of participants' behaviour, physiology and experience over time, often with them wearing devices to record data.

The most enjoyable thing about working in this collaboration is that everyone brings a different perspective. When you only work with people from your own discipline, they will all have been through very similar training routes, so will often come up with similar solutions to problems. At the end of the day, diversity of thought is great.

Psychology is not as old a discipline as some of the other sciences, so if we are honest, there is huge scope for improvement in research methods, theory and applications. We need new psychologists to bring a healthy scepticism, challenge ideas, explore alternatives and propose new ways forward!

WHY SCHOOLS NEED CLARITY AND MEASURABILITY IN CAREERS GUIDANCE

IN 2013, **THE GATSBY FOUNDATION** COMMISSIONED **SIR JOHN HOLMAN**, NOW THE GOVERNMENT'S INDEPENDENT STRATEGIC ADVISER ON CAREERS, TO SET OUT A FRAMEWORK FOR WORLD-CLASS CAREERS GUIDANCE IN ENGLAND. JOHN TELLS US WHY HE THINKS THE GATSBY BENCHMARKS ARE THE BUILDING BLOCKS TO CLEAR, MEASURABLE AND EFFECTIVE CAREERS PROVISION

HOW DID YOU DEVISE THE EIGHT GATSBY BENCHMARKS?

When you want to answer the question, "What does 'good' look like?", it pays to go overseas to see what other countries do. I got together with the University of Derby, who have specialists in this area, and we looked at six territories where careers guidance is known to be good, based on an OECD study: Germany, Netherlands, Ireland, Hong Kong (China), Ontario (Canada) and Finland. We met with students, teachers, careers leaders, employers and ministry officials and asked them what they do to achieve a good careers balance. We also looked at all the relevant research and surveyed English schools, and from this wealth of data, we sat down and translated it into eight things schools can look at and say, right, this is what we've got to do.

The eight benchmarks are clear and measurable, which turned out to be key factors. I didn't fully realise that the critical things were clarity and measurability until afterwards.

IS IT ENOUGH FOR SCHOOLS TO MEET THESE BENCHMARKS TO SET STUDENTS ON THE PATH TO A GOOD CAREER?

No. If students don't know any mathematics, English, science or geography, the benchmarks alone would be useless. These benchmarks need to be an integral part of education but should complement a rich, strong, knowledge-based curriculum. They will never replace it.

SHOULD THE GATSBY BENCHMARKS BE MANDATORY?

I think it should be in the control of schools and colleges; they are experts in education and they know their students. It would be a mistake to release their benchmark scores and publish them in league tables. It's possible to do all sorts of things with exam results, rankings, league tables, etc., but I wouldn't recommend that. The benchmarks' great strength is that schools and colleges embrace them, understand them and use them to provide better careers guidance. And that's the way it needs to be.

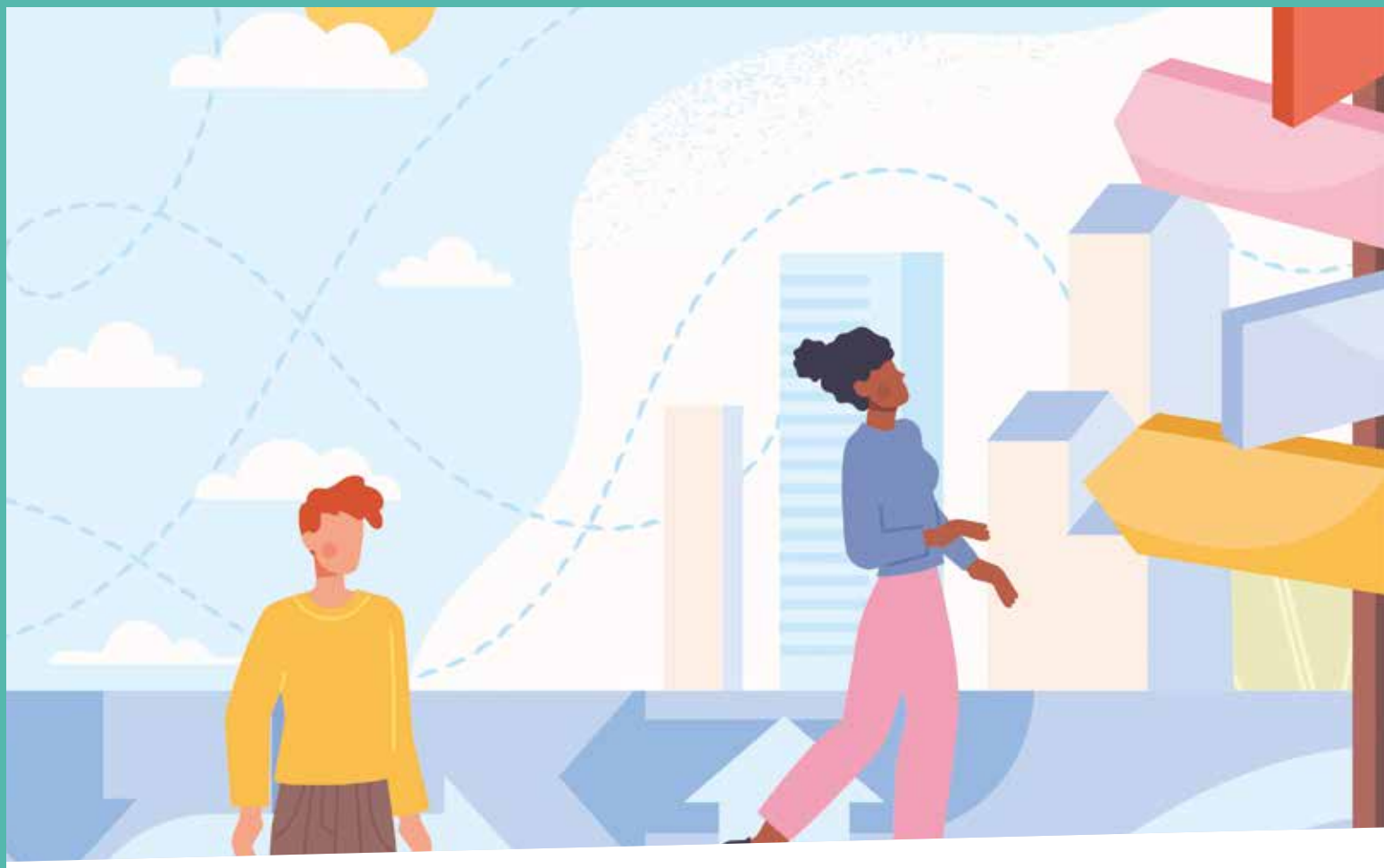
WHERE CAN TEACHERS FIND SUPPORT FOR MEETING THE EIGHT BENCHMARKS?

A very good development has been the creation of The Careers & Enterprise Company in 2015, by the government, to support schools and colleges in meeting the benchmarks. It has been proactive in creating digital tools that schools can use to measure how they're getting on, creating strong employer links, creating Careers Hubs and in supporting schools and colleges in many other ways.

SINCE THE LAUNCH OF THE GATSBY BENCHMARKS, HAS CAREERS GUIDANCE IMPROVED?

We now have the means to measure the outcomes from careers guidance. I'm a scientist and I believe if you can't measure something, or at least have some means of finding out whether something has changed, it makes policymaking much more difficult. Because the Gatsby Benchmarks are measurable, schools can measure what they're doing with their students and then look at the effect on outcomes in a way that I don't think we could 10 years ago.

We now know that, on average, for each benchmark a school achieves, that increases the number of students who are in employment, education or training by 1.4%. If a school achieves all eight benchmarks, you'll have, on average, over 10% more people in employment, education or training. That's a clear outcome. And the effect is twice as large as this for the most disadvantaged schools.



YOU HAVE BEEN APPOINTED THE ENGLISH GOVERNMENT'S INDEPENDENT STRATEGIC ADVISER ON CAREERS GUIDANCE. WHAT WILL YOU BE TELLING GOVERNMENT MINISTERS?

I'm still in the fact-finding phase, which means I'm trying to find out as much as possible about the whole system by which people – adults as well as young people – get careers guidance, particularly when it's publicly funded. So, I've visited job centres, schools and colleges; I've sat in on careers guidance interviews; I'm collecting all the data I need. I'm immersing myself so that I can speak from an evidence base. I have a few impressions, as you might expect, but I haven't formed any clear conclusions yet. By the summer of 2022, I will have provided government ministers with guidance on what we should do.

CAN YOU GIVE AN EXAMPLE OF CAREERS PROVISION THAT IS WORKING WELL?

HETA – the Humberside Engineering Training Association – provides engineering apprenticeships and upskilling training in Yorkshire and the Humber region of the UK. If you'd met some of the people I met in Hull, you'd get a real sense of purpose. They know that the skills they are learning are the skills employers need. And that's the key. If someone thinks they're learning something that's not going to be of use to them, they won't be motivated to learn. But these apprentices knew that what they were doing – welding, for example – is what employers will need out on an oil rig or building a wind turbine. They were highly motivated to get it right. It's not complicated really, is it? We all need a reason for doing things, and good career guidance had led those apprentices to the right place.

WITH THE ONSET OF VAST TECHNOLOGICAL ADVANCES, THE CAREERS LANDSCAPE IS CHANGING RAPIDLY. HOW CAN WE EQUIP PEOPLE IN THIS EVER-EVOLVING WORLD?

> *"We now know that, on average, for each benchmark a school achieves, that increases the number of students who are in employment, education or training by 1.4%."*

The first thing to recognise that, to students, it doesn't necessarily feel like a time of rapid change. I think it's quite easy for adults to get overexcited, particularly older people like me, about the rate of change. That said, we are in quite exceptional times.

Part of the answer is to exploit the changes that are going on. One major change is the pervasiveness and availability of data, and the ability to do things with it. I'm very interested in giving people better access to labour market information – information about where jobs are growing, declining, in demand. If you want to get into a particular job, what qualifications and skills do you need? Are there regional differences around the country?

One issue is that the changes in the data take time to feed through, particularly now, with the speed at which the economy is changing. So, I'm interested in finding a way to provide up-to-date labour market information that demonstrates both the national and the local picture. I think that making available authoritative, recent and locally nuanced labour market information in a form that people can use and understand, whether they be young students, older students, parents, teachers, employers, is a very important thing and we need to move faster on this.

WHAT ARE THE GATSBY BENCHMARKS?

Sir John Holman was asked by the Gatsby Charitable Foundation to undertake an independent, international review of career guidance in England. Working with the University of Derby, the project visited six overseas territories, analysed good practice in English schools and reviewed existing literature. The data informed John's *Good Career Guidance* report, which defines 'good' and outlines a framework of eight benchmarks that secondary schools and colleges can use to improve their career guidance programmes.

The eight benchmarks are:

1. **A STABLE CAREERS PROGRAMME:** Every school and college should have an embedded programme of career education and guidance that is known and understood by pupils, parents, teachers and employers.

2. **LEARNING FROM CAREER AND LABOUR MARKET INFORMATION:** Every pupil, and their parents, should have access to good-quality information about future study options and labour market opportunities. They will need the support of an informed adviser to make best use of available information.

3. **ADDRESSING THE NEEDS OF EACH PUPIL:** Pupils have different career guidance needs at different stages. Opportunities for advice and support need to be tailored to the needs of each pupil. A school's careers programme should embed equality and diversity considerations throughout.

4. **LINKING CURRICULUM LEARNING TO CAREERS:** All teachers should link curriculum learning with careers. For example, STEM subject teachers should highlight the relevance of STEM subjects for a wide range of future career paths.

5. **ENCOUNTERS WITH EMPLOYERS AND EMPLOYEES:** Every pupil should have multiple opportunities to learn from employers about work, employment and the skills that are valued in the workplace. This can be through a range of enrichment activities including visiting speakers, mentoring and enterprise schemes.

6. **EXPERIENCES OF WORKPLACES:** Every pupil should have first-hand experiences of the workplace through work visits, work shadowing and/or work experience to help their exploration of career opportunities, and expand their networks.

7. **ENCOUNTERS WITH FURTHER AND HIGHER EDUCATION:** All pupils should understand the full range of learning opportunities that are available to them. This includes both academic and vocational routes and learning in schools, colleges, universities and in the workplace.

8. **PERSONAL GUIDANCE:** Every pupil should have opportunities for guidance interviews with a careers adviser, who could be internal (a member of school staff) or external, provided they are trained to an appropriate level. These should be available whenever significant study or career choices are being made. They should be expected for all pupils but should be timed to meet their individual needs.

FINDING FAULTS

VOLCANOES ARE FED BY MAGMA THAT RISES THROUGH CRACKS IN THE EARTH'S CRUST, BUT WE DO NOT REALLY UNDERSTAND HOW THESE CRACKS FORM AND WHAT THEY TELL US ABOUT THE RISKS OF VOLCANIC ERUPTIONS. **DR CRAIG MAGEE,** FROM THE **UNIVERSITY OF LEEDS** IN THE UK, IS TRYING TO SEE BELOW THE EARTH'S SURFACE TO LEARN MORE

TALK LIKE A STRUCTURAL GEOLOGIST

FAULT – where an earthquake creates a crack through the Earth's crust, offsetting the rocks on either side

GRABEN – valleys created by faults

MAGMA – molten rock

DYKE – a vertical crack in the crust, which transports magma

SEISMIC REFLECTION – firing sound waves into the crust and measuring the reflections from different layers of rock

LIDAR – Light Detection and Ranging: bouncing lasers off a surface and measuring the reflections to see how far away it is

DYKE INJECTION – the injection of magma into a dyke

Volcanoes are a major, and often unpredictable, natural hazard. Millions of people around the world live in areas directly at risk from volcanic eruptions, and many more can be indirectly affected by hazards such as large ash clouds generated by volcanoes. Dr Craig Magee, a structural geologist at the University of Leeds, is researching how magma moves through the crust to erupt at the surface. Through this research, he hopes to improve methods for predicting volcanic eruptions and answer important questions about how volcanoes form on Earth and on other planets.

WHAT ARE DYKES AND DYKE-INDUCED FAULTS?

Dykes are vertical cracks in the Earth's crust, which transport magma from depth up towards the surface, where it may erupt at volcanoes. However, most dykes stop before they reach the surface. Instead, they create two faults which extend from the surface down to the top of the dyke, forming a 'V' shape, with the point of the V at the top of the dyke. These are dyke-induced faults. The rock between the two faults slips down relative to the rocks outside, forming a valley at the surface. These fault-created valleys, called graben, are seen in many volcanically active areas on Earth, such as Hawaii, Iceland and Ethiopia. The goal of Craig's research is to use the structure of dyke-induced faults to understand where magma is moving below the surface and how much of it there is. This information can then be used to predict where volcanic eruptions are most likely to take place.

Currently, we have a lot of information about what dyke-induced faults look like at the surface of the Earth, but we do not really know what they look like underground. We have experimental and computer models of what dyke-induced faults might look like, but as Craig explains, "the biggest challenge with creating models is finding ways to test them". Dykes and faults are narrow structures, often only a metre or two wide, and buried hundreds of metres below the surface, so we need advanced imaging techniques to see what is happening to these underground structures.

HOW DOES CRAIG IMAGE DYKE-INDUCED FAULTS BELOW THE SURFACE?

Craig uses a technique called 3D seismic reflection to image underground structures. This uses the same principles as a medical

DR CRAIG MAGEE

NERC Independent Research Fellow
University of Leeds, UK

FIELD OF RESEARCH

Structural Geology

RESEARCH PROJECT

Investigating the structure of dyke-induced faults to understand how magma is supplied to volcanoes and how to monitor their risks of eruption better

FUNDER

Natural Environment Research Council (Project grant number: NE/R014086/1)

ultrasound scan, but involves firing sound waves down into the Earth's crust and recording when reflections from boundaries between different rock layers arrive back at the surface. Since dyke-induced faults produce breaks in the rock layers, seismic reflection can image the rock layers and see where the offsets are, allowing us to map the position of the faults. Craig has discovered that while most models assume that dyke-induced faults are straight, the real faults that he has imaged are actually very jagged. So, the simple assumptions that we used to predict what the faults look like beneath the surface actually turned out to be wrong.

HOW DOES THIS RELATE TO FAULTS AT THE SURFACE?

Although seismic reflection produces images of the sub-surface, we cannot study the rocks below the surface directly to test our interpretations of the data. Craig is also studying recently formed faults in Ethiopia, where lots of active volcanism and faulting takes place, to see if the same jagged structures are present there. To do this, he is using a technique called LiDAR, which uses laser scanning to make maps of the ground elevation, which are accurate to within a few centimetres. He is using two maps of the same area in Ethiopia where there are active faults. In the time between the two maps being produced, there was a dyke injection event and some of the faults moved. By comparing the maps before and after the event, he can make a high-resolution map of where fault movement occurred. By combining this information with other geophysical data, such as the location and depth of earthquakes, Craig can map out the sub-surface structure of the faults and see how they grow during dyke injection events.

WHAT ABOUT GEOLOGY ON OTHER PLANETS?

Graben are found on the surface of several planets and moons in the Solar System, and we know that these bodies have had volcanism in the past so we think they were formed by dyke-induced faulting. However, we have very few ways of investigating the sub-surface of other planets, so it is only by studying how dyke-induced faulting occurs on Earth that we can infer what may be going on beneath the surface on other planets. Using the 3D seismic reflection data, Craig has also found structures called pit craters, associated with the dyke-induced faults. This was the first time these features have been identified on seismic images and studied in 3D. Pit craters are common on other planets and there are many theories about how they had formed – Craig's discovery suggests that dyke-induced faulting may be the cause. They have often been suggested as potential landing sites for crewed missions to other planets, but so little is known about them that it is difficult to assess whether they would be a good choice.

HOW DOES THIS WORK BENEFIT WIDER SOCIETY?

Dykes form part of a network of pathways and reservoirs which feed magma from the deep crust to volcanoes at the surface. These magma plumbing systems are where many of the metal deposits that our society relies on are formed. In particular, many of the key metals that we need for a sustainable future come from magma systems, so understanding how they form is essential for improving mineral exploration and extraction.

Another big motivation for Craig's work on dykes is that it feeds into our understanding of volcano monitoring and eruption prediction. Dykes carry the magma to the surface prior to an eruption, so monitoring dyke activity to see if new magma is rising to the surface is an important aspect of volcano monitoring. The main existing techniques for this involve recording earthquakes and surface elevation changes, both of which are caused by dyke-induced faulting. So, Craig's work helps to improve our models of magma movement. Understanding where faults are likely to break the surface is also important when building infrastructure, such as roads and bridges. Craig illustrates the diverse range of problems that geologists can find themselves tackling, from fundamental questions about how the Earth and other planets formed, to critical resource production, to practical ways to reduce risks from natural hazards.

ABOUT STRUCTURAL GEOLOGY

Geology is the study of rocks: how they are formed, how they change over time, and how this knowledge can be applied to solve human problems. Rocks provide the historical record which we have interpreted to provide us with the evidence for the evolution of life, plate tectonics and past climate changes. They are also the source of the metals and many other raw materials that our society needs. Geology brings together many different skills, from studying and collecting rocks in the field, to advanced chemical analyses to computer modelling.

Day to day life as a geologist is very varied. Some days you might be looking through datasets on a computer, finding new things that nobody has looked at before. Other days, you might be in a lab, building new experiments to model your rocks, or carrying out chemical analyses. Communicating your research to others is an important part of being a scientist, so you also spend a lot of time writing papers and making presentations that will inform other scientists about your new findings. The best days are usually when you get to go out and look at rocks in the field, trying to build a picture of what is going on beneath your feet from what you see at the surface.

"Science is incredibly fulfilling in terms of travel, whether it's physically or virtually," says Craig. "I have met so many wonderful people from everywhere around the world, and visited places no tourist goes. The experiences are incredibly humbling and an inspiration of how the world should be: connected, with everyone getting on. I collaborate with people all over the world. The sharing of ideas and knowledge is one of the best aspects of being a scientist."

As a geologist at a university, you also spend part of your time teaching students to educate the next generation of geologists. You start out as the expert teaching them, but by the end of their projects they know more about their work than you do, which can be very fulfilling, and a great learning experience for you as well.

EXPLORE A CAREER IN STRUCTURAL GEOLOGY

- The easiest place to start is social media – there are so many great scientists talking about their work on Twitter and sharing photos of amazing geology. Craig (@DrCraigMagee) recommends following @seis_matters, @mcnamadd, @inthevolcano, @ThePlanetaryGuy, @KeepItRehol, @Virtualgeol, to name a few. Social media is also where you can easily find out about geological events and societies near you.

- The Geological Society has a great website full of useful careers-related information: **www.geolsoc.org.uk/Geology-Career-Pathways/Careers**

- Many universities have outreach programmes, where their staff visit schools and showcase different subjects. Visit the University of Leeds' website to find out about studying geology: **www.stem.leeds.ac.uk/earthsciences/**

The site also includes taster lecture videos: **www.stem.leeds.ac.uk/earthsciences/environment-taster-lecture-videos/**

- The salary for a geologist is quite variable depending on which area you specialise in, but £25,000-£35,000 is not uncommon for early career positions, and that can rise significantly with experience.

PATHWAY FROM SCHOOL TO EARTH SCIENCE AND STRUCTURAL GEOLOGY

- Craig says, "I did geology, geography, biology and economics at A-Level. But to be honest, I think anyone can go into geology. It's a subject that involves all the sciences and there are plenty of opportunities to bring in art, computing, anything you like really! Anyone can find a part of geology that they enjoy and are good at."

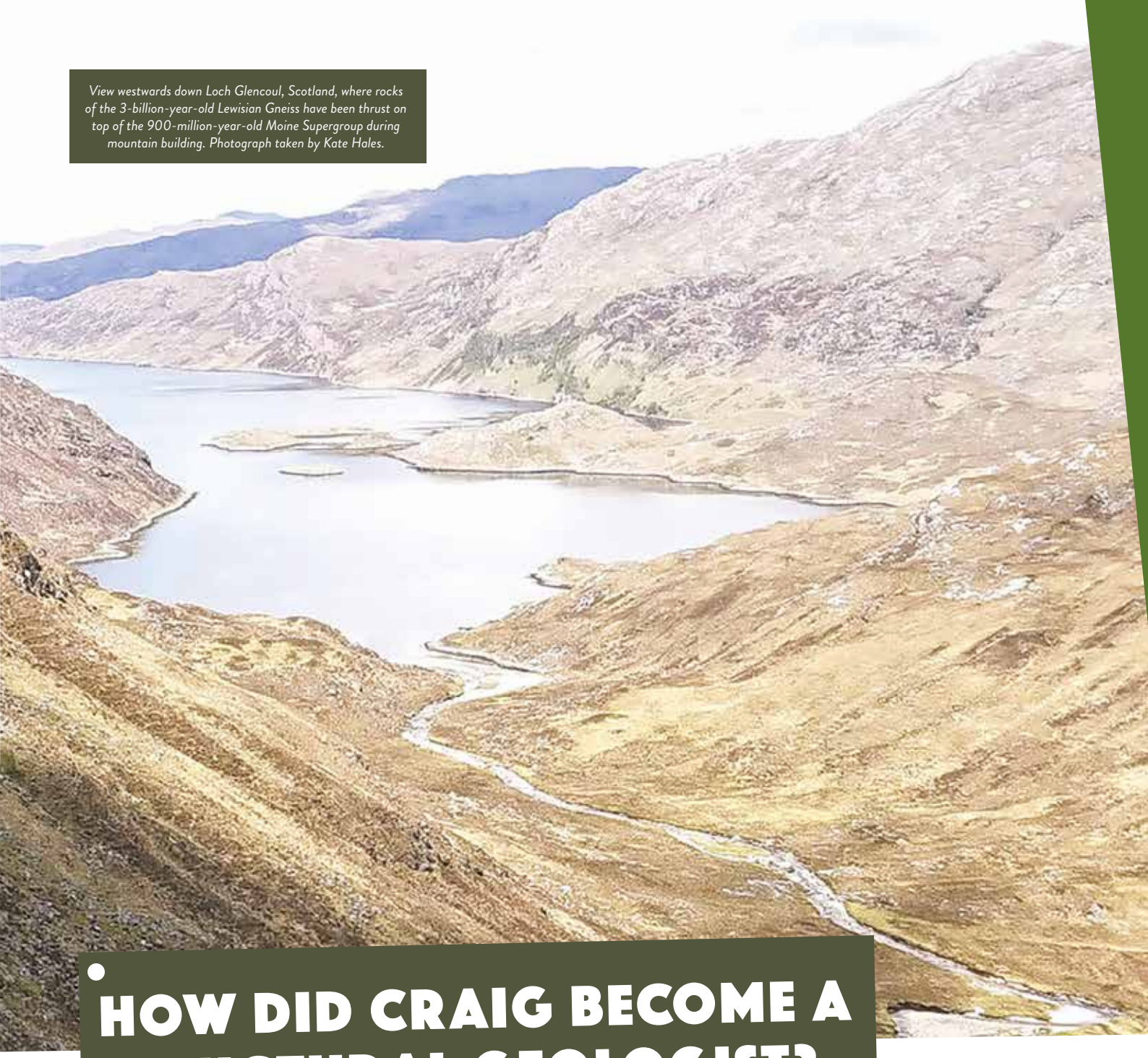
- Many schools do not offer geology A-level but do not let this put you off. People go into geology with a wide range of science subjects.

CRAIG'S TOP TIPS

01 Find something you enjoy and keep at it. Don't be afraid to change your mind or admit you're wrong; we learn most from our mistakes.

02 Earth science is a very broad field so anyone can find a part of Earth science that they enjoy and are good at, no matter their background.

Collecting rock samples of the 3-billion-year-old Lewisian Gneiss in Torridon, Scotland.



View westwards down Loch Glencoul, Scotland, where rocks of the 3-billion-year-old Lewisian Gneiss have been thrust on top of the 900-million-year-old Moine Supergroup during mountain building. Photograph taken by Kate Hales.

HOW DID CRAIG BECOME A STRUCTURAL GEOLOGIST?

WHAT WERE YOUR INTERESTS WHEN YOU WERE GROWING UP?

I spent most my time playing football and computer games. I do remember loving dinosaurs, fossil hunting, and minerals at various times though.

WHO OR WHAT INSPIRED YOU TO BECOME A SCIENTIST? WHAT MOTIVATES YOUR WORK TODAY?

Nothing really! I just followed doing what I enjoyed, from physical geography at GCSE to geology at A-Level. I'm incredibly grateful to the support from family and teachers though. As for today's motivation, I love my job and enjoy most aspects of it. As we spend most of our lives working, I figured I may as well do something I enjoy.

WHAT ATTRIBUTES HAVE MADE YOU SUCCESSFUL AS A SCIENTIST?

