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sonke siya phambili
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MOVING FORWARD WITH

RESEARCH FOR IMPACT

2022

ACKNOWLEDGEMENTS

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Prof Wim de Villiers
Photo by Stefan Els

FOREWORD

Although many of our top academics did – and continue to do – cutting-edge research on COVID-19, I am also relieved and grateful that the coronavirus no longer dominates headlines. As such, we decided to broaden the scope of our annual research publication this year, and highlight the interdisciplinary approach my hard-working, talented colleagues are assuming in order to produce the most meaningful research possible.

In 2021, the focus of our annual publication showcasing our research highlights was solely on COVID-19-related research. It provided extensive coverage of the research that academics across all disciplines at Stellenbosch University (SU) were conducting on the topic of the pandemic and its effects.

In terms of SU's *Vision 2040 and Strategic Framework 2019–2024*, 'research for impact' remains one of our core strategic themes. We use our five strategic research areas (the natural environment, health and human security, social justice and development, human creativity and social innovation, and systems and technologies for the future) as the lens through which we filter our endeavours. In this publication, we have included at least two stories from all five areas to showcase and elevate the important initiatives and innovations happening not only on our campuses but also in the field.

The articles cover an array of topics, from data avalanches that help solve global problems to the burdens of disease, pandemics and climate change. We also feature articles that assess the risks of polio in South Africa, explain how machine learning is used to tackle ecological challenges, and expand our awareness of South Africa's economic history. Furthermore, there are articles on robotic surgery, slavery in the old Cape Colony and the study of intergenerational trauma, to name but a few.

One of our other core strategic themes is 'purposeful partnerships and inclusive networks'. In order to produce impactful research, we