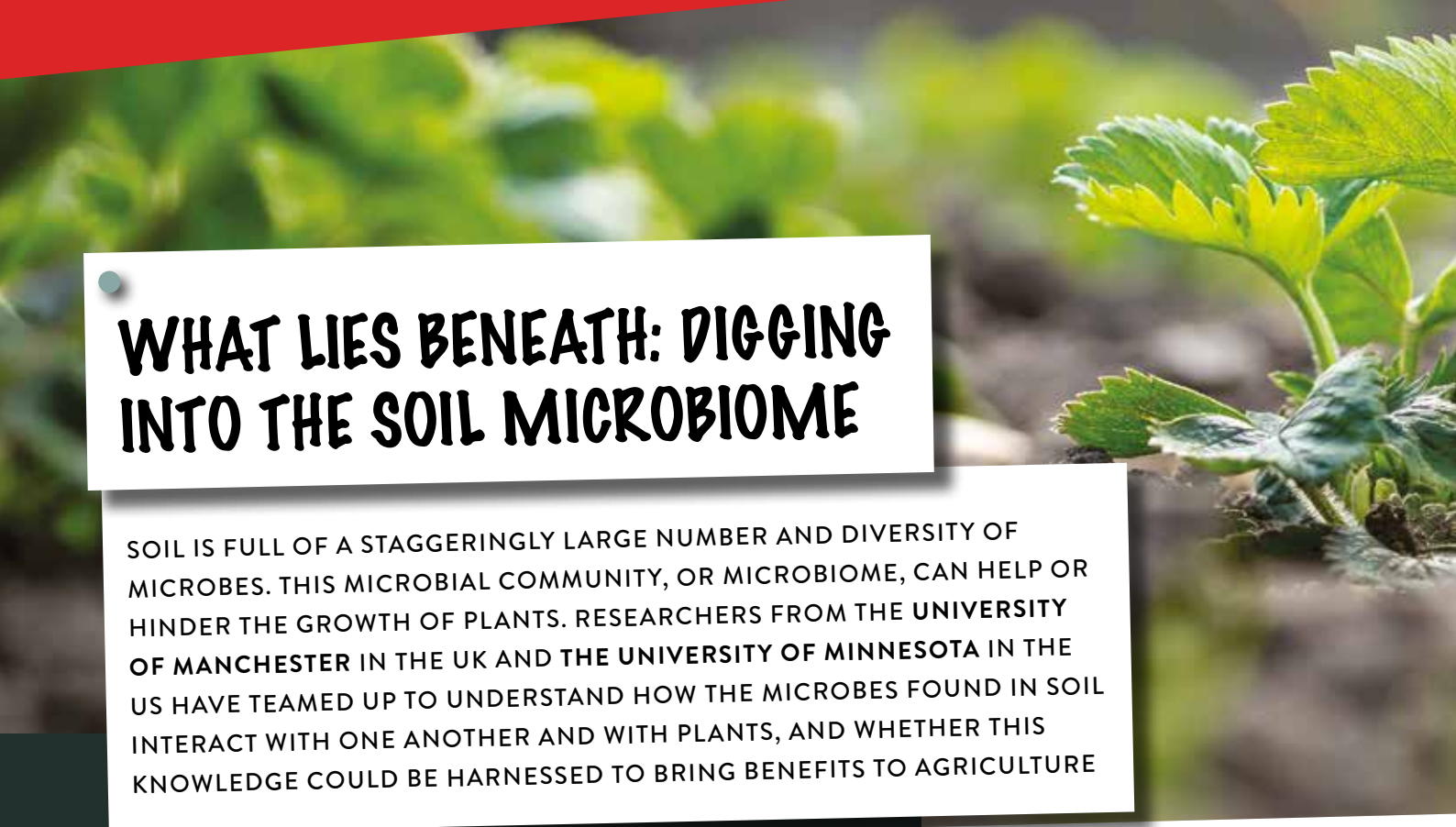
There's a misconception that scientists are great at maths; I'm useless at it! I think the key attribute for a successful scientist is being able to admit your weaknesses and find people to work with who complement them.

TO WHAT EXTENT DOES YOUR LOVE OF GEOLOGY SPILL OVER INTO YOUR FREE TIME?

I love geology because it offers a whole new perspective on the landscape around you. You go to a scenic spot and whilst most people enjoy the view, you get to enjoy seeing how it evolved over millions, or even billions, of years.

WHAT ARE YOUR PROUDEST CAREER ACHIEVEMENTS SO FAR?

I have won several awards, which I am proud of, but I think my proudest achievement was helping a student write up their project as a paper for a new journal called *Volcanica*, which is freely accessible to everyone everywhere. We have the first paper in the journal – issue 1, volume 1, page 1! (You can read it at: **www.jvolcanica.org/ojs/index.php/volcanica/article/view/2**)



WHAT LIES BENEATH: DIGGING INTO THE SOIL MICROBIOME

SOIL IS FULL OF A STAGGERINGLY LARGE NUMBER AND DIVERSITY OF MICROBES. THIS MICROBIAL COMMUNITY, OR MICROBIOME, CAN HELP OR HINDER THE GROWTH OF PLANTS. RESEARCHERS FROM THE **UNIVERSITY OF MANCHESTER** IN THE UK AND **THE UNIVERSITY OF MINNESOTA** IN THE US HAVE TEAMED UP TO UNDERSTAND HOW THE MICROBES FOUND IN SOIL INTERACT WITH ONE ANOTHER AND WITH PLANTS, AND WHETHER THIS KNOWLEDGE COULD BE HARNESSED TO BRING BENEFITS TO AGRICULTURE

TALK LIKE A MICROBIOLOGIST

DRY LAB – a scientific laboratory involving principally computational work

SIGNAL – a biological, chemical or physical event that leads to a change in an organism's behaviour

EMBEDDED GENETIC RECORDER (EGR) – an engineered DNA sequence that can 'record' the response to an unknown signal

GENOME – the complete set of genes of an organism

MICROBE – a microorganism, such as a bacterium

MICROBIOME – all the microorganisms of a particular environment

PATHOGEN – a microbe that causes disease

PLASMID – a small DNA molecule carrying genetic information that is easily exchanged between organisms. Often used for genetic modification

WET LAB – a scientific laboratory involving practical experiments

The soil microbiome can have a profound effect on the productivity of crops, which leads to challenges for agriculture. While microbial pathogens can sometimes decimate entire fields, other microbes can help boost growth and productivity. To make things more complicated, microbes exchange signals with each other that change their functions in complex ways. Five teams of researchers, two from the University of Manchester in the UK and three from the University of Minnesota in the US, have joined forces to understand the complex interactions going on beneath the soil's surface.

MICROBIAL MURMURINGS

"To feed the world's population, we need healthy soils that nourish our crops," says Jeremy Chacón from the University of Minnesota. "Understanding soil ecosystems helps us understand how to keep the soil healthy." Currently, agricultural practices impact the soil microbiome in diverse ways, including through tillage, nutrient amendments, and pesticide use, but we have little insight into the specific consequences of these practices on microbiome composition or functions. Moreover, chemical pesticides can kill microbial friends and foes alike and can also damage the environment. Getting a deeper understanding of soil microbiomes will help farmers move towards more sustainable management solutions.

However, given the many different interactions taking place, gaining this understanding is no simple undertaking. "Microbiomes can profoundly affect plant growth and health, such as through suppressing disease or enhancing drought tolerance," says Jack Connolly from the University of Manchester. "Signalling within the soil plays a key role in influencing these impacts." Tapping into this signalling process could therefore yield key insights. "If we know how bacteria talk to each other, we can interfere with that cross-talk in ways that bring benefits for crops," says Jeremy. "We can also 'eavesdrop' to get advance warning of whether pathogens will become a problem."

LISTENING IN

The researchers are cracking this communication code using a range of clever tools in their arsenal, each yielding unique insights. "Bacteria talk to one another using signal molecules," says Kamila Schmidt from the University of Manchester. "We can analyse these interactions using 'omics' approaches – genomics, transcriptomics or metabolomics." These techniques tell researchers if the bacteria can make signals, are trying to make signals, or if signals were made. For instance, metabolomics involves extracting and analysing the signal molecules being released.

Another technique involves some nifty genetic engineering. "We insert an engineered DNA sequence, which we have named an Embedded Genetic Recorder (EGR), into the genome of the target soil microbe," says Maxime Boneza

from the University of Minnesota. "The EGR is designed to be activated when a particular signal is received, and what makes the EGR unique is that this activation can be detected in the soil allowing us to 'listen in' on signalling events where and when they occur."

A TALE OF TWO UNIVERSITIES

While the two universities are working closely together, they each have their own areas of focus. The Minnesota team is developing the EGRs, while the Manchester team is looking into how to get genetic material (such as EGRs) into the genome of a particular bacterium called *Streptomyces*. "These bacteria are prolific antibiotic producers, and widespread members of soil microbial communities, but are often particularly challenging to genetically engineer," says Jack. "We are engineering new plasmids to allow us to manipulate the genomes of these strains."

Once these tests have gone through, the two teams will combine their work. "EGRs developed in Minnesota will be delivered into hundreds of locations within the *Streptomyces* genome using the genetic methods optimised by the Manchester team," says Jack. "This will allow us to record the complex response to a diverse mixture of soil signals impacting on our recorder strains at once."

COMBINING SKILL SETS

"This project is bringing together a diverse range of disciplines, including biology, chemistry, mathematics and computational biology," says Stephen Heinsch from the University of Minnesota. "While the project is rooted in microbial ecology and plant pathology, we are making use of the latest advances in synthetic biology, high-throughput chemistry and computational analyses."

This diversity is brought to life by the different skill sets of the researchers. While those in the 'wet labs' are directly investigating and modifying these microbial communities, the researchers in the 'dry labs' are taking a different, complementary, approach. "We will make computer models that represent how microbial species grow when they have different resources available," says Jeremy. "These models will help us predict how different species will compete or cooperate, and so help us theorise how to modify microbiomes in useful ways." As well as modelling, the computer labs will also be essential for data processing. "Our methods produce huge datasets with immense complexity," says Stephen. "Techniques such as machine learning will help us find patterns within this complexity."

SOCIETAL IMPACT

The team hopes that ultimately their research will help agriculture develop sophisticated and eco-friendly approaches to boosting yields. "This knowledge could unlock tangible benefits to crops, using an optimised soil microbiome to fight pathogens and promote growth," says Jack.

Though agriculture will be a primary beneficiary, Stephen believes this work could herald the beginning of a new era for other sectors too. "In the near future, we may be able to design beneficial microbial communities for the human gut, or to clean up environmental pollutants," he says. "In the far future, my dream is to see engineered microbial communities being used to terraform other planets!"

MEET THE TEAM

DR JACK CONNOLLY
NATURAL PRODUCT BIOCHEMISTRY
THE UNIVERSITY OF MANCHESTER, UK

I work in the wet lab and am developing technologies to edit the genomes of key soil bacteria. We will use these methods to insert Minnesota's EGRs into the *Streptomyces* genome.

I have a background in microbiology, including working with *Streptomyces*. I was drawn to this project because the lab is run by highly regarded experts, and I felt it would be a great place to progress to independence myself. I find our multifaceted project intriguing, and there is lots left to understand.

I am motivated by the need to understand each system we investigate – such as why mutated bacteria behave in a certain way, or the effects of changing a DNA sequence. I enjoy the investigative process of the lab and the subsequent analysis and thinking.

As a youngster, I was naturally drawn towards mathematics and physics, and after school I worked in statistics. It was during this time that I became intrigued by molecular biology, in particular the beauty of the core rules behind how cells function.

I am analytical, logical and methodical in my lab work. I enjoy the collaborative nature of our work and have the perseverance needed to overcome the challenges that come up.

At school, biology and chemistry would be important, but otherwise I recommend letting your natural interests guide you. At university, consider courses such as biological sciences, biochemistry or chemistry.

Follow what you find interesting and exciting at each academic stage. While I was an undergraduate, I would never have guessed I would end up specialising in natural product biochemistry.

DR KAMILA SCHMIDT
BIOCHEMISTRY
THE UNIVERSITY OF MANCHESTER, UK

I provide technical support for experiments that quantify microbial signal molecules. I do a mixture of experimental and computational work.

I completed a PhD in biochemistry with a project in metabolomics, and then worked as a research technician in a synthetic biology project. My current role builds on my previous experience.

I am curious about the outcomes of our experiments and projects and enjoy seeing how the knowledge gained can be applied to the wider world.

At school I was interested in science and music. My mum was a biology teacher and got me interested in science. I was also inspired by the TV show Star Trek, which demonstrates through fiction how science can play a pivotal role in discovery.

I enjoy learning new techniques, new scientific methods, and new software that all advance our scientific knowledge. I also enjoy working with students and scientists from all around the world.

The sciences are all useful at school. At university, specialising in chemistry, biochemistry or biotechnology are all sensible routes.

Never give up. If you really want something, work hard and you'll get there.

WENDY HUGHES
PLANT PATHOLOGY
THE UNIVERSITY OF MINNESOTA, USA

For this research, I will perform experiments looking at how EGRs can be used on a broader ecological platform, once the EGRs have been developed by the other teams.

I joined this research project when one of the lab heads and I discussed my interest in microbial communication, and she offered for me to participate in the meetings.

I am motivated by the mystery surrounding microbial communication. The idea of microbes talking to one another using chemicals fascinates me!

I was always interested in science as a child. This interest solidified when I found a connection between my high school chemistry class and biology class and realised that all science is connected.

Becoming comfortable with failure has really helped me. In science, more experiments fail than succeed – handling it well and learning from it is how you enjoy working in the field.

Microbiology needs a core understanding of lots of subjects. I blew off organic chemistry but now find myself relearning it. A broad biological and chemical understanding will help you out.

Don't be afraid to ask for help when you need it, whether in class, work, or your personal life.

MAXIME BONEZA
MICROBIAL ENGINEER
THE UNIVERSITY OF MINNESOTA, USA

I am a PhD student working to genetically engineer plasmids so that they deliver the EGR into *Streptomyces*.

I have a Bachelor of Science in chemistry, and before joining this project spent two years working for an industrial chemical manufacturing company. When I began my PhD thesis, I immediately felt connected to this project, due to the way it related to agriculture and the aspect of natural product discovery. I had no experience working with microorganisms so there was a steep learning curve involved.

Knowing that this research could have a positive impact on agriculture provides me with motivation. Our findings could revolutionise the way that farmers protect plants from pathogens.

Growing up, I was interested in herbal medicine, until I moved to Houston. Then I wanted to be an astronaut, but this changed again once I was in college, working with an advisor to understand the antioxidants found in herbal plants. I believe this is where my interest as a researcher began in earnest.

I am resilient and pour everything I have into a task. I also take feedback seriously and use this to help my growth.

Recommending what you should study is tricky because it depends on your own interests and curiosities. I personally did a lot of chemistry courses at college, which I certainly don't regret.

Always have the curiosity to learn new things. Respond to feedback but do not let it slow yo down.

STEPHEN HEINSCH
COMPUTATIONAL BIOLOGY
THE UNIVERSITY OF MINNESOTA, USA

I am in a hybrid role between the wet lab and dry lab. In the wet lab, I have contributed to the development of the EGR and sequencing microbial genomes, while in the dry lab I lead an engineered microbiome gene-expression study to learn about unique genetic responses to chemical signalling.

I have a background in both molecular biology and computer science, and began working on the engineered microbiome gene-expression study when I started my PhD. Later, my work came to fit in nicely with the project involving soil signalling.

I am intrigued by big, complex problems, and am drawn to develop solutions to them. The thought of deploying technology I helped develop into the world excites me.

As a child, I was deeply interested in language and computers, and spent time studying Japanese and video game programming. It wasn't until college I became interested in biology. One of my professors shared an analogy of cells as factories and proteins as custom-built machines and, given my background in programming, this piqued my interest in synthetic biology.

Being willing to accept when my assumptions are incorrect, and not being discouraged by failure, have both helped me enormously in my career.

Start programming as soon as you can. There are so many free resources online that you can use to teach yourself. Subjects such as biology and chemistry are also important at school. For me, my most useful college classes were cell biology, genetics, biochemistry and organic chemistry. I also recommend taking mathematics classes, especially in statistics, calculus and linear algebra.

Get involved in research in your field as early as possible. Solving problems in the lab is a great learning experience.

DR JEREMY CHACÓN
MICROBIAL ECOLOGY
THE UNIVERSITY OF MINNESOTA, USA

I make computer model representations of the *Streptomyces* bacteria we study. I input the functions of all the genes that code for metabolic enzymes and then see how the bacteria grow in various simulated environments.

I have worked a lot with computer models in the past but wanted to be a part of something with a more applied outcome, so when this opportunity arose, I jumped for it.

I enjoy solving problems, being creative and being surprised. Science provides an outlet for all these things.

I've always loved ecology, even though I didn't know it was called that until college. I was the kid who'd be watching insects when I was supposed to be playing sports. I am also an avid fiction reader and amateur musician.

I pressure myself to finish things. There are very few external deadlines in science, so you have to impose this structure yourself. Additionally, I don't mind being wrong or not understanding – as scientists we are always trying to understand new things, which involves a lot of being wrong along the way.

In addition to science courses, I recommend working on your writing and mathematical ability. I also believe it's important to keep your creative side going, so an arts subject is useful.

The skills you need within a lab can be very different to those needed in the classroom. I strongly recommend finding a way to spend some time in a lab. This will help you learn what lab work is like, and also begin to develop a network or even find a mentor.

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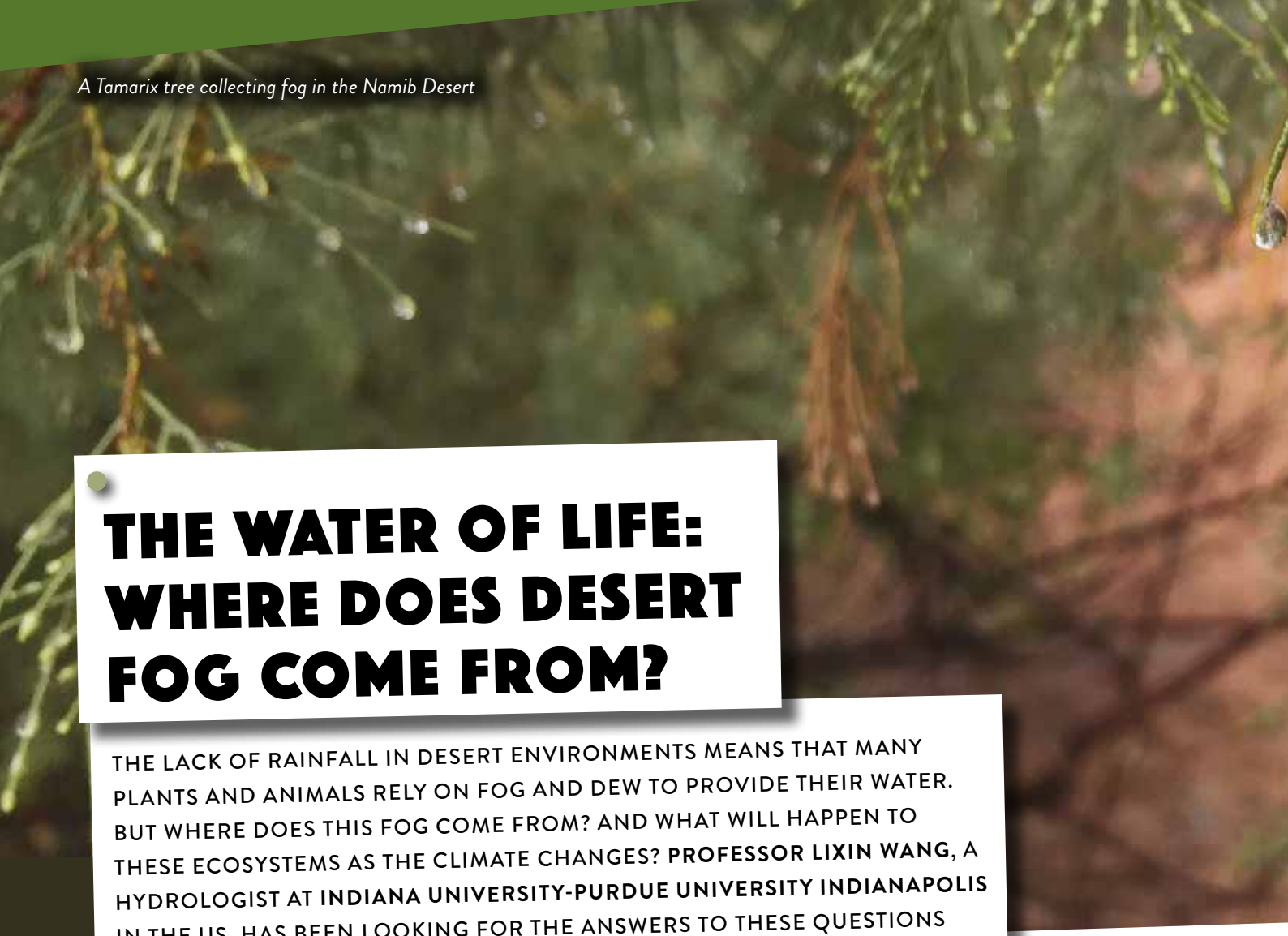


A Tamarix tree collecting fog in the Namib Desert

THE WATER OF LIFE: WHERE DOES DESERT FOG COME FROM?

THE LACK OF RAINFALL IN DESERT ENVIRONMENTS MEANS THAT MANY PLANTS AND ANIMALS RELY ON FOG AND DEW TO PROVIDE THEIR WATER. BUT WHERE DOES THIS FOG COME FROM? AND WHAT WILL HAPPEN TO THESE ECOSYSTEMS AS THE CLIMATE CHANGES? **PROFESSOR LIXIN WANG**, A HYDROLOGIST AT **INDIANA UNIVERSITY-PURDUE UNIVERSITY INDIANAPOLIS** IN THE US, HAS BEEN LOOKING FOR THE ANSWERS TO THESE QUESTIONS

TALK LIKE A HYDROLOGIST

DEW - water droplets which condense onto cooled surfaces

DRYLANDS - areas where the rate of evaporation is much greater than the rate of precipitation, making water a scarce resource

FOG - closely-packed water droplets suspended in the air

HYDROLOGY - the study of how Earth's water moves, is stored and is used

ISOTOPES - forms of an element which have the same number of protons in their atomic nuclei, but different numbers of neutrons, meaning they have different masses

PRECIPITATION - water which falls to Earth e.g. rain, hail, snow

TRANSPIRATION - a process of water movement through plants before evaporation to the atmosphere from the plant surface

Covering over 40% of our planet's land surface, drylands are home to a third of the world's population. Including deserts (such as the Sahara in north Africa) and grasslands (such as the Great Plains in the US and Canada), key features of drylands include their low and unpredictable levels of rainfall, low levels of plant coverage and fragile ecosystems. To survive in such harsh conditions, plants and animals cannot rely solely on precipitation to provide their water. Instead, they have evolved methods to capture additional moisture contained in fog and dew. For example, certain beetle species endemic to the Namib Desert harvest the fog water using their wing scales and their unique body positions during fog events.

As Earth's climate warms, hydrologists predict that the water contained in drylands will become even scarcer, making the future of these ecosystems increasingly uncertain. Professor Lixin Wang, a hydrologist at Indiana University-Purdue University Indianapolis (IUPUI), studies the formation and origins of fog and dew in drylands around the world. His results are providing important insights into how these environments are changing, and how the organisms that live there will need to adapt to survive.

HOW DO FOG AND DEW FORM?

Even in drylands, the air contains water vapour. Under the right conditions, this gaseous water can condense to form droplets of liquid water. Fog occurs when the atmosphere reaches saturation. Water droplets will form, suspended in the air, which can be intercepted by leaves or branches. Dew forms when water vapour condenses onto a cold surface, resulting in droplets forming directly on the ground or leaves. In both cases, plants and animals can take up the precious water in these droplets. In dryland environments, fog and dew usually form during the cool nights, before being evaporated once the sun rises.

The formation of fog and dew are incredibly important processes, but as Lixin explains, we still have much to learn about them. "Fog and dew sustain the survival of vegetation and other organisms in drylands," he says. "But their sources and the specific roles they play are not yet fully understood." As researchers seek to understand more about how drylands are being transformed by climate change, knowledge of these processes has never been more important.

PROFESSOR LIXIN WANG

Department of Earth Sciences,
Indiana University-Purdue University
Indianapolis, USA

FIELD OF RESEARCH

Hydrology

RESEARCH PROJECT

Investigating the sources of fog and dew in dryland environments

FUNDER

National Science Foundation
(IIA-1427642 and EAR-1554894)

HOW DOES LIXIN COLLECT FOG AND DEW?

Unlike measuring precipitation, which can simply be collected in a container as it falls from the sky, measuring fog and dew is not so easy, and there are currently no standardised methods to do this. Lixin uses custom-designed fog and dew collectors, which he installs at his field sites in drylands around the world. His fog collector is a large net, which intercepts the suspended water droplets as they move through the air. As they collect on the large surface area provided by the fibres of the net, the droplets grow and eventually fall into a container below. His dew collector is simply a sheet of metal inclined at 45°. As the dew condenses onto the metal overnight, the droplets will run down the metal sheet and into a collection container.

Every morning, Lixin and his team must collect the fog and dew samples very early in the morning. "Evaporation will affect our measurements and the interpretation of our results," explains Lixin, "so we must collect the samples before the sun evaporates them. Also, some of our measurements, such as plant water potential, need to be taken before the sun rises, when plant transpiration is minimum." This involves some very early starts to the working day!

WHERE DOES THE FOG COME FROM?

In the Namib Desert in southern Africa, scientists have long assumed that the life-sustaining fog which appears many mornings is produced by moisture from the Atlantic Ocean. Lixin wanted to test if this was true.

To do this, he analysed the chemical composition of the water contained in the fog and dew samples that were collected in the Namib. "Water is made of hydrogen and oxygen atoms, and both elements have multiple naturally occurring isotope forms," explains Lixin. "Waters from difference sources, such as seawater and local groundwater, have small isotopic differences in their compositions." So, by measuring the mass of hydrogen and oxygen atoms in the water samples, Lixin could identify exactly where the moisture came from.

And, contrary to popular belief, the isotope analysis revealed that less than half of the desert's fog originates from the sea. Instead, much of the moisture comes from local water, contained in the soil.

WHAT IS THE FUTURE OF DRYLANDS?

Lixin believes his results from the Namib Desert could have important implications for our understanding of other dryland environments. As the climate changes, the Earth's drylands are predicted to become even drier, depleting their levels of groundwater. Since local water is an important potential source for fog, less groundwater will mean less fog, and therefore less water for plants and animals to drink.

Already, ecologists have observed that fog-dependent beetles in the Namib Desert are migrating towards the coast, where fog is more plentiful than inland as it is supplemented by ocean moisture. "Fog and dew inputs will likely decrease due to a warming climate," Lixin says. "The more variable rainfall and decreased fog and dew inputs will negatively affect all living organisms in the desert."

Ultimately, with knowledge of where fog and dew originate, Lixin and his team are giving scientists a far clearer picture of the threats which dryland ecosystems face, and how they may transform in the coming decades. This understanding can help us to protect these fragile environments and enable the many people living in Earth's drylands to prepare for the approaching changes to their lives.

ABOUT HYDROLOGY

Hydrology is a diverse field of science, which studies how water moves throughout Earth's land, ocean and atmosphere. Some hydrologists investigate how water resources can be better managed to improve sustainability, others develop new ways to protect people from floods and drought. Lixin specialises in 'ecohydrology,' a branch of hydrology that studies the interaction between vegetation and the water cycle.

WHY IS HYDROLOGY SUCH AN IMPORTANT FIELD TO STUDY?

Water is the single most important natural resource on Earth. Without water, no life could survive. Dryland environments are now home to 2.5 billion people, so understanding how water moves and is used in these regions is essential.

We need to know how ecosystems survive in such hostile, dry conditions in order to protect the natural environment and the communities living there. At the same time, too much water can also be deadly, with floods posing severe threats to communities and infrastructure around the world. Hydrologists seek to gain a better understanding of all natural and human-influenced processes related to water.

WHAT DOES A HYDROLOGIST'S DAY INVOLVE?

With such a range of topics studied by hydrologists, no two researchers will carry out the same tasks in their day-to-day lives. But hydrologists will often travel to exciting locations all around the world to conduct fieldwork or present results at conferences. For Lixin, a day in the field involves waking up very early to visit his fog and dew collectors before the sun rises.

"I still remember my first field trip to Africa, 15 years ago when I was a PhD student at the University of Virginia," Lixin says. "We did fieldwork in the Kalahari Desert in Botswana. Everything was new to me there – the landscape, the culture, the food. I just loved it. It's such a great feeling to sleep in a tent in the middle of nowhere, so close to nature."

WHAT CHALLENGES WILL FUTURE HYDROLOGISTS HAVE TO SOLVE?

Climate change is perhaps the greatest challenge that humans have ever faced, and the work of hydrologists is crucial to understanding how our planet will change in the coming decades. For Lixin, this will involve investigating how more unpredictable rainfall and the unsustainable use of groundwater will impact fragile dryland ecosystems.

Future hydrologists will study the changing water availability in all ecosystems, as a result of climate change and human extraction. They will examine how variations in the water cycle will influence our cities, while trying to find solutions to the increasing presence of floods and droughts. And they will encourage sustainable water management in communities around the world, ensuring that this most precious resource is available for everyone.

Ultimately, the next generation of hydrologists will be at the front line of global efforts to understand and adapt to a changing world.

EXPLORE A CAREER IN HYDROLOGY

- As such a wide and varied field, you could become an academic hydrologist like Lixin, studying whichever aspect of hydrology most interests you. Or you could apply your knowledge to roles in sustainable water management or flood engineering.
- The American Geophysical Union has useful resources for school students: **www.agu.org/Share-and-Advocate/Share/Community/K-12-Education-Resources**
- Lixin gives talks and runs tours of his lab for high school students, as well as organising training courses for teachers: **earthsciences.iupui.edu/~lxwang/Lixin_Wang/Summer_Training.html**
- "Find opportunities to get some research experience early," advises Lixin. Contact professors, who will be happy to talk about their research and provide advice. Lixin's contact details can be found through his webpage: **science.iupui.edu/people-directory/people/wang-lixin.html**

PATHWAY FROM SCHOOL TO HYDROLOGY

At school, study maths, physics, chemistry, biology and geography.

Lixin recommends developing your writing skills, as written communication is important for scientific research.

Undergraduate degrees in Earth science, environmental science, geology or physics would offer a direct route into hydrology, but as an interdisciplinary subject, other courses could also lead there.

As the sun rises at the Gobabeb Namib Research Institute, fog recedes from the Namib Desert

HOW DID LIXIN BECOME A HYDROLOGIST?

The city I grew up in is surrounded by mountains and a large river runs through it. Since I was very young, I loved to climb mountains, explore caves, and catch fish, birds and insects to raise them at home. Despite my mom's disapproval, I managed to maintain a small 'zoo' at home! I was fascinated by living organisms and liked to study them. In middle school, I became interested in science fiction and I even wrote a couple of science fiction stories – they never got published. I think my interests in living organisms and science fiction triggered my passion to explore unknown things and do research.

The name my parents gave me means "being creative" in Chinese. My father has been always telling me do things creatively, I think this greatly influences my career choices.

I really enjoy the intellectual freedom and time flexibility of being a scientist. Although I work a lot, it's often my own decision how long I work, when I work and what I work on.

I have an undergraduate and master's degree in biology and a PhD in environmental science. My PhD research was on African savannas, a dryland. Water is a key player in such systems and that made me interested in hydrology. It was a natural transition from biology to ecohydrology as I look at the water cycle through the lens of biology and vegetation. There were new skills I needed to learn for the transition, but being a scientist, you always need to learn new things, so this was not a real barrier for me.

I enjoy travelling and always want to see new places. I have been to 49 states in the US and have been to all six habitable continents. I would love to visit Antarctica before catastrophic changes occur in West Antarctica, which I really hope do not happen in my lifetime.

I truly enjoy what I am doing every day. In the future, I think I will continue doing what I do now, trying to do better in every aspect.

LIXIN'S TOP TIPS

01 Find your passion.

02 Try to improve your writing skills early on.

03 Be persistent.

MEET KUDZAI FARAI KASEKE

Dr Kudzai Farai Kaseke is a postdoctoral researcher at the University of California, Santa Barbara in the US. Following an undergraduate degree in agriculture and soil science from the University of Zimbabwe and a master's in conservation ecology from the University of Stellenbosch, Farai completed a PhD at IUPUI where he was supervised by Lixin.

My undergraduate studies gave me a broad understanding of environmental sciences and sharpened my laboratory technical skills. My master's introduced me to dryland ecosystems and developed my research and writing skills. These skills were the foundation of my work with Dr Wang, who then introduced me to the fascinating world of isotopes. This elevated my research expertise such that we could tackle and answer questions that had not been answered before.

My participation in the study of fog and dew in dryland environments involved data collection during field work, laboratory analysis, data analysis, writing and publishing scientific papers and disseminating our results. Highlights included collaborating with international institutions, international travels and presenting our work at conferences.

As an early career scientist, I am proud to have already collaborated at the international stage. I have also published 20 scientific papers. These have helped advance my career and some have garnered wide media attention meaning our work is reaching a much larger audience.

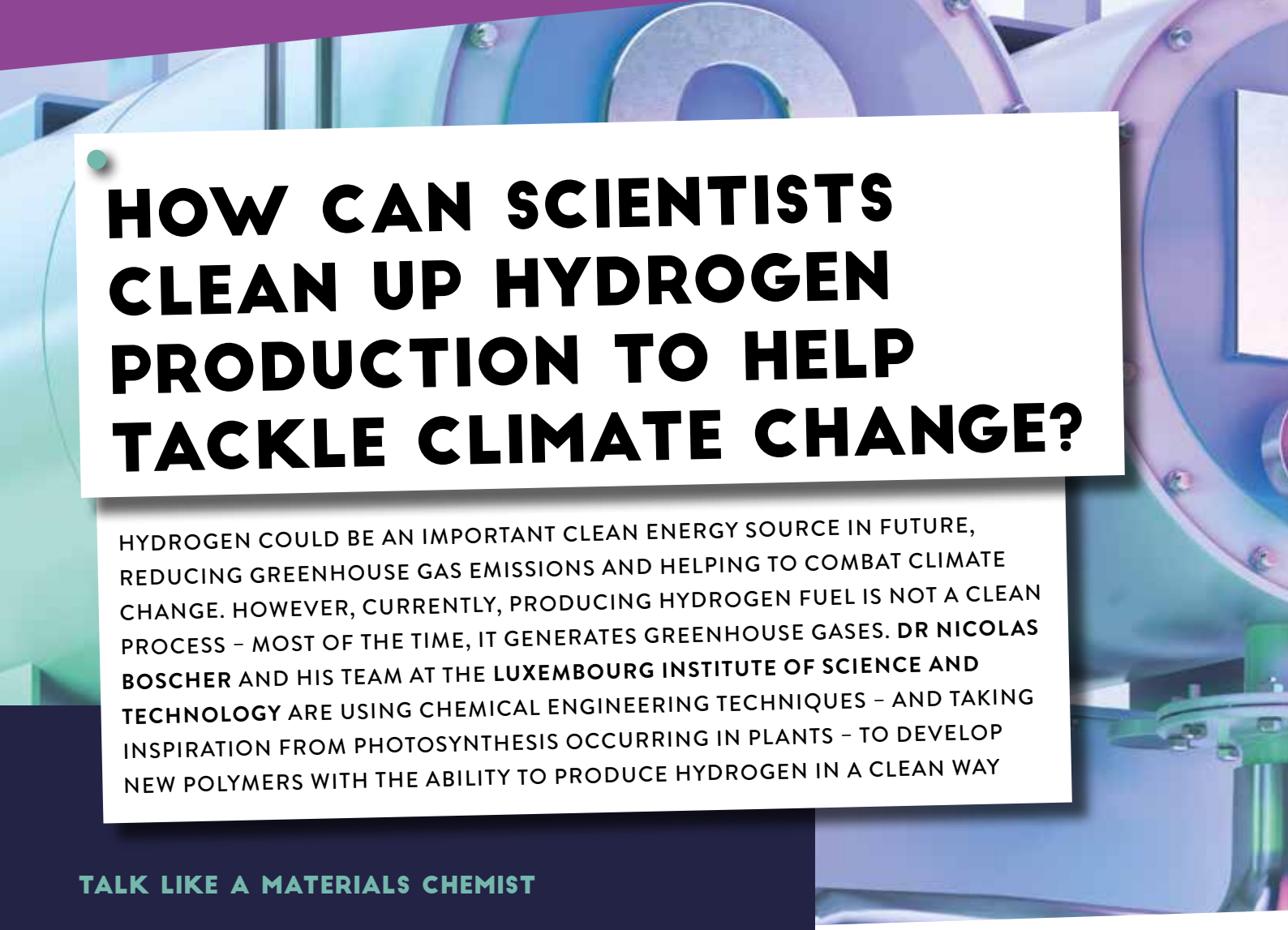
In the future I hope to continue publishing scientific articles, expand to policy issues and secure my own funding. At the same time, I would like to encourage and mentor young people of colour into the environmental sciences to show this as a viable career pathway for them.

FARAI'S TOP TIPS

01 Get a broad understanding of environmental science before specialising, which will give you versatile knowledge of multiple fields.

02 Learn to code because this is becoming an essential skill across all disciplines – getting comfortable with coding while you are in school will make your progress easier.

03 Talk to as many scientists or professors as you can to find out more about opportunities.



HOW CAN SCIENTISTS CLEAN UP HYDROGEN PRODUCTION TO HELP TACKLE CLIMATE CHANGE?

HYDROGEN COULD BE AN IMPORTANT CLEAN ENERGY SOURCE IN FUTURE, REDUCING GREENHOUSE GAS EMISSIONS AND HELPING TO COMBAT CLIMATE CHANGE. HOWEVER, CURRENTLY, PRODUCING HYDROGEN FUEL IS NOT A CLEAN PROCESS – MOST OF THE TIME, IT GENERATES GREENHOUSE GASES. **DR NICOLAS BOSCHER** AND HIS TEAM AT THE **LUXEMBOURG INSTITUTE OF SCIENCE AND TECHNOLOGY** ARE USING CHEMICAL ENGINEERING TECHNIQUES – AND TAKING INSPIRATION FROM PHOTOSYNTHESIS OCCURRING IN PLANTS – TO DEVELOP NEW POLYMERS WITH THE ABILITY TO PRODUCE HYDROGEN IN A CLEAN WAY

TALK LIKE A MATERIALS CHEMIST

GREENHOUSE GASES – gases such as carbon dioxide in the Earth's atmosphere which trap heat, causing climate change

FOSSIL FUELS – fuels like coal, oil and gas that form from fossilised remains of plants and animals over millions of years and emit greenhouse gases when burned

CLEAN ENERGY – energy that does not generate pollutants or greenhouse gases

PHOTOCATALYST – a material which uses light energy to generate or accelerate a chemical reaction

CHLOROPHYLL – a green molecule found in plants that absorbs sunlight, powering photosynthesis

MICROPOROUS – a material containing tiny holes known as pores

POLYMER – a large molecule composed of many repeated subunits

SYNTHESIS – combining or joining many small parts to make a connected whole

Burning hydrogen does not produce greenhouse gases, which means that it has the potential to be a clean fuel powering cars, planes and other processes currently dependent on fossil fuels. However, the production of hydrogen fuels usually generates greenhouse gas emissions. Around 95% of hydrogen is currently produced from fossil fuels, limiting its potential to be a truly clean energy source.

Dr Nicolas Boscher and his international team at the Luxembourg Institute of Science and Technology combine their expertise from a range of scientific fields, aiming to find new, clean ways of producing hydrogen. Perfecting methods like these and cleaning up hydrogen production may help the world to reduce greenhouse gas emissions and tackle climate change.

A CLEAN FUEL

Most hydrogen is currently produced from methane or natural gas, in a process that generates carbon dioxide – a greenhouse gas. Scientists are trying to develop alternative hydrogen production methods that do not generate greenhouse gas emissions so that hydrogen can be used as a clean fuel. For Nicolas and his team, this involves working on a process called photocatalytic water splitting. Their methods mimic part of the process of photosynthesis whereby plants use energy from the sun to transform water (H_2O) and carbon dioxide (CO_2) into oxygen (O_2) and sugar ($C_6H_{12}O_2$). Nicolas explains, "For over three billion years nature has been implementing water splitting using sunlight". Photocatalytic water splitting is artificial photosynthesis that uses light to split H_2O molecules into H_2 and O_2.

MIMICKING PHOTOSYNTHESIS

Nicolas explains that he and his team create new polymer photocatalysts by joining together smaller chlorophyll-like molecules or other strongly coloured molecules. The resulting photocatalyst must have two key properties: 1) it can absorb light and turn it into energy, 2) it is microporous with active sites that molecules can bind to so that chemical reactions can take place. Nicolas says, "Imagine an intensely coloured polymer foil on which hydrogen and oxygen bubbles form when immersed in water, under sunlight."

SYNTHESISING NEW POLYMERS

"The synthesis of our photocatalytic polymers is not straightforward," says Nicolas. Some of

The CLEANH2 project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 865985). The TODAM project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101031568. The POLYPORPH project has received funding from the Luxembourg National Research Fund (FNR) under the CORE programme (C15/MS/10340560).

EXPLORE A CAREER IN MATERIALS CHEMISTRY

- Materials chemists use chemistry techniques to understand how materials work, and to design and synthesise interesting new materials which will be applied for useful purposes.
- It is common for materials chemists to work as part of a team with a mixture of expertise, such as engineers and physicists.
- The Luxembourg National Research Fund has lots of useful information on its site, including details of science events: **www.fnr.lu/**
- Salaries can vary depending on where materials chemists work, for example in a university or another organisation. According to www.glassdoor.co.uk, the national average salary for a researcher is €61,000 per year in Luxembourg.

DR NICOLAS BOSCHER

Lead Researcher at the Luxembourg Institute of Science and Technology, Luxembourg

FIELD OF RESEARCH

Materials Chemistry

RESEARCH PROJECT

CLEANH2, TODAM & POLYPORPH – developing materials chemistry techniques for the clean production of hydrogen fuels, reducing greenhouse gas emissions

FUNDERS

European Commission, Luxembourg National Research Fund (FNR)

the molecules used have poor solubility – they do not dissolve well in liquids – which means that it is difficult to synthesise usable polymer photocatalysts using a traditional 'wet chemistry' approach (with mainly liquid chemicals).

To overcome this problem, Nicolas and his team use molecules in a gas state to synthesise their polymers while modifying them to be useful. Nicolas says this gas phase approach opens the doors to other opportunities, like trying different molecules as polymer subunits and engineering polymers in new ways. Nicolas has been working on gas phase synthesis of new materials since he started his PhD in 2004, collaborating with different scientists in the UK, USA and Luxembourg to develop methods and find new solutions to research problems. This formed the foundations for the work of his current research team, which combines a range of expertise to develop methods for producing photocatalytic polymers.

NICOLAS' TOP TIPS

01 Be determined and methodical. Developing a rational and structured approach will provide you with the courage to go to unexplored fields and tackle challenges.

02 Complement your skills. Do not stick with what you already know or what you have done in the past. Learn from your colleagues, develop new skills and merge them with your expertise to explore things from a new perspective.

03 Keep an open mind and learn from your mistakes. Consider every opinion, especially criticisms, which are often excellent opportunities to improve yourself. Do not let failures and mistakes stop you. Analyse them, learn from them and adapt your approach to succeed next time.

THE BENEFITS

If hydrogen can be produced in a way that does not produce greenhouse gases, it could be an entirely clean fuel used in a wide range of applications, contributing to the fight against climate change. For example, while transitioning from petrol and diesel to electric cars could be another important way of reducing greenhouse gas emissions, large vehicles like buses, trains, trucks, ships and planes would require prohibitively heavy batteries (~1500 kg) to be powered by electricity. Hydrogen fuel could be a much more useful alternative. Hydrogen can also be used for clean heat and power generation.

Aside from hydrogen production, the research being done by Nicolas' team could also provide the foundations for a wide range of new approaches in chemistry. Photocatalysts could be engineered to mimic other biological processes and power chemical reactions, such as producing plastics from carbon dioxide. Nicolas says that this would represent a giant step towards much more sustainable approaches in chemistry which do not use fossil fuels, known as 'green chemistry', shaping the work of future chemists.

MEET THE TEAM

DR DRIALYS CARDENAS-MORCOSO

NATIONALITY: *CUBAN*
AREAS OF RESEARCH: *RADIOCHEMISTRY, APPLIED PHYSICS*

I joined CLEANH2 to contribute to understanding the structure and properties of the molecules used in the project.

Since childhood, I have been curious and keen to understand nature's processes. As I grew up, I participated in science projects at school. During my master's and PhD, I focused on the synthesis and characterisation of materials for the development of efficient light-powered devices and particularly solar fuels production. Now, I am bringing what I have learned to CLEANH2, helping to understand and develop solar hydrogen production systems.

Growing up in Cuba, I was impressed by the scientific advances in my country, particularly in biotechnology and in the development of materials, despite limited resources. I believe that the investment in technical-scientific development in Cuba over recent decades motivated many people of my generation to lean towards scientific careers.

I am also very concerned about environmental issues and their consequences, especially for future generations. I decided, as far as possible, to gear my scientific career towards developing approaches that can contribute to a sustainable future.

I feel very proud of contributing to projects aiming to develop practical devices for producing clean fuels from abundant and feasible materials. My future goal is to lead a research project developing new materials and approaches than can help to meet, in a safe and environmentally friendly way, current energy demands.

DR MAREK KRZYSZTOF CHARYTON

NATIONALITY: *POLISH*
AREAS OF RESEARCH: *ORGANIC CHEMISTRY (FUNCTIONAL DYES), MATERIAL SCIENCES*

In the TODAM project, I am responsible for designing, synthesising and understanding basic properties of synthetic organic (carbon-based) dyes.

I was raised in a region known as 'the Green Lungs of Poland' because of its vast forest, post-glacial lakes, basins and river valleys. I used to spend a lot of time in woods learning about wildlife, different environments and how ecology relates to modern society.

As child, I often watched documentaries and read books related to botany and zoology. I found the most fascinating parts were related to discovering a new functionality of a known species. This led me towards nature-inspired organic chemistry and bio-based materials.

For me, the most rewarding thing in the field of synthesis of organic dyes is when non-coloured compounds (simple and small molecules) react to form products with intense colours (larger molecules with more complex structure). The challenge is that even small differences in the reaction conditions or traces of impurity in the substances used can lead to results that can't be reproduced. However, sometimes an unfortunate mistake leads to a very fortunate discovery. A scientist should always try their best to understand what has happened in the reaction flask!

THE TEAM'S TOP TIPS

01 Be disciplined and tenacious – in scientific research, you sometimes have to keep working hard even when you don't see immediate success. But if you persevere, the outcomes can be very rewarding.

02 Be curious, and don't shy away from exploring challenging questions as they may be the most important ones to answer.

03 Be passionate! As Steve Jobs said, "The only way to do great work, is to love what you do".

DR KAMAL BABA

NATIONALITY: *ALGERIAN*
AREAS OF RESEARCH: *CHEMICAL AND PROCESS ENGINEERING*

As a kid, I was always curious about how things work. I wanted to understand the workings of artificial things such as an electric toy car, a home radio, the dynamo of a bike, but also natural phenomena such as day and night, seasons, rain, and snow. I learned lots at school, but also learned by watching TV and through life experience – when something broke at home, I was always happy trying to fix it!

I came to in the field of science very late and by chance. When I decided to study chemical engineering, I was dreaming of being an engineer in the oil and gas industry, which is one of the best sectors to work in in Algeria. However, after finishing my first degree I decided to continue my studies and live abroad. During my master's in France, I had several opportunities to visit the research lab where many of the lecturers were working. It was very interesting to see how scientists and their students, engineers and technicians work. At the end of my master's, I was convinced by one of my lecturers to do a research internship in the lab with them. It was a very exciting and motivating experience, and it felt natural to continue the experience as a PhD researcher.

MAX HEIDERSCHEID, MSC

NATIONALITY: *LUXEMBOURGISH*
AREA OF RESEARCH: *INORGANIC AND ORGANIC CHEMISTRY*

During my PhD, I will be involved in the development, characterisation and investigation of the influence of different molecules on the generation and properties of photocatalysts.

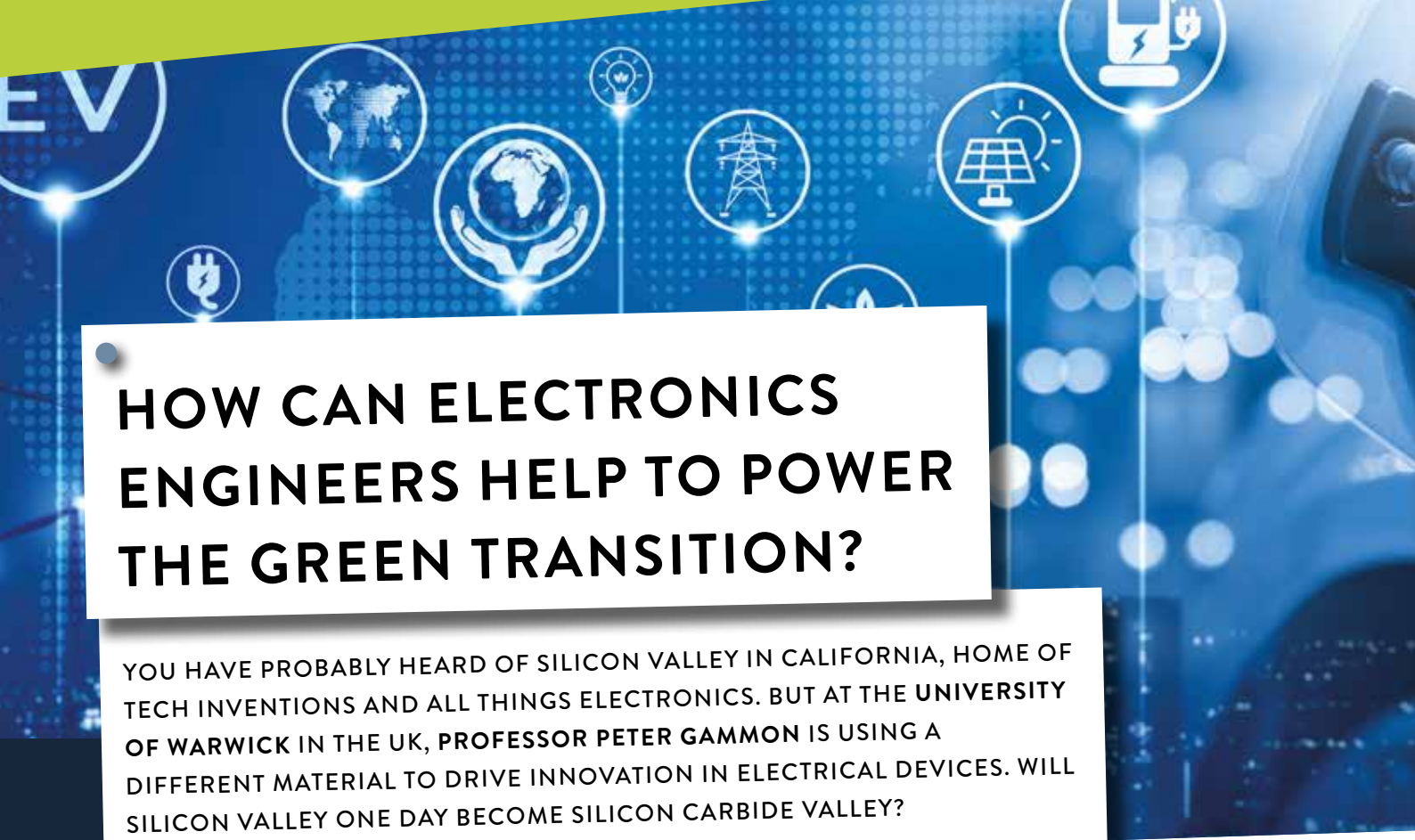
Growing up in the countryside in Luxembourg, I have always been interested in natural phenomena. High school awakened my interest in natural sciences, especially chemistry. I did my bachelor's degree in inorganic chemistry where I took part in a project, synthesising catalysts that are able to produce hydrogen by artificial photosynthesis. I continued with my master's in bio-organic chemistry with focus on synthesising modified building blocks for DNA and RNA. My PhD research combines all my fields of interest, focusing on the goal of clean fuels for future.

The most exhausting and rewarding thing about chemistry is that it consists of several fields and is very broad! It is quite challenging to build up basic knowledge at first, but when you can connect all the knowledge it allows you to understand many natural phenomena. A big advantage of natural sciences and especially chemistry and materials science is that you can apply what you have learned and obtain physical proof of the applied knowledge.

Although I am still at the very beginning of my scientific career, I am very proud of the fact that I have a bachelor's degree in inorganic chemistry, a master's degree in bio-organic chemistry and am now doing a doctorate in materials science. At each of these stages, I have ventured into new waters to pursue my current areas of interest. I am also very proud to be involved in a project that aims to produce renewable energy to help make the world a more sustainable place.

PATHWAY FROM SCHOOL TO MATERIALS CHEMISTRY

- The members of Nicolas' team have varied backgrounds and have bachelor's and postgraduate degrees in different fields related to chemistry, physics and chemical engineering. However, they have one important thing in common – they all pursued their passions and interests, which lead them to bring their individual skillsets to the team's research activities.
- Being involved in a project like CLEANH2 requires an undergraduate degree (usually followed by a postgraduate degree) in a related field – so it is worth researching different types of chemistry and materials science courses to see what sparks your interest. As Max explains, "It is important to have a good general knowledge of chemistry, as well as physics and mathematics. By gaining this basic knowledge, you quickly realise what you are most interested in and which path and specialisations you will take."
- Drialys highlights the importance of networking, meeting and talking to people when exploring a career in this field. She advises, "Don't miss the chance to participate in science festivals or young scientist conferences usually held by the universities. In addition, you can look for opportunities of internships in laboratories."
- More information on pursuing a career in chemistry can be found here: **nationalcareers.service.gov.uk/job-profiles/chemist**



HOW CAN ELECTRONICS ENGINEERS HELP TO POWER THE GREEN TRANSITION?

YOU HAVE PROBABLY HEARD OF SILICON VALLEY IN CALIFORNIA, HOME OF TECH INVENTIONS AND ALL THINGS ELECTRONICS. BUT AT THE **UNIVERSITY OF WARWICK** IN THE UK, **PROFESSOR PETER GAMMON** IS USING A DIFFERENT MATERIAL TO DRIVE INNOVATION IN ELECTRICAL DEVICES. WILL SILICON VALLEY ONE DAY BECOME SILICON CARBIDE VALLEY?

TALK LIKE AN ELECTRONICS ENGINEER

ALTERNATING CURRENT (AC) – electrical current which reverses direction periodically. Electricity is transported to your home as AC

DIRECT CURRENT (DC) – electrical current which only flows in one direction. Most of your gadgets run on DC

NATIONAL GRID – the network and infrastructure that produces electricity and distributes it to consumers

SEMICONDUCTOR – a material which is an insulator at low temperatures but an electrical conductor at high temperatures

TRANSISTOR – a component of electrical circuits which switches between AC and DC

"Power electronics is everywhere!" says Professor Peter Gammon, an electronics engineer at the University of Warwick. "It is responsible for converting electricity between its two fundamental forms – alternating current (AC) and direct current (DC)." Your phone and laptop chargers contain transistors, electronic switches that turn on and off thousands of times per second to convert the AC electricity coming from the wall plug to the DC electricity required by nearly all home appliances. "The heat you feel from the charger when it is plugged in is the wasted power that is not going to your phone or laptop," says Peter.

Increasing our production of renewable energy will help to reduce our carbon emissions, yet up to 10% of all renewable energy generated is wasted before it even reaches your phone, laptop or lightbulbs. At each stage of transporting this electricity, from wind farm to National Grid to your house to your phone, a small amount of electricity is wasted as it heats up the transistors it travels through. If we could make these transistors more efficient, less energy would be wasted. And that is what Peter is trying to achieve.

WHAT IS A TRANSISTOR?

"A transistor is an electrical switch – much like a light switch," Peter explains. Traditionally made from silicon, a cheap but not very efficient semiconductor, transistors are the key components of modern electronics and have enabled the massive growth in computing over recent decades. Without transistors, the modern world would be a very different place!

Peter likes to use the analogy of a dam across a river to describe how a transistor functions. "The purpose of the dam is to turn the flow of water downstream from the reservoir above on and off, whilst the purpose of the transistor is to turn the flow of electrical current downstream from a battery on and off." Using this same analogy, the voltage of the battery corresponds to the water pressure behind the dam.

Peter and his team are focused on designing and building transistors. "It is our job as designers of transistors to make them more efficient, so that we waste less of the power we generate," explains Peter. And to do this, he is creating them out of silicon carbide.

THE NEW SUPER MATERIAL

Silicon carbide is a compound formed from alternating atoms of silicon and carbon arranged in a hexagonal crystal pattern. It is relatively common in outer space but is extremely rare on Earth – the first time silicon carbide was detected naturally was in the remnants of a meteorite! All the silicon carbide we use on Earth is synthetic. It has been manufactured for use in bulletproof vests, as brake discs in super cars, as an alternative to diamonds in jewellery and even as the abrasive surface on skateboards.

In recent decades, engineers have started to use silicon carbide as a semiconductor, where it has several advantages over pure silicon when used for power electronics. Peter returns to the dam analogy to explain. "Building a transistor out of silicon carbide rather than silicon is like building a dam out of reinforced concrete rather than regular concrete," he says. "The extra-strong reinforced concrete allows us to hold back the same volume of water with a thinner dam – similarly, the use of silicon carbide allows us to withstand the same battery voltage with a thinner semiconductor." In turn, thinner semiconductors make for transistors which can operate with lower electrical resistance, thereby improving efficiency.

PROFESSOR PETER GAMMON

Professor of Power Electronic Devices, University of Warwick, UK

FIELDS OF RESEARCH

Electronics Engineering, Electrical Engineering, Materials Science

RESEARCH PROJECT

Developing silicon carbide technology for electric vehicles, satellites and the National Grid

FUNDER

Engineering and Physical Sciences Research Council

This work was supported by the EPSRC, under award number EP/V000543/1, the SiCSat Project.

An example of this has occurred in the manufacture of electric cars. Transistors in the car's power converter transform the DC electricity stored in the battery to AC electricity which is needed by the car's motor. Tesla was the first company to replace silicon transistors with silicon carbide ones, making its converter significantly more efficient than it was before. By wasting less energy, the car can travel further before it needs to be recharged, or the number of heavy, expensive batteries the car needs can be reduced.

HOW DOES PETER MANUFACTURE HIS SILICON CARBIDE TRANSISTORS?

Sophisticated engineering is required to develop the electrical circuitry which will power the green transition. This is highly interdisciplinary work, involving electronics engineering, electrical engineering and materials science.

To make his silicon carbide transistors, Peter begins with a very thin circular wafer of silicon carbide that is 100 mm in diameter and less than half a millimetre thick. "Making the transistors on top of this wafer is a process involving up to 20 individual steps," he says, "each of which changes the way that current flows through the material." These steps include growing more silicon carbide on the surface of the wafer, using a process called epitaxy, then oxidising these surfaces, depositing metals and etching trenches in them. This is microscopic engineering, involving physical and chemical changes on a scale of less than one thousandth of a millimetre. Working in a cleanroom to ensure the electronics remain absolutely spotless, Peter and his team can produce hundreds of transistor chips on a single silicon carbide wafer. These are then cut up and individually packaged, ready to sell to manufacturers for use in electronic devices.

SILICON CARBIDE ON SATELLITES

As well as its use in electric vehicles, silicon carbide can be used in many other high voltage electronic systems to increase efficiency and so reduce wasted energy. This includes powering data centres, in robotics and in the infrastructure of the National Grid itself. Peter is particularly interested in the application of silicon carbide in the electronics contained on satellites.

But there are particular challenges when working with electronics in space. "The Earth's atmosphere protects us from a universe full of radiation, with only a few parts of the electromagnetic spectrum – such as visible light – getting through it unimpeded," Peter explains. "But outside of our atmosphere, our satellites must work under constant bombardment of energised particles." This radiation can interfere with the electronic systems onboard satellites, so Peter and his team are researching how to ensure their transistors are protected from radiation bombardment.

There are over 2000 communications satellites in orbit around the Earth, transmitting and receiving data for satellite TV, international phone calls and credit card payments. Getting each one of these satellites into space requires a huge amount of preparation and resources – and money. By replacing the silicon in the satellite electronics with silicon carbide, Peter hopes to decrease the number of satellites that need to be launched, thereby reducing costs and also reducing the amount of resources needed, again contributing to a greener future.

Not only will silicon carbide increase the efficiency of the electronics, but it can also work at a higher temperature than silicon. This will allow the power electronics to sit next to the very hot radio-frequency amplifiers in the satellite that they supply power to. This would free up a lot of space in the satellite, meaning that each satellite could hold more communication channels, meaning we would need fewer of them.

Silicon carbide is also being used in a new generation of small satellites to work on Earth observation. Monitoring climate change requires large numbers of satellites to orbit around the Earth, recording data on everything from ocean colour to glacial retreat. Just as it is replacing silicon in transistors, silicon carbide is also starting to replace aluminium or glass in the mirrors that satellites use to collect their images. So, it turns out that whether you want to drive the green transition by developing innovative technology or by observing the impacts of climate change, you could find a career working with silicon carbide!

ABOUT ELECTRONICS ENGINEERING

WHAT IS THE DIFFERENCE BETWEEN ELECTRONICS ENGINEERING AND ELECTRICAL ENGINEERING?

In general, electronics engineers are focused on the small-scale circuitry within individual electronic devices, while electrical engineers are concerned with how electricity is moved over larger distances, such as in power systems or motors. However, this distinction is often blurred. "In our group we use techniques from electronics engineering and materials science to solve electrical engineering problems," explains Peter. "So, any good systems designer needs to have a very broad knowledge base. I believe that today's interconnectedness of our lives with technology makes this kind of interdisciplinarity essential."

WHAT ARE THE JOYS OF ELECTRONICS ENGINEERING RESEARCH?

Designing and carrying out electronics experiments can be great fun, but it takes a long time. While some researchers prefer this aspect of the work, Peter enjoys examining the results of experiments. "I love nothing more than the moment when I get to sit down with the data to find out if the idea we had at the start of the project – usually months before – worked," says Peter. "Often, it hasn't! Some people love the making, the writing up, or the story telling after, but for me the best bit is getting stuck into the numbers as they give up their secrets."

As with other fields of science, electronics and electrical engineering offer plenty of scope for international collaboration. "I am privileged to be able to go across the world, to Japan, Europe and the US, to discuss my scientific ideas with interesting people," Peter adds.

WHAT ISSUES WILL FACE THE NEXT GENERATION OF ELECTRONICS ENGINEERS?

"Throughout the 21st century electronics and electrical engineers will play a big role in the electrification of every system that previously required fossil fuels to be burnt," Peter says. While this process is gaining momentum in electric cars and trains, other transport sectors such as shipping and aircraft are still a long way from being able to operate free of fossil fuels. The field of electronics engineering will be at the forefront of designing the technology for the green transition.

EXPLORE A CAREER IN ELECTRONICS ENGINEERING

- The Institute of Electrical and Electronics Engineers (**www.ieee.org**) and the Institution of Engineering and Technology (**www.theiet.org**) are dedicated to electronics engineering and the wider field of technology.
- The IET has a section of their website dedicated to careers in engineering and technology (**www.theiet.org/career**), as well as information for students (**www.theiet.org/career/routes-to-engineering/student-hub**) and advice about apprenticeships (**www.theiet.org/career/routes-to-engineering/apprenticeships/introducing-apprenticeships/find-an-apprenticeship**).
- The National Careers Service has information about how to become an electronics engineer and what the job may involve (**nationalcareers.service.gov.uk/job-profiles/electronics-engineer**).
- With a degree in electronics engineering, you could find yourself designing an iPhone, the next Tesla or even an electric aeroplane! Or you could be at the forefront of the green revolution, developing solar cells, wind farms or nuclear fusion reactors. The opportunities for electronics engineers are endless!

PATHWAY FROM SCHOOL TO ELECTRONICS ENGINEER

- A strong background in the sciences, maths and computing is useful in electronics engineering, but Peter also advises that good English language skills are essential for communicating about your work and writing scientific reports.
- Maths, physics, computer science and chemistry are good options to study at A-level. "But don't rule out doing that 'extra' subject in something different to keep your options open," suggests Peter.
- Many universities offer degrees in electronics engineering, but other courses may also cover aspects of electronics, including aerospace engineering, physics, nanotechnology and computer science.
- College and university are not the only routes to becoming an electronics engineer. "Apprenticeships may offer you a good alternative route if you want a more hands-on experience than college will offer you," says Peter. He left school at 16 to do an apprenticeship in industry, learning electronics engineering straight from school.

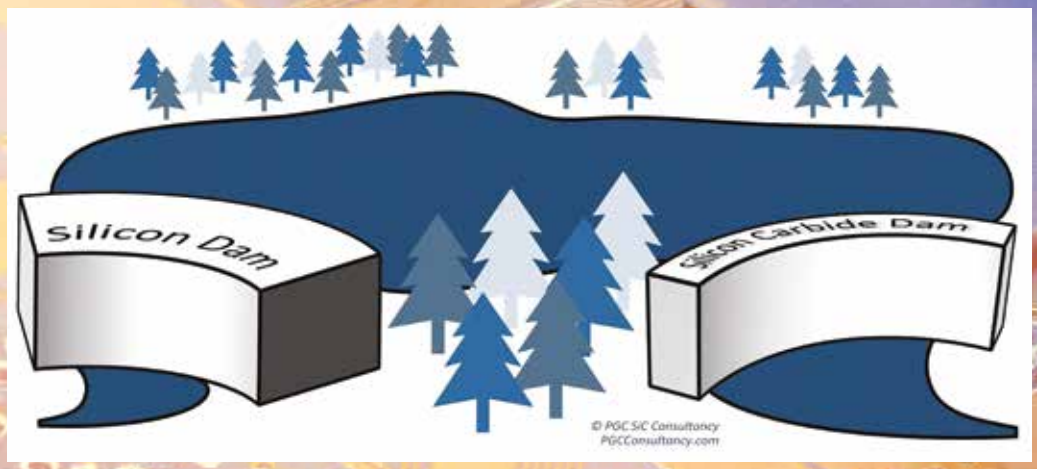
PETER'S TOP TIPS

01 When you don't know the answer to a question, ask! Most people are kind and will help when they can.

02 Learn to be resilient. You will have knocks along the way but always get back up, refocus and go again.

03 Don't be afraid to change your career path if your passions have changed.

04 Take time off to see the world before life becomes full of commitments! I spent time in Australia and New Zealand aged 22 and it was one of the best times of my life. You can start your 45-year-long career later.



Building a transistor out of silicon carbide rather than silicon is like building a dam out of reinforced concrete rather than regular concrete. You can withstand the same voltage of battery with a thinner semiconductor.

HOW DID PETER BECOME AN ELECTRONICS ENGINEER?

AS SOMEONE WHO DESIGNS ELECTRONICS, ARE YOU A 'GADGET PERSON' OUTSIDE OF WORK?

Yes! I am addicted to my phone as much as any teenager and I love the latest laptops and TVs! As an advocate for electric vehicles in my professional capacity, that is the next 'toy' I am saving up for!

WHAT INSPIRED YOU TO BECOME AN ELECTRONICS ENGINEER?

The classic thing of amateur electronics, such as making homemade radios, inspires many young people into electronics, but for me it was computer programming. I loved making games out of simple coding languages. If I were a teenager today, I can imagine nothing better than getting a Raspberry Pi, learning the computer programming language Python (there are many brilliant tutorials online) then making games, robots, music and loads more. In fact, perhaps a Raspberry Pi is another 'toy' that I should treat myself to!

HOW DO YOU STAY MOTIVATED THROUGH THE LONG PROCESS OF MAKING NEW ELECTRONIC COMPONENTS?

It can take the team a year or more to design, develop and test a single new transistor. So, it is important to have goals and milestones along the way. There is satisfaction and pride to be had in each step of the process and celebrating reaching a milestone is as important as getting to the end. Setbacks are inevitable and occur frequently! When they do, we discuss them as a team, get insights from colleagues with different expertise and use our collective experience to find the best solutions.

WHAT DO YOU ENJOY DOING IN YOUR SPARE TIME?

I enjoy keeping active – walking, running and cycling. I also enjoy watching unhealthy amounts of sport on TV – Formula 1, football, NFL and athletics. And of course, I love playing on my phone!

OUT WITH A BANG: THE CHALLENGE OF MEASURING EXPLOSIONS

EXPLOSIONS ARE DIFFICULT TO STUDY BECAUSE THEY HAPPEN SO QUICKLY AND WITH SUCH DESTRUCTIVE POWER. YET KNOWING HOW THEY WORK IS IMPORTANT FOR PROTECTING HUMAN LIVES. SO, A TEAM OF ENGINEERS AT **THE UNIVERSITY OF SHEFFIELD**, UK, HAVE ESTABLISHED THE BLAST AND IMPACT DIAGNOSTICS LAB, WHERE THEY USE THE LATEST TECH AND EXPERIMENTAL TECHNIQUES TO LEARN MORE ABOUT WHAT HAPPENS WHEN STUFF BLOWS UP

TALK LIKE AN ENGINEER

EXPLOSION – a sudden catastrophic release of energy, causing a pressure wave

LOAD – a force, deformation or acceleration applied to something, such as a structure

PRESSURE WAVE or **BLAST WAVE** – when a disturbance causes a change in pressure emanating outwards from a source

SENSOR – a device that measures physical properties, such as light, heat or pressure

Though we all instinctively know an explosion when we see one, the physical processes behind them are pretty complex. "Explosions happen when a lot of trapped energy is suddenly released," explains Dr Sam Clarke, a civil engineer at the University of Sheffield. This energy creates a pressure wave, expanding outwards from the site of detonation, and it is this pressure wave that causes damage to people and infrastructure.

His colleague Dr Sam Rigby, also a civil engineer, explains in more detail. "An explosion is a chemical reaction that converts an explosive material into a high-pressure, highly dense gas," he says. "This gas then rapidly expands and violently forces the air surrounding the explosive out of the way." Understanding this process in more detail can help engineers predict the effects that explosions will have on structures, which is why Sam and Sam have established the Blast and Impact Diagnostics Lab. If engineers know how structures will respond to explosions, then safety measures can be improved to hopefully ensure lives are saved during future blasts.

STRONG BUT SENSITIVE

The trouble is, explosions are very hard to measure. "You need equipment that can record intense pressures (many times stronger than steel) which are applied and removed in a miniscule amount of time (less than a thousandth of a blink of an eye)," says Sam R. This requires equipment that is both robust enough to survive the explosion but sensitive enough to record these very rapid changes in conditions.

Traditionally, the pressure of explosions has been measured from further away or averaged out over a larger surface area, which does not give much information about the precise goings-on within the explosion itself. The Blast and Impact Diagnostics Lab is hoping to change this, and so the team is designing bespoke apparatus to measure explosions, providing fundamental insights into the physical processes that occur extremely close to an explosive.

As well as measuring explosions themselves, the team is also interested in their effects on nearby structures. "To design structures that are more resilient to explosions, we have to understand the loads they are exposed to," says Sam R. So, experiments are being conducted in the lab to investigate how structures respond to the loading caused by an explosive blast wave.

MEASURING THE BIG BANG

To conduct an explosion, the team uses plastic explosives. "These high explosives have about the same energy in them as a Mars Bar," says Sam C. "The difference is that you can't detonate a Mars Bar!" Once the explosives have been moulded to the desired shape,

BLAST AND IMPACT DIAGNOSTICS LAB

Department of Civil and Structural Engineering, University of Sheffield, UK

FIELD OF RESEARCH

Engineering

RESEARCH PROJECT

Investigating explosions and their effects on structures

FUNDER

Engineering and Physical Sciences Research Council

a detonator is added then the firing pack is activated.

"We clear the area and give a warning on-site before the actual detonation happens," says Genevieve Langdon, a Professor of Blast and Impact Engineering. "That's the simple bit. The tricky bit is measuring what happens!" The team uses an array of sensors, all of which must survive the explosion and take accurate recordings at the same time.

Ultra-high-speed cameras film the event, collecting up to a million photos per second. These images show how the blast waves develop during the explosion and how any structures in the path of the explosion react to the expanding pressure wave. The explosion is also filmed by cameras that can observe qualities not visible to the naked eye. Infrared cameras measure temperature changes during the explosion while X-ray cameras allow the team to see inside the explosive event.

Pressure gauges measure the pressure applied by the blast wave itself – the rapidly moving air caused by the expansion of gas within the explosive. "This pressure load will exert a hard 'push' on a structure, like a very intense wind, which can cause the structure to deform or break," says Sam R. By studying the magnitude of this pressure loading at different distances from the source of detonation, the team will learn how much pressure buildings in the path of an explosion will be subjected to.

EXPLOSIONS IN THE REAL WORLD

Lives and structures are most at risk from explosions in warzones. The team hopes their findings could help protect soldiers from improvised explosive devices, such as roadside bombs. "We've been able to identify the properties of soil types which affect how dangerous a buried explosive may be," says Sam C. "Next we will try to understand why these properties affect the explosion, which is where the new lab comes in."

Sometimes, explosions happen on a massive scale, such as the tragic explosion in Beirut in August 2020. Obviously, explosions at this scale cannot be replicated in a lab – but that does not mean they cannot be studied. "Blast waves scale quite nicely according to 'cube root' scaling," says Sam R. "This means the properties of a small and large explosion will be the same, just scaled according to their size." Small-scale explosions conducted in the lab can therefore be scaled up to help understand city-scale explosions such as the Beirut blast. However, the blast wave of 'real-life' explosions will interact with structures such as buildings, and so the next step for the team is to understand how the expanding pressure wave will be influenced by obstacles.

While the team certainly enjoy the excitement of creating explosions for their experiments ("Of course it's fun to blow stuff up!" says Andy, a technician in the lab), the work conducted in the Blast and Impact Diagnostics Lab has a much greater purpose and will ultimately help save lives and protect infrastructure from the devastating effects of explosions.

EXPLORE A CAREER IN ENGINEERING

• A-levels in physics and maths are necessary for most engineering courses, but Gen and Sam R. both suggest considering creative subjects too, to ensure diverse ways of thinking and connection with real-world issues.

• Sam C. and Sam R. are civil engineers. The Institute of Civil Engineers (**www.ice.org.uk/what-is-civil-engineering**) provides a wealth of resources about careers in civil engineering, including advice about what subjects to study and interviews with civil engineers at all stages of their careers.

• Gen is a chartered mechanical engineer. If you want to achieve chartered engineer status, check that your university courses are accredited by a national engineering body such as the Institution of Mechanical Engineers (**www.imeche.org**) or the Royal Academy of Engineers (**www.raeng.org.uk**)

• Gen recommends finding work experience to learn more about what engineering actually is. "Engineers work everywhere – factories, laboratories, design offices, consultancy firms..." she says. "Go and see the variety of engineering roles for yourself."

• Not all engineering roles require a university education. Andy is a technician at the Blast and Impact Diagnostics Lab. He advises students to be hands on and open to learning new skills if they are interested in working in an engineering lab. "Offer to help wherever you can," he says. "You never know where it might lead!"

MEET DR SAM CLARKE

I'm the Principal Investigator of the Blast and Impact Diagnostics Lab. This means I'm in charge of ensuring we deliver what we promised – which recently involved spending £1 million on new equipment! It's great to finally have the resources to investigate ways to reduce the impact of explosions on the world around us.

I enjoy the varied nature of my job, and the fact that no two days are the same. One day I'll be in the classroom teaching students, and the next I'll be out on-site blowing things up!

When British troops were deployed to Iraq and Afghanistan, we realised we had an opportunity to help protect them through understanding the engineering properties of soil. The characteristics of the soil in which an explosive is buried will determine how dangerous the explosion will be. I've been involved with the engineering aspect of explosions ever since.

I've always been interested in construction. I loved LEGO sets as a kid, and still do! I couldn't decide between architecture and engineering, so I completed the University of Sheffield's unique Structural Engineering and Architecture degree, which let me delay my professional career choice. I soon realised that I loved engineering, especially soils, which always provide a challenge.

I always have a project on the go outside of work, mainly home improvement projects or furniture design. I'm also a very keen cyclist and having the Peak District on my doorstep is great.

MEET DR SAM RIGBY

My research focuses on understanding the loading that acts on structures following an explosion. The forces produced by explosions far exceed those normally considered in civil engineering, and they are applied and removed so suddenly that they introduce all sorts of interesting behaviour into structures.

My role in the lab focuses on numerical modelling and developing quick methods for predicting blast loading parameters. These methods will be based on our explosion experiment results and could provide a 'shortcut' to the more computationally demanding solutions currently in use. We aim to provide simple techniques for practicing engineers to predict the effects of explosions.

I've seen close to 100 explosions in my lifetime, and it never gets boring! I like the fact that we get an insight into this hidden world where events happen so quickly, through our ultra-high-speed cameras, so we can see what is really going on. Plus, I love when I receive the results of a particular test – looking at the screen and thinking, "I'm the only person in the world who knows this." It's quite a feeling!

Civil engineering, by definition, is about people. My research ultimately aims to protect people from explosions and knowing that my work could save lives really spurs me on. I also love the variety of civil engineering, the mix of practical work with number crunching. This is very apparent in my job, where my time is split between blowing things up in a muddy field and computer programming at my desk.

I was always designing things when I was younger. I remember sketching out a toy giraffe, including a cross-section, and giving the blueprint to my mum to pass on to Santa ready for Christmas! I carried this inquisitive nature into school and became interested in maths and physics. I initially thought I wanted to be an architect, but as soon as I realised engineering involved creative design as well as mathematics, I was sold.

Outside of work, I play for my local rugby team and enjoy playing guitar. I am also a huge craft beer nerd – we're blessed to have several great breweries in Sheffield. And I love walking in the Peak District with my wife and young son.

MEET PROFESSOR GENEVIEVE LANGDON

I am a mechanical engineer by training. This field is very broad and covers anything connected to how things move or respond to loads. This feeds into industries such as manufacturing, structures, energy production and fluid motion. My specific interest is much more niche, namely how materials and structures respond to explosions. Explosions and their effects are both devastating and fascinating to me.

I would be lying if I said I don't enjoy blowing things up! I enjoy the challenge of unpicking what happens during an explosive event, and how to use this information to prevent damage and injury in the real world. The physics and engineering challenges involved require a clever team, and I love being able to work with excellent people.

I enjoy the mix of different things I get to work on. Engineering is at the interface of science and the real world – taking theory and putting it into practice. I like the hands-on nature of experiments, and the chance to use my brain to interpret their results.

When I was a child, I wanted to be the first woman in space, but was beaten to it! When I was about 12, I learnt about the field of engineering (and that being an engineer didn't mean being a car mechanic) and set my eyes on that for the rest of my time in school. I was one of only two girls in my school to take Design & Technology at GCSE. My one regret is being too narrowly focused on science-leaning subjects – I wish I had taken GCSE drama! I thought arts and engineering are incompatible, but they certainly are not.

Outside of work, I spend a lot of time with my family, and I like to sing, write poetry and read. I also preach at my local church and am doing an online theology degree in my spare time. Though all these interests are very different to engineering, I find the range of perspectives they give me very stimulating and life-giving.

MEET ANDY HIBBERT

I'm a technician in the Blast and Impact Diagnostics Lab. I run a selection of high-speed video cameras, as well as doing on-site photography. I also help with the general day-to-day running of the laboratory.

The sense of achievement I get when our hard work produces great results is the best part of this project – as well as the chance to blow stuff up! I also enjoy getting to watch videos back in super slow motion, seeing exactly what happens during an explosion.

As a technician, a typical day starts off with a team meeting and discussing the plans for the day. Then we will prepare the test area and I will set up the cameras. Finally, it's time to make a bang and retrieve the data we have just captured.

It was through photographing BMX riding that I became interested in slow-motion filming. I understood the fundamentals of photography and became involved with filming explosions, ultimately working with lots of different types of cameras and equipment as a career.

THE TEAM'S TOP TIPS

01 The better you do at school, the more choices you have in life. Try and give your best to whatever you do, without burning yourself out.

02 Find something that you enjoy, sparks your imagination and gets you excited to learn more. Don't be afraid to follow what you love.

03 Don't be put off if you don't achieve what you want straight away. Things can take time.

04 Show interest and talk to people! Enjoy yourself and try to make a positive difference to the people around you.

BUILDING A CAMERA TO SEE THE FIRST GALAXIES

AS ASTRONOMERS LOOK DEEPER INTO SPACE, THEY REQUIRE BETTER INSTRUMENTS TO DO SO. A JOINT TEAM OF SCIENTISTS AND ENGINEERS AT **CARDIFF UNIVERSITY**, UK, AND THE **NATIONAL INSTITUTE OF ASTROPHYSICS, OPTICS AND ELECTRONICS**, MEXICO, HAVE RISEN TO THIS CHALLENGE. WITH THE NEW TECHNOLOGY IN THEIR GROUND-BREAKING CAMERA, WE COULD SOON BE LEARNING MORE ABOUT THE FORMATION OF THE UNIVERSE'S BIGGEST STARS AND OLDEST GALAXIES

TALK LIKE AN ASTRONOMER

ABSOLUTE ZERO – the lowest temperature possible, equal to 0 Kelvin or -273.15 °C

ELECTROMAGNETIC RADIATION – travelling electric and magnetic waves, commonly known as light

VISIBLE SPECTRUM – the range of wavelengths of electromagnetic radiation which can be seen by the human eye

WAVELENGTH – the distance between one wave crest to the next

Have you ever tried to imagine seeing colours that you have never seen before? Have you wished you could see with x-ray vision or could spot things at night with infrared eyes? Astronomers do not have to imagine what it is like to see beyond the visible spectrum. They have long been finding new perspectives on stars and galaxies by tuning into different wavelengths of electromagnetic radiation. Observing the sky at a new wavelength can reveal completely new information about the Universe.

However, there are still some wavelengths that have been invisible to astronomers until recently. These wavelengths cannot be detected using standard equipment, requiring researchers to design and make their own devices if they want to capture the information that they contain. One of these 'blind spots' is in the millimetre range (around the boundary between infrared and microwaves). That is why a team of scientists and engineers, including Dr Sam Rowe at Cardiff University and Dr Víctor Gómez and Marcial Tapia at the National Institute of Astrophysics, Optics and Electronics have been working on the Mexico UK Submillimetre Camera for AsTronomy, or MUSCAT.

WHAT IS MUSCAT?

MUSCAT is a camera, but you might not recognise it as one if you saw it. For a start, it looks like a metal cylinder 1 metre wide and 1 metre tall, with a window in the top and some electronics attached to the outside. Despite its size, MUSCAT does not come with its own lens, but relies on a separate piece of equipment to collect light for it. In this case, the 'lens' is a 50-metre-wide telescope called the Large Millimeter Telescope (LMT).

The job of the camera itself is to measure radiation of millimetre wavelengths collected by the LMT. To do this, a huge number of technical components are required, which have been the focus of this collaborative project. "This project is unique in that almost every aspect of the instrument has been designed, built, assembled and tested by our own engineers, researchers and students," explains Sam.

WHAT DOES THE CAMERA CONSIST OF?

Optical components filter, reflect, and guide incoming electromagnetic radiation (light) to where it needs to go. The goal of these components is to focus all the millimetre wavelengths collected by the telescope – and only the millimetre wavelengths – onto the detectors. To do this, filters are used to block other wavelengths of light before an arrangement of mirrors reflects the radiation onto a region called the focal plane.

The detector is the part that measures the incoming electromagnetic radiation. MUSCAT requires a new type of very sensitive detector to measure the very faint light signals, called

The team acknowledge RCUK and CONACYT for funding through the Newton Fund project ST/P002803/1

kinetic inductance detectors (KIDs). Víctor was responsible for designing the KIDs for MUSCAT. A significant challenge for building a camera with KIDs is that they only work if they are cooled almost to absolute zero. So, a complex cooling system also had to be designed to cool the camera to 0.1 Kelvin (-273.05 °C).

Another challenge when it comes to measuring light at millimetre wavelengths is that all objects above absolute zero emit radiation. Because objects on Earth are much warmer than the objects in space that MUSCAT is trying to image, they emit about a million times more electromagnetic radiation at millimetre wavelengths. This room temperature electromagnetic emission would saturate the detectors, so filters are used to keep out the excess radiation.

The final part of the camera is the readout system, which captures signals from the detector and turns them into digital data. Sam and Marcial have been developing the electronics and software to do this, allowing astronomers to analyse the new millimetre information being received from space.

WHY IS THE LMT AT THE TOP OF A MOUNTAIN IN MEXICO?

After years of designing and building, MUSCAT is now on its way to the summit of Sierra Negra to be installed at the LMT. At 4,600 metres above sea level, Sierra Negra is the fifth highest peak in Mexico. The reason for this location has everything to do with the millimetre wavelengths that the LMT was built to observe.

The millimetre part of the electromagnetic spectrum is strongly absorbed by water molecules. Therefore, humid air and clouds in the atmosphere will soak up any of these wavelengths coming from space before they reach the ground. The high altitude of the LMT means there is less atmosphere between it and space, and therefore less chance of the radiation being soaked up. Furthermore, Sierra Negra has a very dry climate, meaning the atmosphere often opens up like a 'window' into space.

WORKING TOGETHER ACROSS CONTINENTS

Scientific advancements are collaborative efforts, and the development of MUSCAT clearly highlights this. The technology transfer between institutions has allowed team members in both Cardiff and Mexico to gain new skills and knowledge while working together to build a state-of-the-art camera for astronomical observations. There were difficulties to working collaboratively with a 6-hour time difference, with researchers having to stay up late or wake early in the morning to keep in touch with their colleagues on the other side of the Atlantic. But despite this, the collaboration has been a huge success. And most importantly of all, as Marcial notes, "establishing scientific collaborations strengthens the bonds of friendship between institutions and nations."

WHAT DISCOVERIES COULD MUSCAT MAKE?

Historically, very few astronomical observations have been from millimetre waves. However, it is estimated that about half of all the light in the Universe ever emitted by stars has been absorbed by dust and re-emitted at millimetre wavelengths. What have we been missing out on?

For a start, we will be able to see into cold clouds of interstellar dust that absorb the ultraviolet, visible and infrared wavelengths emitted by the stars. These interstellar clouds absorb then re-emit the energy back into space at millimetre wavelengths. Being able to see this radiation will help us to understand more about how very large stars form.

Furthermore, millimetre wavelengths will allow astronomers to see back in time to the earliest galaxies formed after the Big Bang. This is possible because the Universe is expanding like a balloon, meaning the light from the furthest away galaxies is effectively 'stretched', increasing its wavelength into the millimetre range.

In the years to come, hopefully MUSCAT will allow astronomers to answer many of the unanswered questions about the Universe in which we live.

DR SAM ROWE

Cardiff University, UK

DR VÍCTOR GÓMEZ

National Institute of Astrophysics, Optics and Electronics, Mexico

MARCIAL TAPIA

National Institute of Astrophysics, Optics and Electronics, Mexico

FIELD OF RESEARCH

Astronomy Technology

RESEARCH PROJECT

Designing an astronomical camera to measure millimetre wavelength radiation

FUNDERS

Research Councils UK, Consejo Nacional de Ciencia y Tecnología, Newton Fund

ABOUT ASTRONOMY TECHNOLOGY

Our curiosity to solve the mysteries of the night sky and find our place in the Universe has driven some of the greatest inventions in history. Today, building the tools of observational astronomy requires expertise across a wide range of fields, including physics, mechanical engineering, electronics, digital signal processing, software programming and data analysis.

The sense of wonder when looking into the sky is a strong motivation for designing the technology required to do this. "There's something very rewarding about building something that can detect light that has travelled almost halfway across the Universe from some of the most distant and ancient galaxies," says Sam. As Victor comments, "Studying distant sources, from galaxies and star formation to planets and comets, is like taking a look into the past. This is because the light takes millions of years to reach us, so we see the galaxies as they were millions of years ago."

WHY IS ASTRONOMY TECHNOLOGY IMPORTANT?

While we need observations of space to help us understand more about our place within the Universe, the technology developed for astronomy often makes its way back down to Earth to solve problems closer to home. Wireless networks now used in computers were originally developed to sharpen images from astronomical telescopes, and the X-ray technology designed for astronomical observatories is now used to scan your luggage at the airport.

Astronomy is the oldest science, and for centuries, developments in optics and astronomy technology have led to advances in human technology. "Astronomy technology offers an idea of the scope of human ingenuity," says Marcial.

Furthermore, many of the technologies and techniques used to look into space are now being used to observe the Earth, which is more important than ever due to climate change. Satellite images using a range of different wavelengths lead to new discoveries every day about the world's oceans, forests, icecaps and atmosphere.

WHAT ARE THE CHALLENGES IN ASTRONOMY TECHNOLOGY?

The day-to-day challenges of astronomy technology involve designing and building specialist technical equipment to characterise new devices, working at ultra-low temperatures with novel materials and developing computer code for automating tests and measurements. The longer-term challenges are about problem solving – it takes a lot of careful planning, organisation and experimenting to create a new instrument like MUSCAT. In the future, astronomers will aim to build more advanced telescopes with larger arrays of ultra-sensitive detectors, so there will be no lack of technical challenges for the next generation of astronomers, physicists, engineers and computer scientists.

PATHWAY FROM SCHOOL TO ASTRONOMY TECHNOLOGY

- Study STEM subjects at school such as maths, physics and computing. Languages are also useful for working on international collaborations.
- An undergraduate degree in physics or astrophysics would provide a direct route to astronomy technology, but a degree in electronics engineering or computer science could also lead there.
- Attend workshops and summer schools to broaden your knowledge of the field and find out about the opportunities available.
- Most astronomy instrumentation jobs will require a relevant master's or PhD.

MEET SAM

READOUT LEAD
CARDIFF UNIVERSITY

Growing up, I played lots of computer games, watched lots of Star Trek and read lots of books. I loved learning new facts and particularly enjoyed flicking through countless editions of the Guinness Book of World Records. I enjoyed camping with family and friends, and still do, and I always pack a pair of binoculars for a spot of star gazing before relaxing by the campfire.

There were no scientists in my family before me, but my grandfather was a satellite television engineer, and I was always wowed by the high-tech gadgets in his workshop. And my grandmother was a big fan of alien abduction conspiracy stories which definitely engaged my critical thinking skills from a young age.

Spectacular astronomical events were all great sources of inspiration for me – the passing of Comet Hale-Bopp when I was 11, the total solar eclipse when I was 14 and the transit of Venus when I was 18.

I've worked on lots of projects during my career but completing the build of the MUSCAT instrument with such a fantastic team of collaborators is definitely my proudest achievement. Finishing my undergraduate degree and PhD were also proud moments for me, as was seeing Marcial successfully defending his master's thesis on which I was his co-supervisor.

I look forward to helping the team get the instrument installed and running at the telescope so we can start observations and data analysis and hopefully generate some really interesting scientific outputs. Beyond that, my ambition remains to develop more advanced technology and to use it to uncover more facts about our Universe.

MEET VÍCTOR

DETECTOR DESIGN LEAD
NATIONAL INSTITUTE OF ASTROPHYSICS, OPTICS AND ELECTRONICS

As a child, I always liked creating things, especially electronics. I loved knowing you could create great instruments with small devices, as practically all technology depends on electronics.

I have always liked to look at the sky and see the stars and know that they exist beyond our solar system. After finishing my degree in electronics engineering, that was the motivation to do a master's and a PhD in astronomical instrumentation. I focused on the design of detectors, since with these small devices we can create images to observe and study the Universe.

Achieving my PhD and collaborating in this great project have been highlights of my career so far. I have obtained knowledge of detector design and the skills to characterize detectors. These detectors are part of the focal plane array of MUSCAT and I am eagerly waiting for the commissioning at the LMT site to make scientific observations.

One of my ambitions is to be able to design, manufacture and characterize this type of detector at the National Institute of Astrophysics, Optics and Electronics (INAOE) and seek applications both in science and in some other areas.

MEET MARCIAL

ANALYSIS PIPELINE DEVELOPER AND READOUT ENGINEER
NATIONAL INSTITUTE OF ASTROPHYSICS, OPTICS AND ELECTRONICS

I acquired a taste for astronomy from a very young age. I read with great enthusiasm an old book that my father bought in a street market which dealt with mysteries and curiosities of the world and space. There, I read about the dazzling intensity of a quasar capable of blinding the light of the galaxy that hosts it, or about black holes, objects so massive where not even light can escape its gravitational field. Reading it captivated me and instilled in me a taste for astronomy.

Thanks to the influence of my father, I acquired a taste for designing and creating machines in his carpentry workshop, which later led me to study mechatronics engineering.

A decisive event occurred during university when I participated in a scientific summer project at INAOE that allowed me to apply my engineering knowledge in astronomy. The experience of combining two of my greatest passions led me to follow the path of astronomical instrumentation.

Several people influenced me to pursue a scientific career, including my high school physics teacher, Professor Luis Gil, whose way of understanding and transmitting science is inspiring, and my graduate thesis advisor, Dr Abraham Luna, who showed me the possibility of applying engineering to astronomy.

I feel very proud to have obtained a scholarship to study for six months at the Catholic University of Chile, where I studied astronomical instrumentation and met fabulous researchers who reinforced my conviction to follow this path.

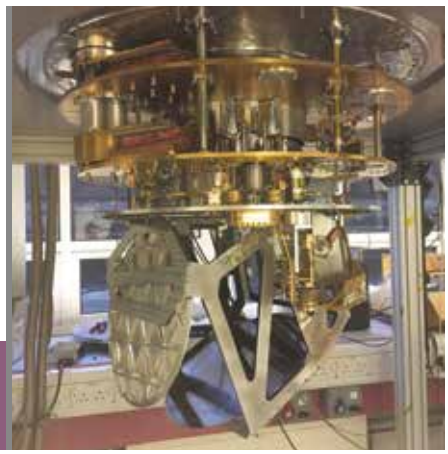
At the moment, my ambitions are focused on successfully completing my doctorate, writing a good thesis and participating in various publications. Then, with all the experience acquired and the team formed in Mexico thanks to MUSCAT, I would like to propose, design and build the next millimetre camera for the LMT.

THE MUSCAT TEAM'S TOP TIPS

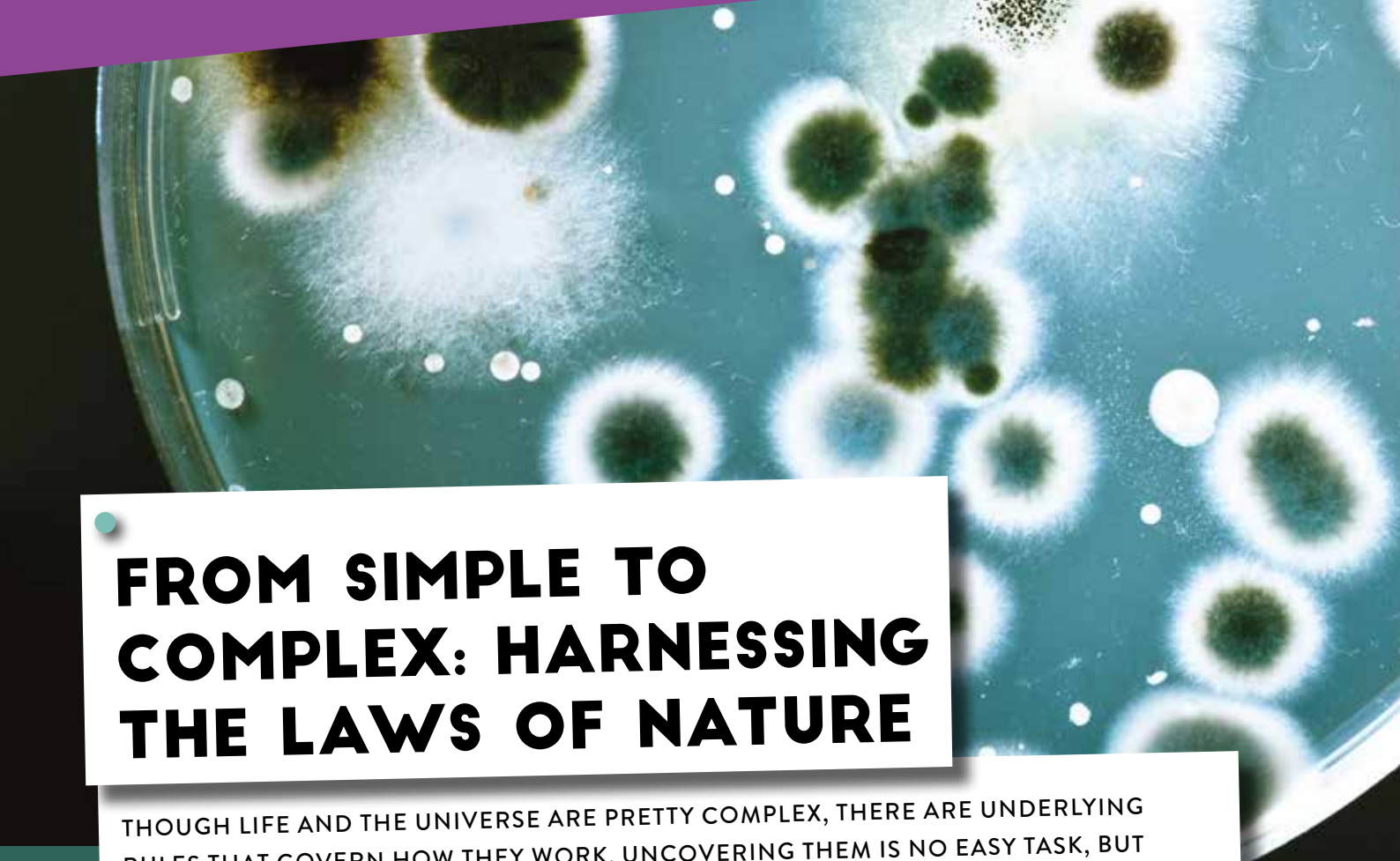
01 There are many aspects to astronomy instrumentation with lots of interesting areas in which to specialise. But it is important to start by developing a strong understanding of basic physical principles.

02 Work hard and never be afraid to ask questions. Remember, there is no such thing as a stupid question – you'll learn much more than if you keep quiet.

03 If you want to study and develop an instrument, try it no matter how difficult it is. It is very rewarding in the end when you succeed!



The interior of MUSCAT without the radiation shields. Light from the telescope comes in through the window at the top (not visible) and passes down through the filter stack in the centre of the camera until it reaches the mirrors at the bottom which direct it onto the detector array. The gold-plated cooling stages, cryogenic refrigerators and mechanical support legs can be seen at the top of the image.



FROM SIMPLE TO COMPLEX: HARNESSING THE LAWS OF NATURE

THOUGH LIFE AND THE UNIVERSE ARE PRETTY COMPLEX, THERE ARE UNDERLYING RULES THAT GOVERN HOW THEY WORK. UNCOVERING THEM IS NO EASY TASK, BUT **DR SERIM ILDAY** AND HER TEAM AT **BILKENT UNIVERSITY** IN TURKEY BELIEVE THEY HAVE CRACKED AN IMPORTANT ONE. USING SIMPLE INGREDIENTS – WATER, POLYSTYRENE BALLS AND AN ULTRA-FAST LASER – THEY HAVE UNCOVERED SOME FASCINATING UNIVERSAL TRUTHS, WHICH HAVE VERY PROMISING REAL-WORLD APPLICATIONS

GLOSSARY

AGGREGATE – when a structure is formed from a mass of individual particles

BROWNIAN MOTION – the random motion of particles suspended in a fluid

COLLOID – a mixture of particles of one substance dispersed through another substance

CRYSTAL – a structure made up of an ordered aggregation of atoms

SELF-ASSEMBLY – when the components of a system organise themselves into a structure or pattern without any external direction

How do simple things become complex? This is a question that has flummoxed scientists for centuries. How do atoms group together to form complicated structures such as crystals or even cells? How do cells group together to become organisms? This concept is known as self-assembly – when the particles involved combine or aggregate into something more complex.

Though we know complexity is built from simple building blocks, knowing how exactly this happens is trickier to decipher. Now, pioneering research from the the National Nanotechnology Research Centre of Bilkent University in Turkey (Bilkent-UNAM) is uncovering these answers, and with some surprising results. Using a deceptively simple apparatus, they have found the physical 'rule' that determines how particles aggregate. The rule applies to particles of many shapes and sizes, which means it stands to become a key physical principle for understanding the world.

COLLOIDS – WHAT ARE THEY?

Dr Serim Ilday has been interested in this area ever since her PhD, which involved manipulating atoms to form a unique nanostructure. It is very difficult to assess what individual atoms are doing when a structure forms, so her team now uses a proxy: polystyrene balls in water. A colloid is a name given to any mixture where one substance is microscopically dispersed through the other. "Our colloid uses artificial 'atoms' (the polystyrene balls), but the physical processes that lead to complex pattern formation follow the same rules," says Serim.

Without any external influence, particles will move randomly within water, moving whichever way they are pushed by the water molecules – a behaviour known as Brownian motion. "For colloids to self-assemble, you need to inject external energy," says Serim. "This has to be delivered at a very precise moment to a very precise area." Her team uses ultra-fast laser pulses, which heat a tiny area of the water. This creates a convection current – the hot water moves to colder areas, and is replaced by colder water – and this flow carries particles along with it. "Think of a wave in the ocean, that drags surfers along with it," says Serim. These particles will collect in the same area and form an aggregate.

Once these particles begin to aggregate, a positive feedback loop forms. "When you pack spheres, you end up having voids between them, which slows down the water flow," says Serim. "However, water is still flowing fast towards the aggregate, so will quickly carry more particles close to the

aggregate, which the particles will join as soon as the flow slows." In this way, the aggregate grows larger and larger, though the effects of Brownian motion will be stripping it of particles at the same time. "By accounting for these effects, we can manipulate the distances between colloids, creating a large variety of patterns and crystals," says Serim.

WHY THIS IS IMPORTANT

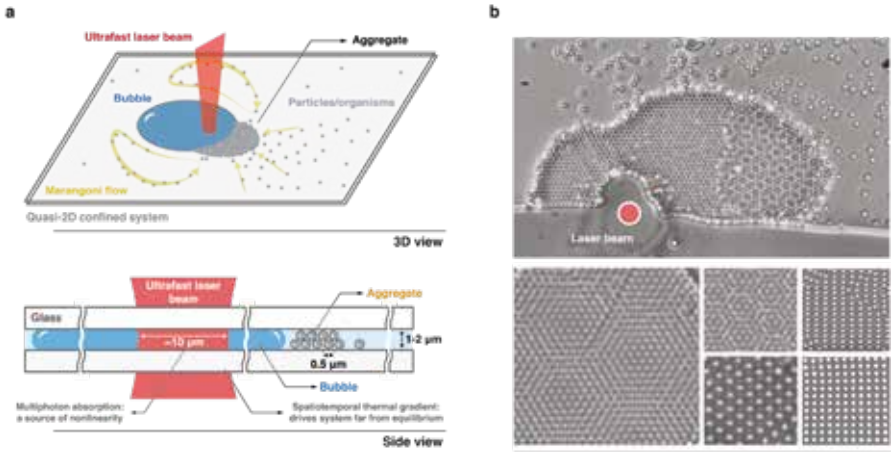
The team's reliance upon physical rather than chemical processes is the key to why their results are so widely relevant. "Self-assembly research has tended to rely upon chemistry," says Serim. "Colloids were usually decorated with materials sensitive to magnetic, electric or light fields, and placed in complex chemical mixtures. I needed a simpler system, where everything that happens only resulted from the system's internal dynamics, not because someone engineered them." Her polystyrene-water mixture does exactly this – no chemical interactions are taking place, so they can be sure the behaviour they see is down to internal processes.

"Our system is unique because it's purely physical," says Serim. "This means we can quantify and mathematically formulate how it works, and this can be generalised to other systems – as diverse as economics, ecology or sociology." Serim believes the system lays a cornerstone for uncovering the 'physics of life'. This is a decades-old idea that all living systems can be broken down into physical and mathematical processes, but while theoretically accepted, it has been very challenging to pin down these processes – until, perhaps, now. It is unusual for the results of an experiment to be applicable to so many different systems, at so many different scales, which is why the team's results have sent ripples through the scientific community.

IN THE REAL WORLD

"Physical forces are universal and apply to everything, living and non-living," says Serim. Her team has even used their techniques on nanoparticles, which follow the rules of quantum physics, forming new crystalline structures. These structures could have unique properties that are potentially useful for all manner of real-world applications. And that is not all – at the other end of the size spectrum, the team's techniques work for living things, too. "In our system, we can use the same method to collect living bacteria, yeast or human cells, and move them around in whatever way we want – even putting them into shapes, like stars or rectangles."

This could bring big benefits for medicine. If a patient is suffering from an unusual disease, it can be time-consuming to work out which treatment to use. This is largely due to the necessity of growing – or 'culturing' – a population of the pathogens from a sample, so the scientists have enough pathogen cells to see what they respond to. But Serim's system could be used to make the pathogens in a sample all gather in one place and force them to intake a particular drug. This could mean that no culture time is needed, because scientists can get a substantial sample size just by using physical forces to gather the microbes together. Serim concludes: "This method in its current form cannot replace common practices, but over time, it could be developed and optimised until it's an effective healthcare tool."



a) Sketches of the experimental setting, where colloids are quasi-2D confined and driven by the laser induced flows. b) Microscopy images showing various patterns formed spontaneously by 500-nm polystyrene spheres. Top: Spheres form a honeycomb lattice in the left of the image and a quasicrystal in the right. Small images on the right, from top left to bottom right: A Moire pattern with a small unit cell, a rectangular lattice, a centered rectangular lattice, a square lattice.

DR SERIM ILDAY

Assistant Professor
National Nanotechnology Research Center (UNAM) and Institute of Materials Science and Nanotechnology, Bilkent University, Turkey

FIELDS OF RESEARCH

Physics, Materials Science, Nanotechnology

RESEARCH PROJECT

Using simple physical models to reveal fundamental rules of self-assembly applicable across many different systems

FUNDERS

European Research Council, The Scientific and Technological Research Council of Turkey

ABOUT PHYSICS

Serim's background is in physics, although her work also relates to materials science and nanotechnology. Physics is the study of energy, forces, mechanics, waves and the structure of atoms and the physical universe. The word 'physics' comes from ancient Greek and means 'knowledge of nature'. Given that physicists can tackle a range of problems from cancer treatment to climate change and artificial intelligence, a career in physics will put you on the frontline. We ask Serim about the wonderful world of physics.

WOULD YOU RECOMMEND A CAREER IN PHYSICS?

Absolutely. Physics education teaches people to think outside the box, and gives them profound observational and analytical skills. You'll understand that there are simple yet elegant physical explanations to the world around you: How trees branch, why the sky is blue, how flocks of birds make decisions – these questions are just a few examples. A physics understanding fosters problem-solving and decision-making, which will make you ideal candidates for a variety of jobs, from academia to positions in the public or private sectors, plus exciting and innovative fields such as robotics and data science.

WHAT ARE SOME EXCITING EMERGING FIELDS OF PHYSICS?

Recently, subjects such as complex systems, biophysics, dark energy and matter, artificial intelligence and quantum computing have gained much interest. Within the next few years, I believe each of these will expand the limits of our understanding of the universe, the capabilities of technology, and our knowledge of ourselves. I recommend reading popular science books on these topics and visiting websites of publications such as *Quanta Magazine* or *Physics World*.

HOW CAN STUDENTS WITH AN INTEREST IN PHYSICS FIND OUT MORE?

Many universities and research institutes have outreach programmes. Here in Turkey, we encourage the younger generation to visit our labs and talk to us, and we visit schools and teach students about ideas in physics through games and short presentations. For anyone interested in complex systems, statistical physics or biophysics, you are welcome to contact me or my research group for help or advice.

EXPLORE A CAREER IN PHYSICS

- Many universities and research centres around the world run outreach activities, which can be an excellent way to get a taste of a particular subject or field. For instance, the Konya Science Center in Turkey ran an interactive introduction to nanotechnology.
- National and international organisations run outreach programmes for physics. For instance, the American Physical Society has a wide range of events and resources for schools: **www.aps.org/programs/outreach/index.cfm**
- Salaries for physicists can vary widely. According to SalaryExpert, the average physicist salary in state universities Turkey is 123,000 ₺ (£11,000). This is about four times the average salary in Turkey. Salaries in private universities are even higher.

PATHWAY FROM SCHOOL TO PHYSICS

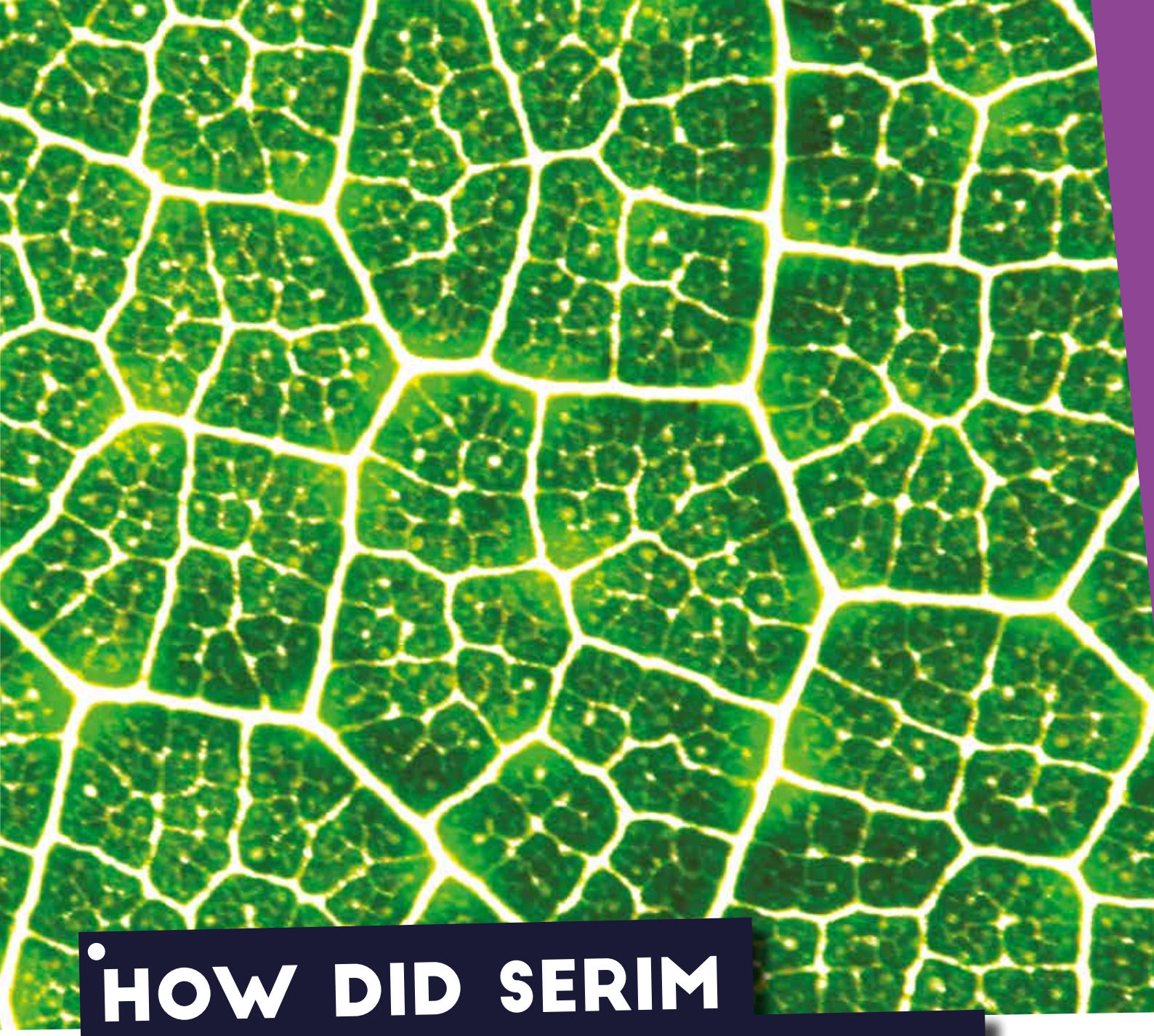
An undergraduate degree in physics requires a robust knowledge of physics and mathematics, while biology, chemistry and computer science can also be highly useful. Courses in materials science and nanotechnology usually have similar requirements. It is always worth checking the requirements of courses that might interest you before selecting subjects to study.

SERIM'S TOP TIPS

01 Read widely. This will help open your mind to diverse ideas and different perspectives, broadening your horizons. Discuss the things you learn with others and listen to their approaches to understanding concepts. In addition, write down your own ideas to rationalise them – what are their weaknesses and strengths?

02 If you can, visit scientists in the lab. They will often be eager to talk about their research and offer learning opportunities for you.

03 Never give up. Failures teach us the most and are precious to a scientist. They will teach you to identify and correct your mistakes, and nothing is more satisfying than discovering something important that nobody else yet knows!



HOW DID SERIM BECOME A PHYSICIST?

DID YOU ALWAYS WANT TO BECOME A SCIENTIST?

Yes! When I was a child, my best friend was a screwdriver – it helped me investigate the insides of the TV, radio, torch, iron, you name it. I also remember reading about the fantastic inventions of great scientists, though feeling pretty desperate that it seemed they had left nothing more to discover!

WHAT INSPIRED YOU TO GET INTO PHYSICS?

I wanted to understand the world around me. I trained in chemistry and maintained an interest in biology and engineering, which all taught me to pay attention to minute details, perform careful experiments, and practise laboratory skills. However, physics taught me to look at the world from a broader perspective and connect the dots between different ideas.

HOW DID YOU MOVE INTO NANOTECHNOLOGY?

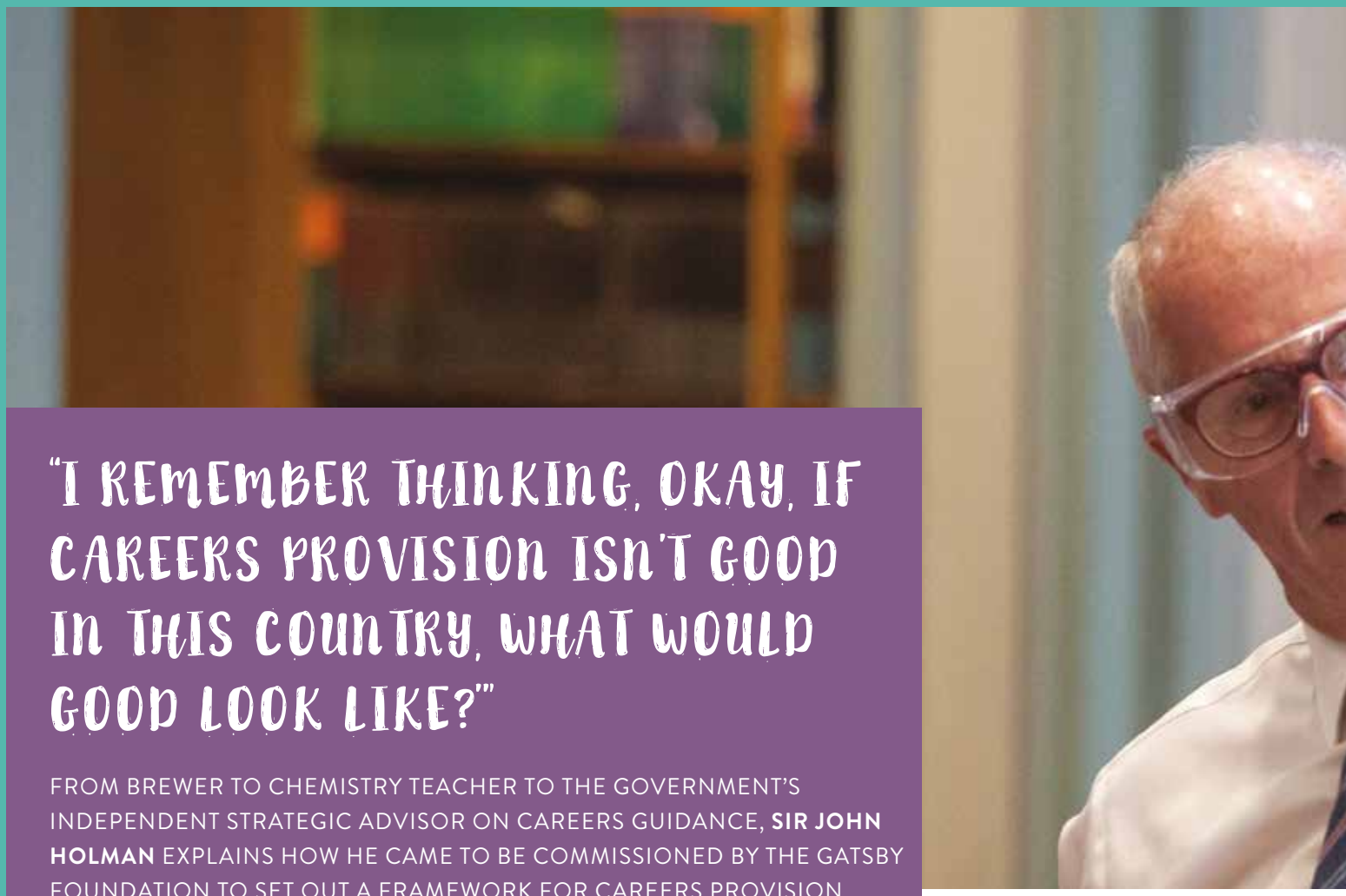
Nanotechnology was an emerging and thrilling research field when I was studying chemistry at university. Naturally, I wanted to know more about it and understood that I should first study materials science and physics, which I did during my PhD. At this time, I discovered a brand new nanostructure with unusual electrical and optical properties.

YOU ARE THE RECIPIENT OF SEVERAL AWARDS, INCLUDING THE L'OREAL-UNESCO AWARD FOR WOMEN IN SCIENCE. DOES THIS RECOGNITION HELP DRIVE YOU?

Curiosity is my main driving force, but recognition certainly does help fuel my work. They confirm how important our work is to the scientific community and the wider world. I also take great joy in seeing the ideas that exhilarate me resonate with others.

WHAT DO YOU LIKE TO DO OUTSIDE OF WORK?

I like to spend time with my family, and walking provides me with time to think and plan. I also read a lot!



"I REMEMBER THINKING, OKAY, IF CAREERS PROVISION ISN'T GOOD IN THIS COUNTRY, WHAT WOULD GOOD LOOK LIKE?'"

FROM BREWER TO CHEMISTRY TEACHER TO THE GOVERNMENT'S INDEPENDENT STRATEGIC ADVISOR ON CAREERS GUIDANCE, **SIR JOHN HOLMAN** EXPLAINS HOW HE CAME TO BE COMMISSIONED BY THE GATSBY FOUNDATION TO SET OUT A FRAMEWORK FOR CAREERS PROVISION

YOU STUDIED NATURAL SCIENCES AT THE UNIVERSITY OF CAMBRIDGE AND YET YOU HAVE BEEN KNIGHTED FOR YOUR SERVICES TO EDUCATION. WHY DID YOU VEER TOWARDS TEACHING AFTER GRADUATING?

As sometimes does happen with teaching, I didn't really go into to it as my first choice, but it soon became my preference. I'm very interested in the science of food and drink and I had a job lined up with a brewery. They were going to train me with a master's in brewing technology, but I woke up one morning and thought, 'I don't want to be a brewer'. It was one of those situations where I hadn't reflected enough on the reality of what I was getting into.

I had done a little bit of teaching at school, and I quite liked it, so I went to the university careers office and asked them if they had any teaching jobs. They had a position for a chemistry teacher at an independent boarding school. I found straight away that I really enjoyed it.

YOU SAY THAT IF YOU HAD YOUR TIME AGAIN, YOU WOULD HAVE PREFERRED TO START YOUR TEACHING CAREER AT A REGULAR COMPREHENSIVE. WHY?

One of things I like about being involved in education, is that you feel you're doing good for people and you're helping people. I'd just rather help people who need more help. It's a feeling a lot of people have who decided to go into state schools rather than independent schools. I don't have a deep antipathy towards independent schools, it's just that I wish that all the state schools were so good that independent schools didn't exist.

YOU HAVE TAUGHT LEARNERS OF CHEMISTRY AND SCIENCE AT ALL LEVELS FROM 11-YEAR-OLDS TO UNDERGRADUATES, AS WELL AS CREATED CURRICULA AND WRITTEN BOOKS FOR STUDENTS. IS THERE AN APPROACH TO TEACHING THAT HAS SERVED YOU WELL AS AN EDUCATOR?

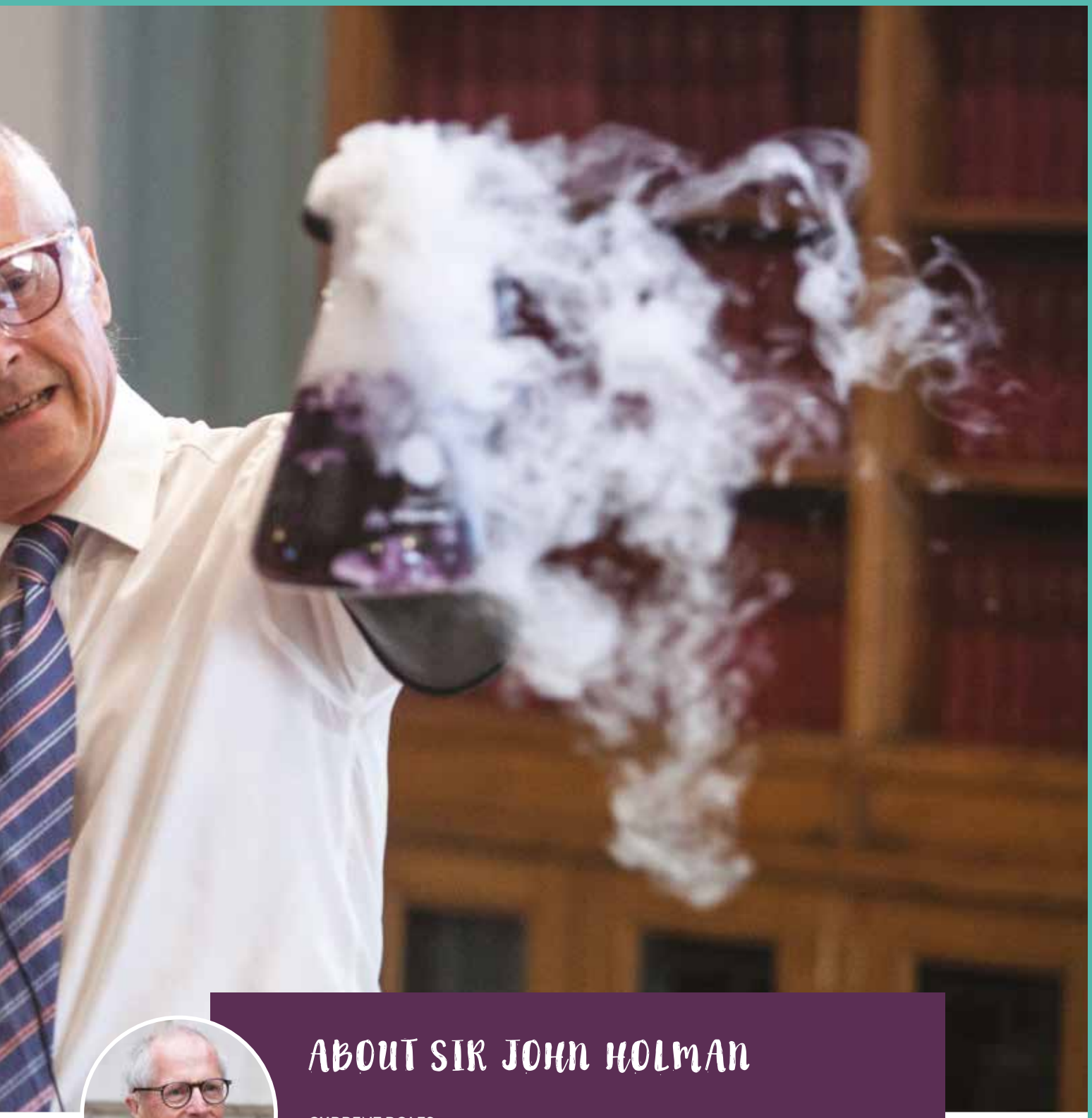
I've always found that relating science to society and the applications of science gets people sitting up and interested. Showing science in context is the way to do it. In fact, the first chemistry book I wrote was called *Chemistry in Context*, which sums up the approach, really.

Then there's experimental work, which is the essence of science. Teaching science without experiments is like trying to teach literature without books. I've always made sure that experimental work plays a big part in all my teaching.

HOW DID YOU COME TO WORK WITH THE GATSBY FOUNDATION?

From 2006 to 2010, I was the National STEM Director for the UK Government's Department for Education. My mission was to find ways to get more people studying STEM subjects, particularly a more diverse range of young people. The Gatsby Foundation and its founder, Lord David Sainsbury, were also interested in this question, and it soon became clear that careers guidance was an important part of answering that.

At around 2013, there was a lot of criticism of careers guidance, from the House of Commons Education Select Committee and OFSTED (the Office for Standards in Education), and I remember thinking, 'Okay, if careers provision isn't good in this country, what would good look like?' That was the starting point of the international study I did for Gatsby.



ABOUT SIR JOHN HOLMAN

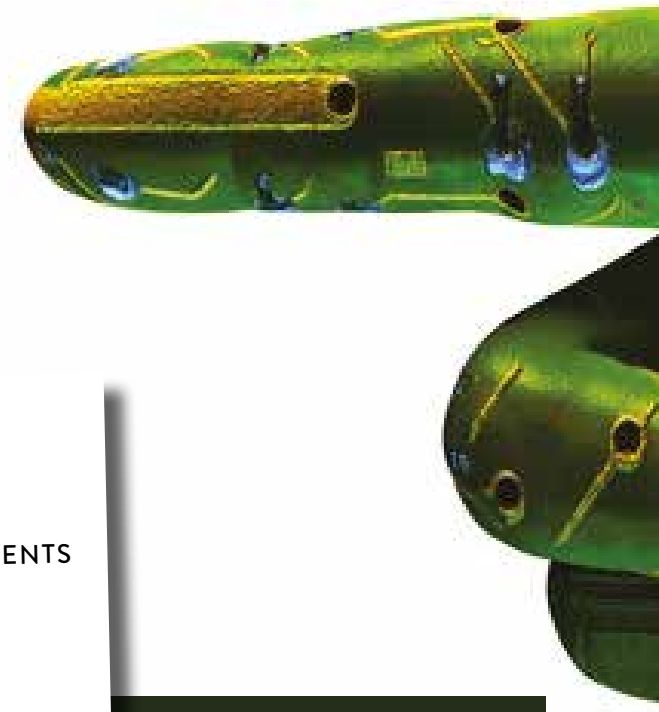
CURRENT ROLES:

Independent Strategic Adviser on Careers Guidance to the Secretary of State for Education
President, Association for Science Education
Senior Adviser in Education, Gatsby Foundation
Adviser, Wolfson Foundation
Chair, UKRI Talent Commission
Chair, The Bridge Group
Professor Emeritus of Chemistry, University of York

FORMER ROLES:

President, Royal Society of Chemistry
Founding Director, National Science Learning Centre
UK Government's National Science, Technology, Engineering and Mathematics (STEM) Director
Headteacher, Watford Grammar School for Boys
Salters' Professor of Chemical Education, University of York

WHAT IF ELECTRICAL STIMULATION COULD TREAT PHANTOM LIMB PAIN?



MOST PEOPLE WHO HAVE HAD A LIMB AMPUTATED WILL EXPERIENCE SOME FORM OF PHANTOM LIMB PAIN. UNFORTUNATELY, CURRENTLY AVAILABLE DRUG TREATMENTS HAVE VARYING SUCCESS. **DR KATHARINE POLASEK**, AT **HOPE COLLEGE** IN THE US, IS INVESTIGATING WAYS TO USE ELECTRICAL STIMULATION TO TREAT THIS PAINFUL PHENOMENON

TALK LIKE A NEURAL ENGINEER

AMPUTATION – the surgical removal of part of the body, such as an arm or leg

CENTRAL NERVOUS SYSTEM – consisting of the brain and spinal cord

EEG – abbreviation of electroencephalogram, which is a recording of brain activity using a special machine. Small sensors are attached to the scalp to pick up the electrical signals produced when brain cells send messages to each other

ELECTRODE – a small piece of metal or other substance that is used to take an electric current to or from a source of power, a piece of equipment, or a living body

NEUROPLASTICITY – the ability of the brain to form and re-organise synaptic connections, especially in response to learning, experiences or following injury

PERIPHERAL NERVOUS SYSTEM – consisting mainly of nerves, which are enclosed bundles of fibres connecting the central nervous system to every part of the body

REFERRED SENSATIONS – sensations felt in parts of the body far away from the site receiving the electrical stimulation

SOMATOSENSORY SYSTEM – the part of the sensory system concerned with the perception of sensations such as touch, pain, pressure and vibration

SURFACE ELECTRICAL STIMULATION (SES) – a non-invasive method of electrical stimulation which involves placing electrodes on the skin

Imagine losing your left arm, but months later you experience pain in your left hand, even though it is no longer there. This is known as phantom limb pain, the painful sensations amputees feel in their missing limbs. Even though the word 'phantom' might suggest otherwise, phantom limb pain is a very real and painful phenomenon, often described as throbbing, burning or stabbing in the part of the body that has been removed. It usually starts soon after the amputation surgery, and its duration and intensity vary from person to person.

Phantom limb pain is estimated to affect up to 80 percent of amputees and can be a long-term problem, so it is essential to find ways of managing and treating the pain. Unfortunately, finding a treatment to relieve phantom limb pain can be difficult, and there are no medications that are specifically aimed at this condition.

Dr Katharine (Katie) Polasek is an associate professor of engineering at Hope College in the US. Katie and her team are using their engineering skills to find innovative ways to relieve phantom limb pain.

WHAT CAUSES PHANTOM LIMB PAIN?

Scientists are still not certain about the exact mechanisms behind phantom limb pain, despite extensive research into the topic. It is most likely due to the brain and spinal cord continuing to send signals down to the nerves of the missing limb. However, no neural signals return and so the brain gets confused. It could be that the pathway (nerve to spinal cord to brain) that used to connect to the missing limb sends signals randomly, which causes confusion in the brain that is interpreted as pain.

"Some people have shown changes in their brain after an amputation where the area of the brain that used to connect to the amputated limb now responds to another nearby body location. For example, if you

Credit: Jon Lundstrom

DR KATHARINE POLASEK

Associate Professor of Engineering
Hope College, USA

FIELD OF RESEARCH

Neural Engineering

RESEARCH PROJECT

Treating phantom limb pain with electrically-induced somatosensation

FUNDER

National Science Foundation

touch their face, a person with an amputated hand may feel the touch in their face *and* in their phantom hand," says Katie. "It's not clear if this is a cause of phantom limb pain, but people who have more of this overlap often have pain."

HOW IS PHANTOM LIMB PAIN CURRENTLY TREATED?

Current treatments for this condition have varying levels of success and do not directly address the neural changes mentioned above. Drugs for nerve pain are commonly prescribed to mask the pain, but these are covering up the issue rather than solving it and can have many negative side effects. Other options include acupuncture, massage and distraction techniques, but again, none of these really address the root of the problem.

HOW CAN ELECTRICAL STIMULATION BE USED AS A TREATMENT METHOD?

When small electric currents are passed through our skin, they activate sensors within the skin, producing a buzzing or tingly sensation that we can feel. This sending of electric currents is known as electrical stimulation. Sometimes electrical stimulation is used to turn on muscles after an injury in an athlete or to help people who are paralysed perform tasks such as grasping a fork or holding a toothbrush. It can also be used to evoke referred sensations, where the sensation is felt away from the site of stimulation. For example, Katie can place electrodes by someone's elbow and use electrical currents to turn on fibres in the median nerve near the electrodes. The signal then travels up to the brain where it is interpreted. "If we activate the right fibres in the right way, we can make it feel like someone is tapping your hand!" says Katie.

The aim of these surface electrical stimulations is to give individuals with amputated limbs the very real impression that a non-painful sensation is happening in the missing body part. This is achieved by activating nerve fibres that used to come from the missing hand or foot, which Katie believes may help counteract phantom limb pain. "We think that allowing amputees to feel non-painful sensations in their phantom hand will reduce or eliminate phantom limb pain," she explains.

HOW FAR IS THE TEAM INTO THIS RESEARCH?

Having investigated effective ways to activate referred sensations, Katie's team carried out further investigations to find out how to best evoke a 'natural' sensation in subjects with an amputation. They stimulated different areas of the skin at different frequencies and asked the subjects questions about what they felt.

Katie and her team have successfully developed a technique to electrically stimulate on the skin at the elbow or knee, but for the participant to feel the sensation in their hand or foot. This occurs in people both with and without amputations.

The team is aiming to evoke a 'natural' sensation, meaning that the sensation felt by the amputee matches a common feeling. A tap on the skin is a good example, says Katie. "It's very common to feel a tingling sensation or pins and needles due to electrical stimulation, however it's hard to do something to someone that looks like pins and needles. We don't like it when our sensations don't match! Tapping is something that I can do on someone's hand or prosthesis as part of the therapy".

The researchers are investigating what happens in the brain when an amputee experiences an actual touch versus an electrically stimulated touch. So far, they have studied the brain by looking at EEG signals in people without amputations to see how they respond to different types of touch. Katie's team is working to make the referred sensation as realistic as possible. After this, the researchers will begin testing their electrical stimulation therapy on people with amputations, recording their brain signals during therapy and seeing whether their brain begins to respond differently. This will help us learn more about the causes of phantom limb pain.

WHAT ARE THE FUTURE IMPLICATIONS OF USING ELECTRIC CURRENTS TO TREAT PHANTOM LIMB PAIN?

Katie hopes that her work will lead to customised therapies for phantom limb pain. She also aims to develop a tool for patients to use at home, making it far easier for people to access treatment. "I would hope that we can provide an inexpensive, at-home treatment for people suffering from phantom limb pain to do on their own. I would like the therapy to be effective and maybe a little fun, so that people will actually do it," she says.

Moreover, by exploring ways to tap into our nervous system and target pain without invasive treatment or drugs, this research could pave the way for therapies for many other neurological conditions.

ABOUT NEURAL ENGINEERING

Did you know that fully functional bionic arms that respond to signals from the brain have been developed for amputees? The user only has to think about moving their hand, and signals from the brain will be detected by electrodes in the bionic arm, causing it to move! This life-changing invention is all due to the work of neural engineers.

Neural engineering is a discipline within biomedical engineering. It focuses on using engineering techniques and skills to understand, interface with and manipulate the nervous system. Neural engineers are interested in understanding how the brain functions, and often create computer models of neural systems to better understand them and how they interact.

WHY DO WE NEED NEURAL ENGINEERS?

Neural engineers are essential for many medical-related technologies and therapies. They might design heart devices such as pacemakers or defibrillators, or develop brain devices to help people with Parkinson's disease or epilepsy, or work on therapies to help people who have suffered from a stroke or spinal cord injury.

DOES KATIE RECOMMEND A CAREER IN NEURAL ENGINEERING?

"Neural engineering is a pretty narrow field, but I love learning about how the different parts of the body communicate and work together to allow us to do all of the amazing things that we can do," she says. "As a neural engineer, I have to understand what the body is doing so that I can use my engineering skills to restore function that has been lost, or take pain away."

EXPLORE A CAREER IN NEURAL ENGINEERING

- You can read more about neural engineering on the IEEE Engineering in Medicine & Biology Society website: **www.embs.org/about-biomedical-engineering/our-areas-of-research/neural-engineering/**
- The Royal Academy of Engineering also has a handy guide: **www.raeng.org.uk/publications/reports/neural-engineering-briefing**
- Neural engineering is a specialised field, so it is useful to read up on the more general field of biomedical engineering. UCAS provides a great summary: **www.ucas.com/ucas/after-gcses/find-career-ideas/explore-jobs/job-profile/biomedical-engineer**
- Practical experience is a good way to find out whether neural engineering, biomedical engineering or engineering in general is the career for you. Hope College hosts ExploreHope which, as Katie says, "runs awesome engineering camps for older kids." Research the engineering departments of universities near you to see if they hold similar camps or outreach activities for schools and students.
- Katie recommends finding a neural engineer and shadowing them, if possible. "Once you get to engineering school, apply for an internship or research experience so that you can start doing real science and/or engineering," she says. "The best way to know if you like something is to try it out!"
- According to Indeed, the average salary for a neural engineer in the US ranges from $91,000 - $150,000, though this will vary depending on your qualifications and whether you work for a company or at a university.

PATHWAY FROM SCHOOL TO NEURAL ENGINEERING

Maths is essential for all forms of engineering. In addition, Katie suggests learning electrical engineering concepts and computer programming. Katie took other science courses about the human body and her favourites were in anatomy and physiology.

KATIE'S TOP TIPS

01 Don't expect getting into a specific career to be a straight path, and don't worry if you're not sure what you want to do.

02 At each stage in your career, make the best decision for you at that time. It's good to have a long-term plan but life often doesn't work out exactly as you planned!

Computer modelling and writing computer code to collect and analyse data are big parts of this neural engineering research project. Credit: Steven Herppich

HOW DID KATIE BECOME A NEURAL ENGINEER?

WHAT WERE YOUR INTERESTS WHEN YOU WERE YOUNGER?

As a child, I always loved to let my imagination take over, using toys and dolls to create new worlds, and I have many happy memories of playing with siblings and friends that way. I loved reading fantasy books, especially those of Madeline L'Engle. As I grew older, I enjoyed playing piano and trombone, and running track and cross-country. I've also loved jigsaw puzzles all of my life.

DID YOU ALWAYS KNOW YOU WANTED TO BE AN ENGINEER?

My father is a civil engineer, so I was exposed to engineering at a young age. I didn't really have an interest in designing bridges or cars, so I didn't plan on becoming an engineer initially. When I was four, I wanted to be a monkey doctor. This progressed to baby doctor, then veterinarian, so I guess I was mostly focused on the medical field. It was in my junior year at high school that I first heard about biomedical engineering, and it sounded perfect for someone like me who was definitely interested in how the body worked but also liked math and solving problems.

YOU HAVE A BSE IN MECHANICAL ENGINEERING AND A PHD IN BIOMEDICAL ENGINEERING. WHY DOES BIOMEDICAL ENGINEERING FASCINATE YOU?

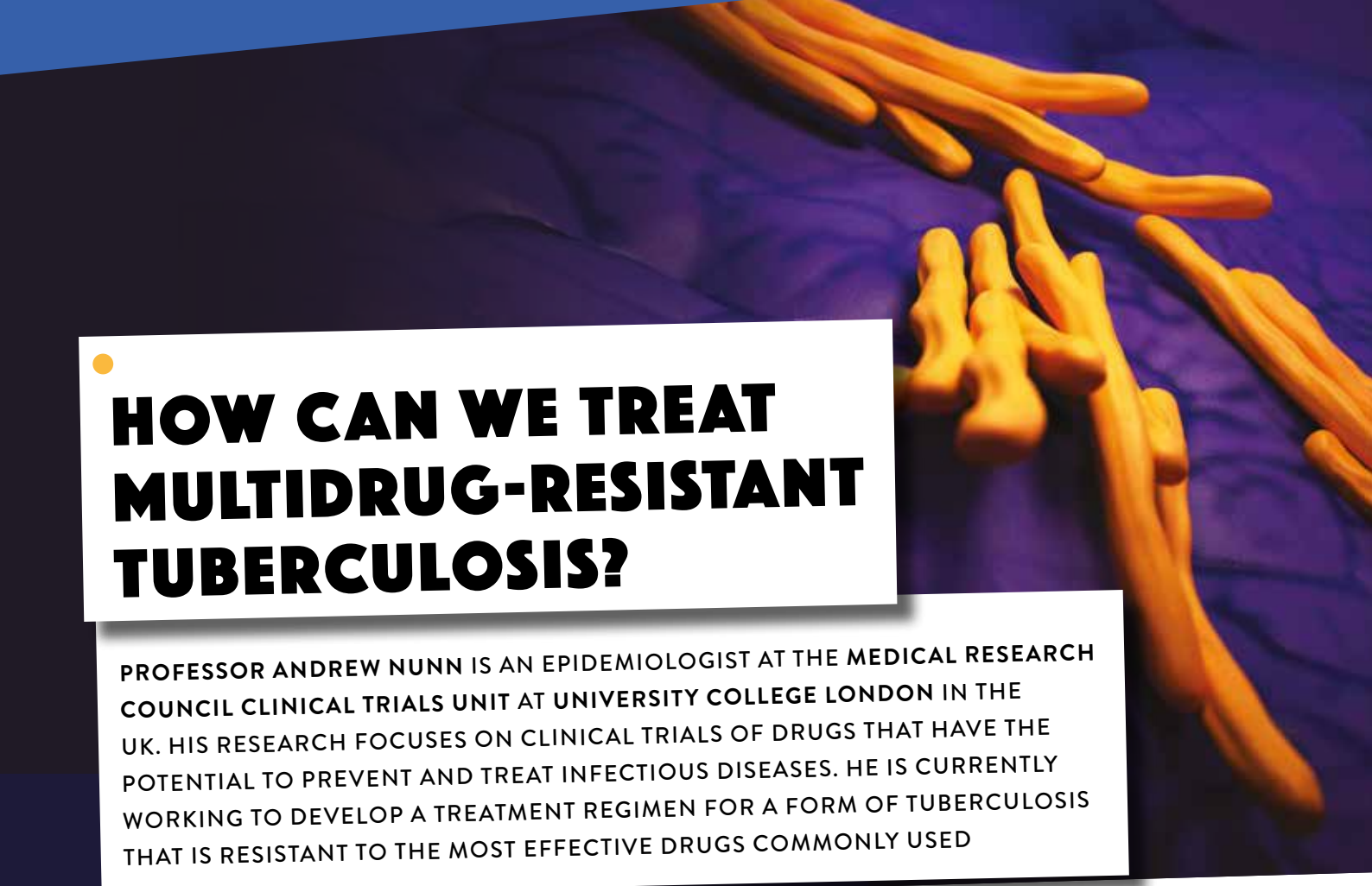
When I was in high school, I remember being fascinated with how muscles produced movement. My favourite muscle was the zygomaticus major – the smiling muscle! In my anatomy and physiology class, I learned the secrets to how muscles contract and create complex movements. Once I started studying engineering, I wanted to learn more.

HOW WOULD YOU DESCRIBE YOURSELF?

I like to solve problems and am very practical and hands-on. I have trouble visualising things that people tell me verbally, so I like to see the problem or draw it, based on a description. Seeing the problem helps me to find a solution.

WHAT DO YOU ENJOY OUTSIDE OF RESEARCH?

I love my work but I also love coming home at the end of the day to my husband Greg and my three boys, Isaac, Teddy and Sam. We also have two dogs and two cats who are always available for pets and snuggles. For my hobbies, I still keep up with running and playing the trombone but I added hockey as an interest when I was in graduate school. Hockey is fun and social, and a great way to exhaust myself and be part of a team.



HOW CAN WE TREAT MULTIDRUG-RESISTANT TUBERCULOSIS?

PROFESSOR ANDREW NUNN IS AN EPIDEMIOLOGIST AT THE **MEDICAL RESEARCH COUNCIL CLINICAL TRIALS UNIT** AT **UNIVERSITY COLLEGE LONDON** IN THE UK. HIS RESEARCH FOCUSES ON CLINICAL TRIALS OF DRUGS THAT HAVE THE POTENTIAL TO PREVENT AND TREAT INFECTIOUS DISEASES. HE IS CURRENTLY WORKING TO DEVELOP A TREATMENT REGIMEN FOR A FORM OF TUBERCULOSIS THAT IS RESISTANT TO THE MOST EFFECTIVE DRUGS COMMONLY USED

TALK LIKE AN EPIDEMIOLOGIST

TUBERCULOSIS (TB) – an infectious bacterial disease that most commonly affects the lungs but can affect any part of the body

DRUG REGIMEN – a prescribed systematic treatment for a course of drugs

DRUG RESISTANCE – the ability of disease-producing pathogens to survive the effects of drugs that would usually kill them

EFFICACY – the ability of a drug to produce the desired effect in a clinical trial setting

EFFECTIVENESS – the extent to which a drug is effective under real-world conditions

ADHERENCE – the degree to which a patient follows the treatment regimen prescribed to them by a healthcare professional

ADVERSE EFFECTS – medical problems that occur whilst a patient is receiving treatment

REPRODUCIBILITY – the ability to produce the same results if a study or experiment is repeated

GENERALISABILITY – the extent to which findings from a study can be applied to other settings

SUPERIORITY TRIAL – a randomised trial designed to assess whether a new treatment or intervention is more effective than another

NON-INFERIORITY TRIAL – a randomised trial designed to assess whether a new treatment or intervention is not much worse when compared to a standard treatment or care

It is estimated that approximately 10 million people currently have tuberculosis (TB) worldwide, with more patients dying from TB each year than from any other infectious disease. Approximately 5% of people with TB have a form of the disease that is resistant to rifampicin, one of the most effective and commonly used drugs used for treatment. Most of these patients also have resistance to isoniazid, another important drug used for treating TB. Based at University College London, Professor Andrew Nunn's research aims to develop an effective regimen to treat patients with drug-resistant TB and thereby reduce its spread.

Before the 1970s, treatment of tuberculosis involved a course of at least three drugs given for a minimum of 18 months. "The results under programme conditions were often poor due to adverse effects and poor adherence to treatment," explains Andrew. In the mid-1960s, a new drug called rifampicin was discovered. "Results from laboratory studies were very promising and the research group I was working with proposed a radical departure from standard treatment, treating patients for only six months with a rifampicin-containing regimen," he says. After positive results in a series of trials, this treatment became standard throughout the world.

MULTIDRUG-RESISTANT TUBERCULOSIS

However, not all patients were treated successfully on this new regimen. Some treatments failed due to poor adherence and resistance developed to drugs in the regimen. Over time, people with drug-resistant TB infected people they were in contact with, adding to the number of patients with drug-resistant TB. Multidrug-resistant tuberculosis (MDR-TB) is the name given to the form of TB that is resistant to the two most effective anti-TB drugs, rifampicin and isoniazid.

Studies conducted in the 1970s and 80s showed that patients with no evidence of drug resistance could be treated effectively with the six-month regimen, provided they adhered to treatment. However, those with rifampicin resistance had poor outcomes, even if they had no evidence of resistance to any other drugs.

"Because 95% of patients with TB have drug-susceptible disease, for many years the focus of research was on this very large patient group. Little attention was paid to patients with rifampicin-resistant TB," explains Andrew.

TREATMENT

The World Health Organization (WHO) collects information on the number of TB cases and treatment outcomes in each country on an annual basis. "For many years, these results have shown that outcomes for patients with rifampicin-resistant TB were very poor, only about 50% achieving a cure or even completing their treatment," says Andrew. Often, those treated unsuccessfully went on to infect other people with rifampicin-resistant TB, and many died from their disease. If treatment is ineffective, the spread of the disease accelerates, thereby infecting an increasing proportion of the population.

"Unlike HIV, there has never been a sustained programme of research to develop new drugs for TB," explains Andrew. The development of TB drugs has been very slow – it took 50 years between the discovery of rifampicin and the licensing of the next new TB drug. "The main reason for this is that TB is predominantly, although by no means exclusively, a disease affecting low- and middle-income countries," adds Andrew.

For patients with rifampicin-resistant TB, the treatment options are even more limited. Until recently, the regimen recommended by the WHO involved treatment for 20 or more months. "Adherence to long regimens is poor and the drugs often have unpleasant side effects which further reduces the effectiveness of the regimen," explains Andrew.

NEW REGIMENS

Much of Andrew's work involves a large-scale, multi-country clinical trial called the STREAM trial (The Evaluation of a Standard Treatment Regimen of Anti-Tuberculosis Drugs for Patients with MDR-TB). The STREAM trial started in 2012 with the objective of evaluating a nine-month regimen which had been developed from a series of cohort studies conducted in Bangladesh and had shown very promising results. Although this regimen had the potential to be a considerable improvement on the WHO-recommended regimen, it had not been assessed in a randomised trial and there were concerns about its reproducibility and generalisability.

In STREAM, patients were randomised to receive the nine-month regimen or the longer WHO regimen. At the time the trial was started in 2012, there were an estimated 450,000 cases of MDR-TB worldwide. Less than a quarter of these were estimated to have been detected, and fewer still were treated.

Clinical trials in TB often build on the work of previous studies, as in the case of STREAM. The process can take a long time due to the length of the treatment regimen and the need to follow patients after treatment has been completed to establish whether those who are cured remain disease free and do not relapse and need retreatment. To assess whether results are generalisable, they need to be conducted in a variety of settings.

SELECTING DRUGS FOR THE REGIMEN

"The nine-month regimens used in the STREAM trial and the Bangladesh study target maximum effectiveness rather than efficacy," explains Andrew. Some drugs considered to have reasonable efficacy may not be effective in real world settings because they are known to be toxic or poorly tolerated; these were not included in the regimen. Doses were chosen to achieve maximum effectiveness. A higher than usual dose of moxifloxacin was used in this regimen to assist in preventing further drug-resistance. As moxifloxacin is known to increase the risk of QT prolongation, a heart rhythm condition that can potentially lead to fainting, palpitations, and, in exceptional cases, sudden death, safety monitoring for QT prolongation was done as an essential part of the trial. Clofazimine, a drug that is used for treating leprosy, was included in the regimen as it had shown potential as a TB treatment in laboratory studies.

THE STREAM TRIAL

424 patients from seven sites in four countries – Ethiopia, Mongolia, Vietnam and South Africa – were enrolled in the first stage of the trial. Patients had to attend the study clinic every four weeks for two and a half years for treatment and follow-up appointments. Sputum samples were collected on each occasion to assess for possible treatment failure or relapse. The outcome of treatment was classed as unfavourable if they were not cured, they relapsed, had to change their allocated regimen, were lost to follow-up or died from any cause.

THE RESULTS SO FAR

STREAM was a non-inferiority trial, meaning that the aim was to check that the new regimen was not much worse than the existing treatment. The difference in the proportion of favourable outcomes between the control regimen (the 20 month WHO-recommended regimen) and the nine-month study regimen was calculated. Although the long WHO regimen had a 1.0% higher success rate, this difference and the confidence interval around the difference was small enough for the new regimen to be considered non-inferior to the long regimen. The proportion of severe adverse effects was very similar in the two regimens. "These results confirmed that the regimen studied in Bangladesh is effective in a variety of settings including countries like South Africa where there is a high level of HIV-TB coinfection," explains Andrew.

WHAT'S NEXT?

Following the initial results of the STREAM trial, the majority of TB programmes are moving away from the long WHO regimen. The WHO will continue to revise its recommendations as new results become available. "The second stage of STREAM is evaluating a fully oral regimen (where there is no need for injections) and a shorter, six-month regimen. It is hoped that, ultimately, regimens of less than six months will be available for all patients with TB," says Andrew.

STREAM is the first multi-centre randomised trial in MDR-TB and the results have been impressive. Over recent decades, Andrew, and researchers like him in the field of epidemiology, have shown that life-changing progress can be made in effective treatments and patient care through well-conducted clinical trials.

PROFESSOR ANDREW NUNN

MRC Clinical Trials Unit, University College London, UK

FIELDS OF RESEARCH

Epidemiology, Clinical Trials

RESEARCH PROJECT

Improving the effectiveness of treatment for tuberculosis patients who have resistance to the major drugs currently used to treat the disease

FUNDERS

Medical Research Council, University College London

ABOUT EPIDEMIOLOGY

As an epidemiologist working on clinical trials, Andrew's days are spent on a wide variety of activities, which may include developing ideas for new studies and study protocols, visiting the sites participating in his studies and discussing issues and progress of ongoing trials. A very important aspect of the work is presenting research findings at conferences and publishing results in peer-reviewed journals, in addition to researching the work of other scientists. Andrew also participates in oversight committees for trials being conducted by other research groups.

Epidemiologists work with scientists from diverse backgrounds to discover ways to improve healthcare. At the same time, they also support colleagues in the developing world to improve their skills. "I was privileged to be part of a research group based in Uganda from 1989-95 which provided very important insights into the dynamics of the HIV epidemic in that country," says Andrew. The research programme was based in a poor rural community where many of those infected and dying were parents of young children. "At the time, very little was known about how HIV was transmitted in sub-Saharan countries like Uganda and no effective treatment for HIV existed, even in the developed world," explains Andrew.

"The coronavirus pandemic is a very good example of the challenges that face epidemiologists when a new disease emerges," says Andrew. As different diseases continue to emerge, future epidemiologists will face fresh challenges as they work to understand the causes of new diseases and how they affect different population groups. It is then the job of epidemiologists to conduct clinical trials to assess preventative and curative treatments for these diseases. "There is likely to be an increasing need for epidemiologists in the future," says Andrew.

EXPLORE A CAREER IN EPIDEMIOLOGY

- The London School of Hygiene & Tropical Medicine has an excellent website, **www.lshtm.ac.uk**, highlighting a wide range of research activities.
- Watch or read the news and scientific journals, particularly those that are open access – such as BMJ Open (**www.bmjopen.bmj.com**), TRIALS (**https://trialsjournal.biomedcentral.com/**) and PLOS Medicine (**https://journals.plos.org/plosmedicine/**) – to keep up to date with public health issues around the world.
- Volunteer with your local healthcare provider or public health charities to gain experience and understanding of how disease prevention works.
- Explore the work that organisations such as the World Health Organization (**www.who.int**) and Centers for Disease Control and Prevention (**www.cdc.gov**) are involved in.
- The Medical Research Council Clinical Trials Unit provides work experience placements to A-level students via its In2Science programme (**in2scienceuk.org**).
- Visit science fairs such as the MRC Festival of Medical Research at University College London (**mrc.ukri.org/about/getting-involved/mrcfestival**).
- According to Glassdoor, the average salary for people working in the field of epidemiology is approximately £42,000.

PATHWAY FROM SCHOOL TO EPIDEMIOLOGY

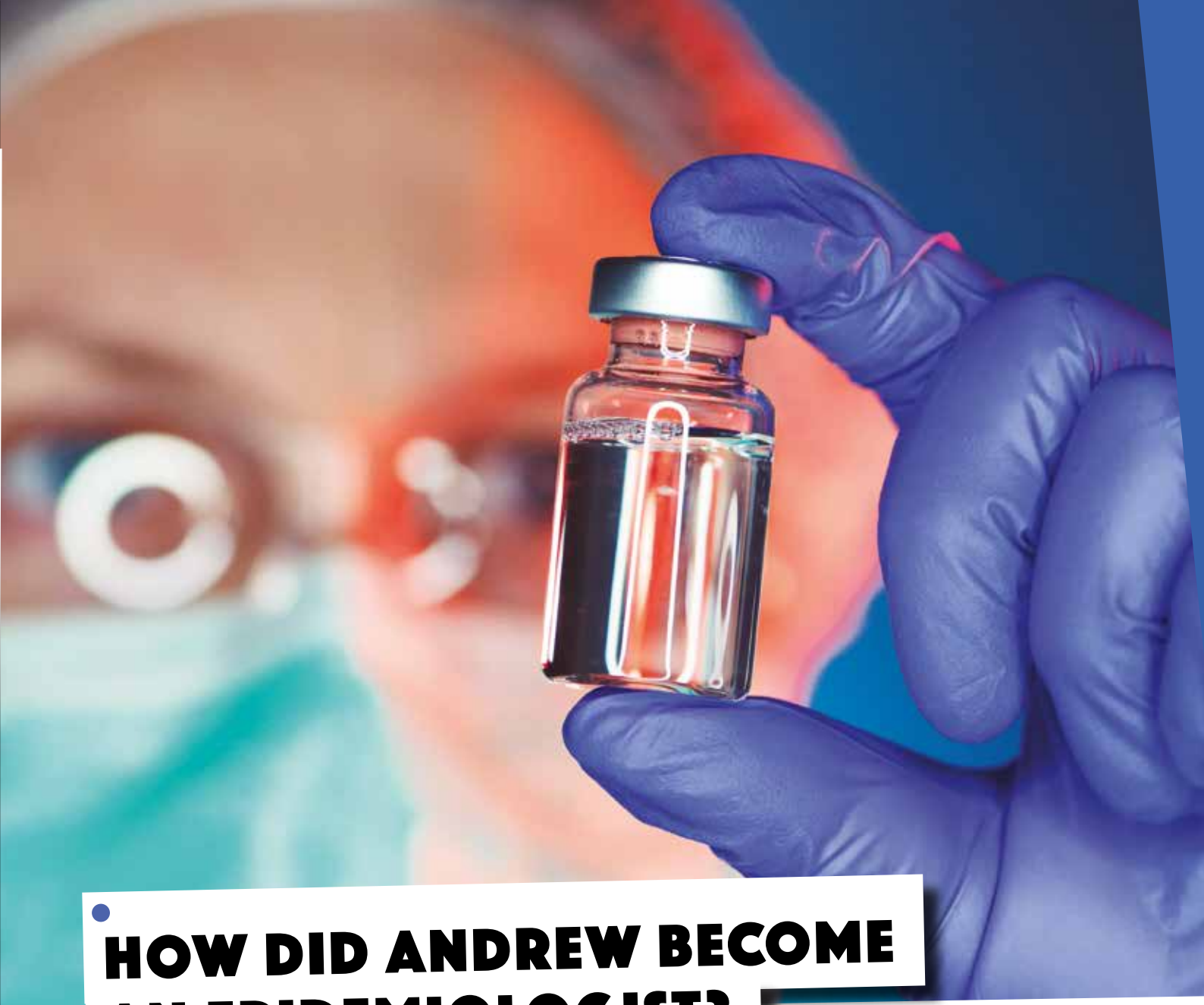
- Andrew explains that epidemiology is a broad field; there are opportunities for those with either a clinical or mathematical background.
- Epidemiological research is very practical, providing opportunities for those with operational skills and interests.
- Subjects such as mathematics and statistics are key for epidemiologists. Biology, chemistry and human geography are also important.
- Attention to detail, critical thinking, clear communication, and knowledge and interest in health issues are important skills for aspiring epidemiologists.

ANDREW'S TOP TIPS

01 Ask yourself or a critical friend whether you have the following qualities: good at maths, attention to detail, the ability to think critically and to communicate clearly, an interest in health issues.

02 Look at epidemiology journals and introductory books on epidemiology and statistics.

03 Find events where you may be able to meet an epidemiologist or biostatistician to find out what they do. University open days may be a good place to start.



HOW DID ANDREW BECOME AN EPIDEMIOLOGIST?

WHAT WERE YOUR INTERESTS WHEN YOU WERE GROWING UP? DID YOU ALWAYS LOVE MATHS AND SCIENCE?

Maths was my favourite subject at school, and I enjoyed books about maths. Although I didn't study statistics at school, it was a subject that always fascinated me. After completing a maths degree, which had a statistics module in it, I decided I wanted to study it further and enrolled on a master's course. At that stage, I didn't know that statistics could have such an important role to play in medicine.

WHAT WAS IT ABOUT MEDICAL RESEARCH THAT YOU FOUND SO INSPIRING?

Just before leaving university, the career's office suggested I should meet with Professor Sir Richard Doll. Professor Doll conducted the landmark study which conclusively demonstrated the link between smoking and lung cancer. I was excited to find that my qualifications could be used in such a worthwhile activity. What I enjoy most is delivering a well-conducted trial – it is even better when there is a positive result which will have an impact on the lives of patients, particularly in poor countries. From the start, I was excited by the prospect of doing a job that could benefit some of those most in need. I have absolutely no regrets about taking this career path and am extremely grateful for the advice I received from the career's office.

WHAT ATTRIBUTES HAVE MADE YOU SUCCESSFUL IN YOUR WORK?

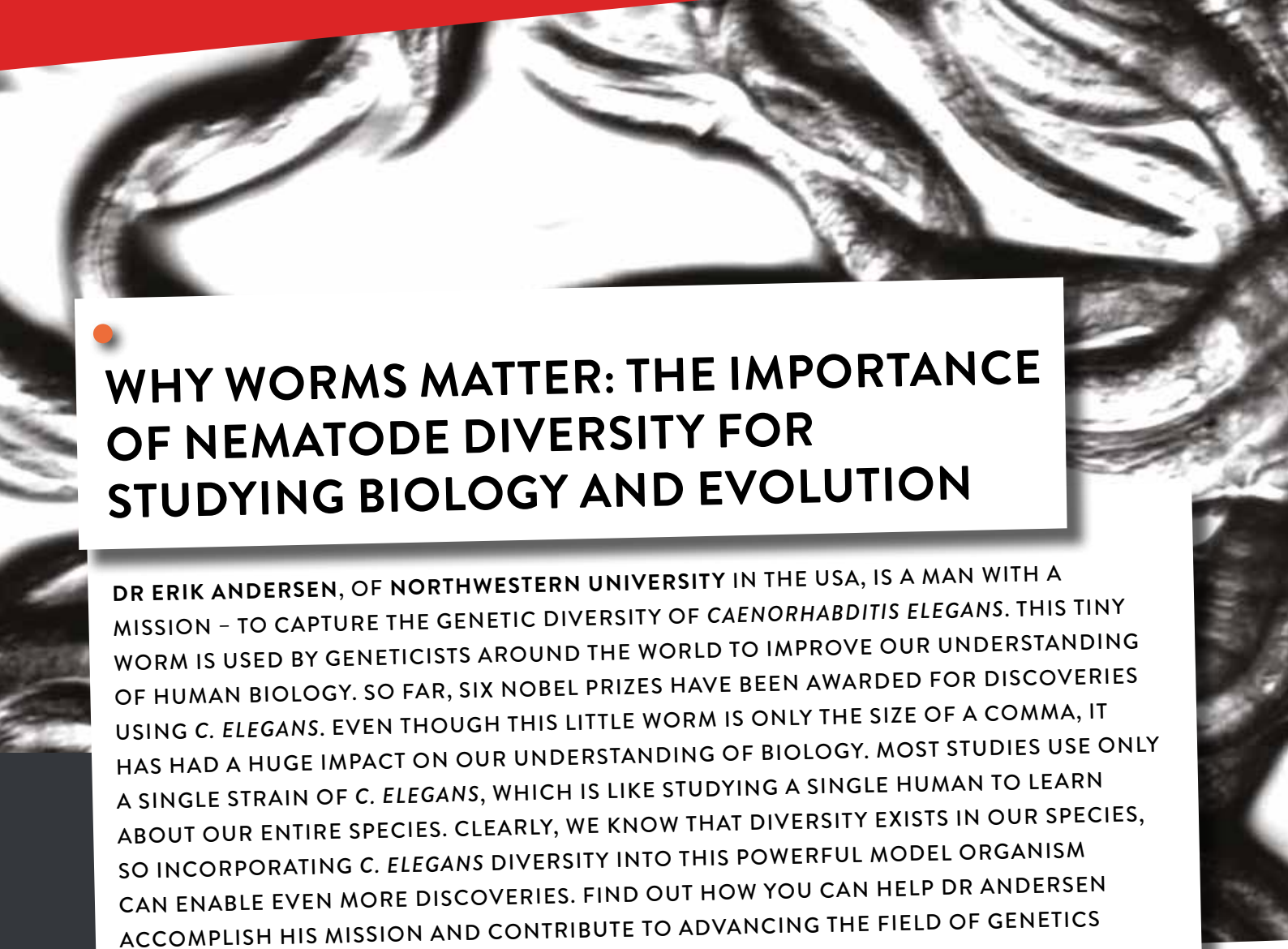
I think the fact that I enjoy my job is a big factor. Attention to detail and recognising the importance of teamwork are also key.

HOW DO YOU OVERCOME OBSTACLES/SWITCH OFF FROM YOUR WORK?

I ask when I need help. This seems simple, but it's a remarkably important thing to do. I enjoy cycling and gardening when I'm not working – this helps me to switch off and enjoy the outdoors.

WHAT ARE YOUR PROUDEST CAREER ACHIEVEMENTS?

Teamwork is an essential part of epidemiology and I am proud of having been able to work with some excellent scientists on important health projects. It was particularly exciting when we made the breakthrough to reduce tuberculosis treatment from 18 to 6 months. The HIV work in Uganda stands out as a great collaboration between local Ugandans and international scientists.



WHY WORMS MATTER: THE IMPORTANCE OF NEMATODE DIVERSITY FOR STUDYING BIOLOGY AND EVOLUTION

DR ERIK ANDERSEN, OF **NORTHWESTERN UNIVERSITY** IN THE USA, IS A MAN WITH A MISSION – TO CAPTURE THE GENETIC DIVERSITY OF *CAENORHABDITIS ELEGANS*. THIS TINY WORM IS USED BY GENETICISTS AROUND THE WORLD TO IMPROVE OUR UNDERSTANDING OF HUMAN BIOLOGY. SO FAR, SIX NOBEL PRIZES HAVE BEEN AWARDED FOR DISCOVERIES USING *C. ELEGANS*. EVEN THOUGH THIS LITTLE WORM IS ONLY THE SIZE OF A COMMA, IT HAS HAD A HUGE IMPACT ON OUR UNDERSTANDING OF BIOLOGY. MOST STUDIES USE ONLY A SINGLE STRAIN OF *C. ELEGANS*, WHICH IS LIKE STUDYING A SINGLE HUMAN TO LEARN ABOUT OUR ENTIRE SPECIES. CLEARLY, WE KNOW THAT DIVERSITY EXISTS IN OUR SPECIES, SO INCORPORATING *C. ELEGANS* DIVERSITY INTO THIS POWERFUL MODEL ORGANISM CAN ENABLE EVEN MORE DISCOVERIES. FIND OUT HOW YOU CAN HELP DR ANDERSEN ACCOMPLISH HIS MISSION AND CONTRIBUTE TO ADVANCING THE FIELD OF GENETICS

TALK LIKE A GENETICIST

NEMATODE – a diverse range of roundworms that inhabit a wide range of environments

PARASITE – an organism that lives off another organism (the host), sometimes causing damage to the host

MODEL ORGANISM – a species that is easy to grow in the laboratory and helps scientists increase our understanding of biological processes shared with humans

CAENORHABDITIS ELEGANS (C. ELEGANS) – a non-parasitic nematode, which is used as a model organism for genetic experiments

GENETIC DIVERSITY – the variation in the genes of individuals among a population or species

GENOME – all the genetic material belonging to an individual organism

ANTHELMINTIC DRUGS – a group of drugs that kill parasitic worms

Roundworms are nematodes, a diverse group of organisms that have adapted to nearly every ecosystem, with over 25,000 known species and likely up to a million different species found across the world. Some of these species are parasites that infect plants, livestock, pets, and even humans. Although these infections are often not deadly, nematodes do cause illness and decrease agricultural productivity.

One species of nematode, *Caenorhabditis elegans*, is one of the most genetically studied organisms on the planet because it is used as a model organism. Model organisms are non-human species that scientists can study to increase their understanding of biological processes shared with humans. *C. elegans* shares many genes with humans and can easily be grown in a lab, making it a desirable target for studying genetic traits that are relevant to humans. The importance of *C. elegans* in genetic research is exemplified by its key role in six Nobel Prize winning studies.

However, most of the research conducted using *C. elegans* is limited to a single laboratory-adapted strain that was isolated from the wild in the 1950s. This means almost all biological and genetic research from *C. elegans* involves identical genetic information from a single individual organism. "This is like trying to study the whole of human biology by just looking at a single person!" explains Dr Erik Andersen.

Dr Andersen is an Associate Professor at Northwestern University, where he is building a collection that contains the genetic information of wild *C. elegans* strains. By understanding the natural variation within *C. elegans* populations, studies using *C. elegans* as a model organism can be improved, advancing our understanding of human biology.

WHY IS *C. ELEGANS* USED AS A MODEL ORGANISM?

C. elegans is a powerful model organism used to study genetics, development, cell biology, and neurobiology. "We know the locations of every cell and the connections of every neuron in *C. elegans* nematodes," explains Dr Andersen. "Importantly, these cells and neurons are the same in every single *C. elegans* animal."

The life cycle of *C. elegans* is only 3.5 days and they can be stored frozen then brought back to life. The worms are about 1 millimetre in size and their genome is 1/30 the size of the human

DR ERIK ANDERSEN

Department of Molecular Biosciences and Department of Cell and Developmental Biology, Northwestern University, USA

FIELDS OF RESEARCH

Genetics, Genomics, Evolutionary Biology

RESEARCH PROJECT

Collecting wild strains of the nematode *C. elegans* and building a resource of natural genetic diversity

FUNDERS

National Institutes of Health, National Science Foundation, Human Frontiers Science Program, American Cancer Society, The Pew Charitable Trusts, March of Dimes

genome and so is much easier to study. All these features mean that *C. elegans* is a powerful model organism. Additionally, *C. elegans* is also a good model to study parasitic nematodes. Unlike parasitic nematodes, *C. elegans* does not require a host organism to grow, meaning it can easily be grown and experimented on in the laboratory. "Unsurprisingly, not many people will volunteer to be a host for a parasitic nematode!" says Dr Andersen.

COLLECTING WILD NEMATODES

To determine the genetic diversity of wild populations of *C. elegans*, Dr Andersen and his team collect broad and unbiased samples of nematodes from natural environments. Dr Andersen needed a location that represented the largest range of genetic diversity and so extensive fieldwork was carried out on the Hawaiian Islands. "We believe that Hawaiian *C. elegans* have more genetic diversity than the rest of the world," explains Dr Andersen. The Pacific region, where Hawaii is located, is likely the source of *C. elegans* before they spread around the globe. This means they have a large stable population that has allowed for greater genetic variation over time.

Dr Andersen and his team collect nematodes in Hawaii every few months, allowing them to discover diverse strains (or genetically unique individuals) that may only exist in certain climates at certain times of the year. "On each collection trip, we go on hikes and pick up rotting fruits, tubers, nuts, fungus or leaf litter every 100 steps," explains Dr Andersen. "With each sample collection, we take a picture, record the substrate temperature, ambient temperature, ambient humidity, and a variety of other environmental parameters." The samples are mailed back to the laboratory, where the nematodes crawl off the vegetation and are collected by scientists, who place them in Petri dishes and allow them to grow.

After a couple of days, the species of each strain can be determined. Any *C. elegans* strains will have their entire genome sequenced, allowing genetic differences in the wild strains to be identified. Each new strain is added to the genetic dataset, building a resource of global *C. elegans* genetic diversity.

A 'CYCLE OF DISCOVERY'

Dr Andersen's laboratory is using this resource to conduct a range of genetic research. The discoveries from *C. elegans* can inform studies in parasitic nematodes, which in turn can inform new studies on *C. elegans* in a 'cycle of discovery'. This cycle of discovery is a powerful method because both *C. elegans* and parasitic nematode species have distinct advantages and disadvantages for their use in laboratory studies.

Dr Andersen has used a cycle of discovery to look at the genetic factors responsible for resistance to anthelmintic drugs. "Discoveries that broadly apply to nematode drug resistance would not be possible without this interplay between the two species," says Dr Andersen. "We use the advantages of *C. elegans* genetics to discover specific genes and molecular mechanisms for drug resistance." And by determining how natural diversity in nematodes enables them to develop resistance to drugs, Dr Andersen and his team are identifying new anthelmintic resistance genes using genetic mapping experiments.

Dr Andersen has also investigated the sensitivity of some *C. elegans* strains to chemotherapy drugs, showing that their natural genetic diversity influences the molecular mechanisms that cause differences in the responses to chemotherapy in humans. These discoveries show that genetic research with nematodes can be transformed to knowledge in human medicine.

HOW CAN YOU HELP DR ANDERSEN?

Dr Andersen's resource of genetic information is essential for ensuring that research using *C. elegans* as a model organism reflects the true genetic diversity of the species. He hopes to increase the number of *C. elegans* strains available to the research community, saying, "We collect, organize, and disseminate these wild *C. elegans* strains and their genome data to the world so that these resources can impact the broader community." Other researchers who work with *C. elegans* can visit Dr Andersen's strain resource and order the strain they want to work with. Dr Andersen's lab will send frozen nematodes of this strain so that the researcher can thaw and experiment on these strains in their own laboratory.

And you can help Dr Andersen by collecting more nematodes for his resource! When you are next on a hike, pick up some rotting material and send it to Dr Andersen. This will almost always have nematodes within it, which Dr Andersen will analyse and add to his collection. "You could add crucial new information to our natural diversity resources," says Dr Andersen. "You might even find a new species!"

ABOUT GENETICS

Model organisms are incredibly important in biology, allowing scientists to learn about shared processes in humans. However, for model organisms to be accurate and useful, they must reflect the true genetic diversity of the population.

This is why Dr Andersen is highlighting the importance of using the natural diversity in wild populations of *C. elegans*. It is important to understand that every individual of a species has slightly different genetic information. Researchers should study this range of genetic information from wild nematodes, not only a single laboratory-adapted strain.

WHAT DOES DR ANDERSEN FIND MOST REWARDING ABOUT HIS FIELD?

Dr Andersen is excited about bringing more genetic diversity to his field. He wants to stop the focus of experiments on a single *C. elegans* strain and for researchers to embrace the genetic diversity that is all around us. "I am excited to bring *C. elegans* natural diversity to the community that focuses on only a single strain," he says. "We have so many more discoveries to make once we incorporate these new strains."

WHAT ISSUES ARE FACING THE NEXT GENERATION OF GENETICISTS?

Dr Andersen believes the biggest challenge facing the next generation of scientists is the recent obsession by funding agencies to focus on 'translational' research, where scientific advances in the laboratory are applied to human health issues, such as for developing new methods to diagnose or treat disease. This makes funding 'basic' research, where scientists try to answer fundamental scientific questions, much more difficult. However, Dr Andersen highlights that basic research often advances human medicine much more than more applied approaches. "From signalling pathways in cancer to genome editing to new mRNA vaccines, no one predicted that basic research would have had these huge impacts," says Dr Andersen.

EXPLORE A CAREER IN GENETICS

- You can visit the website for Dr Andersen's lab (**www.andersenlab.org**) and also visit his website where the genetic collection of wild *C. elegans* strains is organised (**www.elegansvariation.org**).
- Find a lab that works on a topic that excites you. Contact the lab and ask about working as a volunteer. It's never too early to start laboratory research!
- Most faculty at Dr Andersen's institution, Northwestern University, and at other universities, host high school students, undergraduates, and community volunteers to do independent research.

PATHWAY FROM SCHOOL TO GENETICIST

- Genetics is a branch of biology, so take biology classes at school. Some universities may offer undergraduate degrees in genetics, but a general biology degree will allow you to specialise in genetics as you progress through your studies.
- Genetics covers a broad range of topics, from molecular to population to quantitative to developmental genetics. "Take as many of these courses as you can," says Dr Andersen. "Each one will teach you new aspects of inheritance and how to make discoveries using genetics."
- Computer programming and statistics skills are incredibly important. "Programming skills in R, python, and the UNIX command line will give you a huge advantage over standard biologists," says Dr Andersen.

DR ANDERSEN'S TOP TIPS

01 Stay curious. Never trust what you read on the internet or in the literature. Come to your own conclusions after experiments and lots of thinking.

02 Work hard. Throughout history, advances are made by people who do not give up and commit to a problem more than other people.

Dr Andersen showing plates of nematodes in his laboratory storage room

HOW DID DR ANDERSEN BECOME A GENETICIST?

WHAT WERE YOUR INTERESTS WHEN YOU WERE YOUNGER?

From a young age, I was interested in nature and being outdoors. I grew up around lakes and forests, which defined much of my childhood interests. Additionally, I am an avid swimmer. This interest eventually was enhanced by SCUBA diving, providing me with another way to experience nature.

WHAT INSPIRED YOU TO BECOME A SCIENTIST?

In sixth grade, my science class read small packets of current science topics weekly. In one of these classes, we read about genetically engineered corn where genes that encode a crystal toxin from bacteria were added to corn to naturally fight off pest infections. I was amazed that you could take genes from one species and put them into the other. That was the point I realised I wanted to be a geneticist. My early interest was amplified by short lab experiences working with *Drosophila* (fruit flies) and molecular genetics at my local college while I was in high school. I chose my undergraduate school because I knew I could start doing genetics research in my first year.

WHAT ATTRIBUTES HAVE MADE YOU SUCCESSFUL AS A SCIENTIST?

My mother was an Italian immigrant who inspired me to work hard. I get up early and go to bed late, putting everything I can into my research and the people in my laboratory. Additionally, it's important for a scientist to be resilient. I am not slowed by the many difficulties and failures that I often encounter in science and in life. I strongly believe that hard work on many different topics can always yield new discoveries and make every day a learning experience.

WHAT DO YOU ENJOY OUTSIDE OF WORK?

Outside of my research, I spend time with my family, cook, swim, SCUBA, hike, and read.

WHAT ARE YOU PROUDEST CAREER ACHIEVEMENTS SO FAR?

I am most proud of two things. First, the creation of the *C. elegans* natural diversity resource – we have brought natural diversity to the broader *C. elegans* community. I look forward to expanding this resource to other *Caenorhabditis* species. Second, the application of natural diversity to anthelmintic resistance in parasitic nematodes. We have made significant impacts on the discoveries of new resistance loci.

WHAT ARE YOUR AMBITIONS FOR THE FUTURE?

I look forward to expanding our discoveries to new genetic approaches in parasitic nematodes. With current advances in genomics and genetics, many new species can be made into model organisms relatively quickly and easily. I am excited to see what discoveries and new biology these 'models' will bring us.

MAPPING EVERY PROTEIN IN THE HUMAN BODY

ALMOST TWENTY YEARS AGO, THE HUMAN GENOME PROJECT COMPILED THE CODE OF EVERY GENE IN THE HUMAN BODY. NOW, **PROFESSOR NEIL KELLEHER**, OF **NORTHWESTERN UNIVERSITY** IN ILLINOIS IN THE US, WANTS TO DO THE SAME THING FOR EVERY PROTEIN IN EVERY DIFFERENT KIND OF CELL. IT IS A MAMMOTH TASK, BUT HE BELIEVES THAT WITH ENOUGH AMBITION AND COLLABORATION, IT CAN BE DONE – AND IT PROMISES TO BRING HUGE BENEFITS FOR HUMAN HEALTH

TALK LIKE A BIOSCIENTIST

DNA – a nucleic acid that carries the genetic information of living organisms

GENE – a DNA sequence that carries the code for a particular protein

GENOME – the complete set of genes of any organism

PROTEIN – molecules within the body made up of chains of amino acids, coded for by DNA

PROTEOFORM – a specific form of a particular protein, that may differ in shape or structure

PROTEOME – the complete set of proteins of any organism

PROTEOMICS – the study of proteomes and how they function

Proteins have an endless array of possible shapes and structures, which means they can fulfil a huge diversity of functions. They give the body structure, are integral to the functioning and replication of cells, and are ruthlessly efficient at protecting us from disease. Understanding how they work, therefore, can bring huge benefits for medicine and related fields.

Professor Neil Kelleher, of Northwestern University in Illinois in the US, has his sights set on bringing about a major leap forward in our understanding of proteins, by cataloguing every single protein in the human body. The implications of such a project are huge. "The Human Proteoform Project will allow us to know ourselves, and to understand our underlying biology with unprecedented precision," explains Neil.

THE COMPLEX WORLD OF PROTEINS AND PROTEOFORMS

We already have the human genome mapped out thanks to the Human Genome Project, a massive undertaking completed in 2003 that mapped the DNA sequence of every gene within the human body. Since genes code for proteins, shouldn't we be able to extrapolate the human proteome from this? In reality, of course, it is not that simple.

The base sequence of a gene tells us the amino acid sequence of the protein that it codes for, but that is only the start of the story. During and after the processes that create a protein from a gene, there can be any number of additional changes made to the protein. For instance, certain conditions within the cell may lead to the addition of extra features such as carbohydrate groups, or even change the entire three-dimensional structure of the protein. This means that proteins with the same underlying amino acid sequence can have drastically different functions, which cannot be predicted from the gene alone. These differing varieties are known as proteoforms.

Uncovering these differences is a main aim of the Human Proteoform Project. But this is no easy task – Neil estimates there are about one billion different proteoforms within the human body. It will take a monumental collaborative effort, not to mention considerable funding and the latest research technology, to pull it off.

PROFESSOR NEIL KELLEHER

Chemistry, Molecular Biosciences and Medicine, Northwestern University, Illinois, USA

FIELDS OF RESEARCH

Chemistry, Biochemistry, Measurement Science

RESEARCH PROJECT

Mapping every form of every protein within the human body

FUNDERS

National Institutes of Health, select private foundations and private companies

HOW IT WORKS

The first step for the project is to map out the body's 4,000-odd different types of cell. These can be recognised and catalogued according to the unique array of proteins found on each cell surface. Categorising these is important because different conditions within each type of cell can lead to different proteoforms. Once that is complete, the second step involves cataloguing the proteins themselves. This will be achieved by finding their molecular weight – not just a simple weighing-scales measurement, but rather uncovering the identity of every atom within the protein molecule and how they fit together.

The project will use a technique called top-down proteomics to carry out this second step. "Imagine a big pile of gold coins," says Neil. "One of the coins is plastic and has a lighter mass to the others. How do you find it? Do you weigh every coin? Or do you split the pile in half and see which pile is lighter? If you keep splitting the pile like this, you will find the plastic coin faster – this is the 'top down' strategy." Top-down proteomics uses this logic to pinpoint and characterise individual proteoforms in a mixture.

This technique differs from bottom-up proteomics, which involves digesting the proteins first and sorting through the resultant fragments. This can be good for identifying particular proteins, but cannot distinguish between proteoforms because the overall shape and structure of the protein has been lost – so this technique is not suitable for Neil's project.

NOT EXACTLY SMALL FRY

"This project is very ambitious, and poses a significant career risk for me," says Neil. "It will be fantastic if it is completed, but if it does not generate sufficient enthusiasm within the scientific community, it could never materialise." In scale, it can be compared to the Human Genome Project. This became economically feasible when the mapping technology became efficient enough to map the genome at a cost of about $1 per DNA base. Neil believes working on a similar economic model, with a cost of about $1 per proteoform, should mean that the project could be completed within ten to fifteen years.

This is a fairly long timescale and requires a lot of forward thinking from researchers and funders alike. "We have a worldwide consortium of 400 members, with increased funding coming in too," says Neil. "This makes me hopeful that the Human Proteoform Project may come to pass within this decade, and not the next one!"

CHANGING LIVES

Given this project will be so massive and expensive, what benefits could it bring to society? Neil believes that a major application is within medicine. A huge range of diseases, from cancer to heart disease, is caused by faulty proteins – in essence, bad proteoforms. By having an atlas of all these unwanted proteoforms, it will become dramatically easier to detect and combat disease. "This project could accelerate our progress towards next-generation technology, leading to significant improvements in human health," says Neil.

It is widely known that the earlier a disease is detected, the easier it is to treat, and this certainly holds true for cancer – yet detecting it is often not easy. For instance, currently, the most common test for prostate cancer involves screening for a protein called prostate-specific antigen (PSA). However, PSA can exist as many different proteoforms, a number of which are not screened for, so it can commonly be missed. In the future, knowing exactly what these proteoforms are should make the screening test much more sophisticated and accurate.

As well as detection, the project could also help with developing cures. Protein-based drugs are a rapidly expanding form of treatment. They function by detecting and attacking certain proteins – for instance, the proteoforms that exist on the surface of cancer cells. The more proteoforms that are known, the easier it becomes to develop highly specific treatments.

Despite massive advances in medicine in recent decades, a lot of detection and treatment methods are still very generalist. For instance, chemotherapy treatment does not just target cancer cells, and can take a severe toll on the rest of the body too. The Human Proteoform Project has the potential to change this for good, and could revolutionise medicine forever.

Neil's vision reminds us that unwavering ambition and a willingness to take risks can lead people to great things. We wish Neil the best of luck – the future is exciting!

ABOUT PROTEOMICS

Proteomics is the large-scale study of proteins. It concerns the proteome, which is the name given to the entire set of proteins within an organism. Neil explains what it is like to research in this field.

WHAT DO YOU FIND MOST CHALLENGING ABOUT PROTEOMICS?

Unlike genomics, we cannot amplify the molecules that we study. This means we are often working with very tiny amounts of protein, which raises difficulties. This is a core challenge of proteomics, but proteins are massively important for biology, so we make it work.

WHAT HAVE BEEN SOME HIGHLIGHTS OF YOUR WORK IN PROTEOMICS?

Going public about the Human Proteoform Project was a major moment for me. Additionally, I get a lot of pleasure from discovering the precise traits of proteins in the human body. This is a 'positive feedback loop' that has sustained my dedication over decades, despite obstacles along the way.

WHAT TYPE OF PEOPLE DO YOU COLLABORATE WITH?

I collaborate with a very wide range of people. Doctors, clinician-scientists, biochemists, computer scientists, business leaders and research directors all take an interest in my work. Pooling our skills and networks is a fantastic way to make progress.

WHAT WILL BE THE BIGGEST FOCUS FOR THE NEXT GENERATION OF SCIENTISTS WITHIN PROTEOMICS?

Once all the proteoforms are mapped, the next big challenge is deciphering the exact function of each one and how they can be modified.

PATHWAY FROM SCHOOL TO BIOSCIENCE

Neil recommends taking subjects like chemistry and biology, and also computer programming and statistics. Physics and areas of mathematics can also be useful. Once within university, Neil recommends taking courses in cell biology, organic chemistry and genetics.

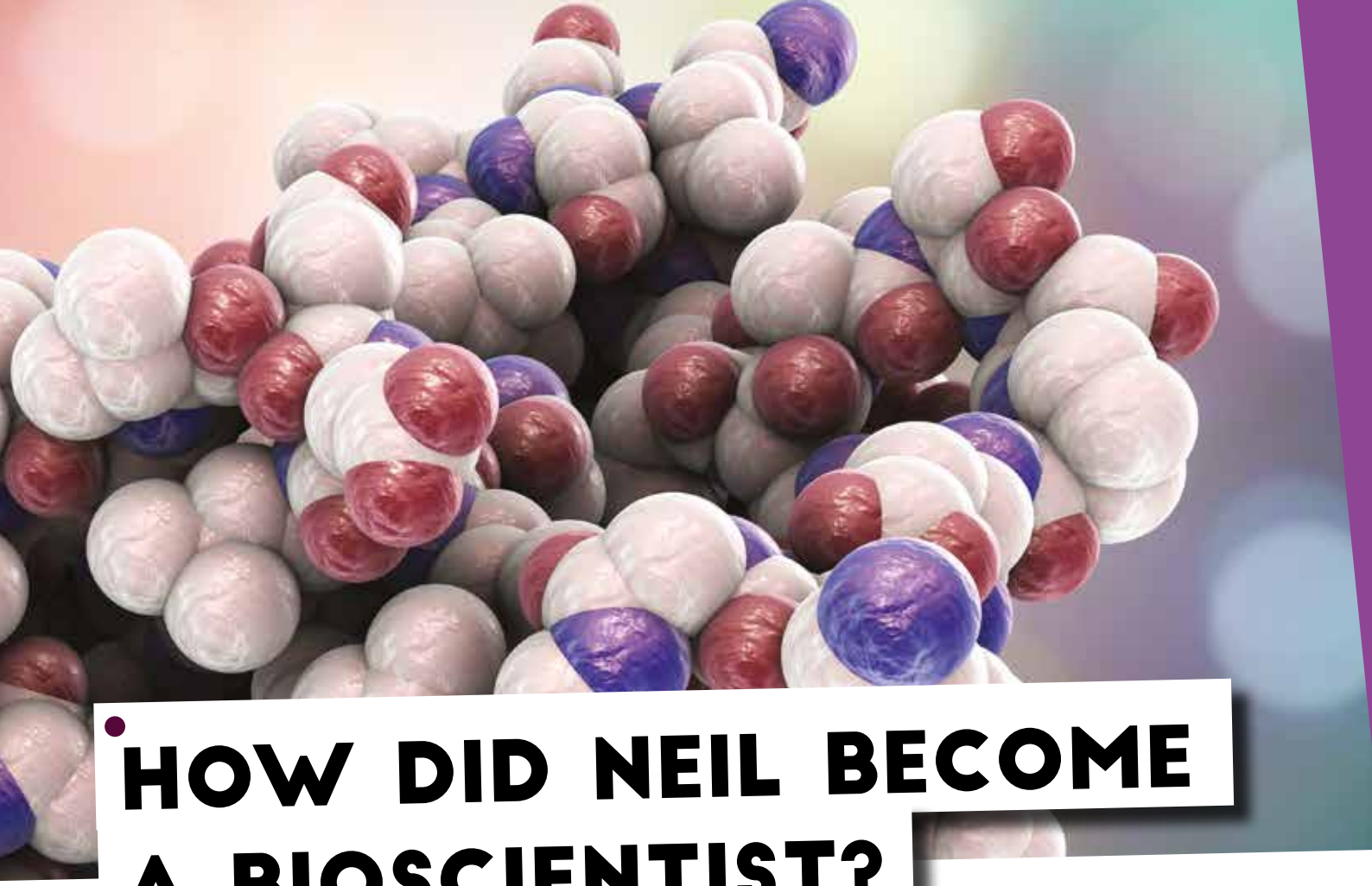
EXPLORE A CAREER IN BIOSCIENCE

- Disciplines such as biochemistry, molecular biology and biomedicine have the potential to lead to a career in proteomics.
- Many universities offer public outreach schemes that help young people get a 'taster' of working in the lab. For instance, Northwestern University, where Neil works, sees many school students visit the campus and engage in summer research.
- According to Payscale.com, the average salary for a molecular biologist is $59k.

Jeannie Camarillo has been a researcher at the Kelleher Research Group for two years and is set to become a leader in the proteomics field.

Phil Compton is a staff member with the Kelleher Research Group. His specialty is in construction and repair of the mass spectrometry devices used to perform top down proteomics.

Dr Ben Garcia is Head of Biochemistry and Molecular Biophysics and leads the Garcia Lab at Washington University in St. Louis. Ben conducted postdoctoral research with Neil and now specialises in developing novel mass spectrometry methods.



HOW DID NEIL BECOME A BIOSCIENTIST?

WHAT WERE YOUR INTERESTS AS A CHILD?

On the academic side, I enjoyed science and woodworking. I liked working with my hands, which helped lead me to a career in lab research. On the sports side, I enjoyed wrestling and golf, which helped me learn fortitude and mental toughness.

WHAT INSPIRED YOU TO BECOME A SCIENTIST?

At sixteen, I took an internship at the chemistry lab of the Weyerhaeuser paper company. It was there I learned that chemists have the solutions to real-world problems – and I even helped solve a small one myself!

WHAT ATTRIBUTES HAVE LED YOU TOWARDS SUCCESS?

Persistence, self-belief and an ability to embrace risk.

HOW DO YOU OVERCOME OBSTACLES IN YOUR WORK?

I find it useful to accelerate towards obstacles – I even revel in the struggle. That has helped me overcome substantial barriers and paved the way to success.

WHAT IS THE PROUDEST MOMENT OF YOUR CAREER?

I believe the highlight of my career is still to come! Having said that, the publications of some of my best research papers have been great moments. I also place great value on training the next generation of scientists.

HOW DO YOU SWITCH OFF FROM WORK?

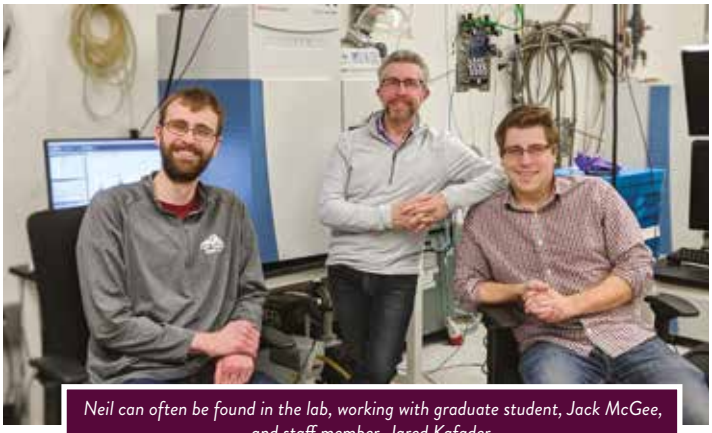
I take pleasure in exercise, especially swimming, golf and jogging.

NEIL'S TOP TIPS

01 Don't follow directly in the footsteps of others. Forging your own path is harder, takes a while – but positions you well in Life!

02 Do find good role models and learn how to learn from them (#networking).

03 Embrace risk – ambition feeds on it!



Neil can often be found in the lab, working with graduate student, Jack McGee, and staff member, Jared Kafader.

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For example, János wasn't massively interested in biology when he was younger. He is now an immunologist!

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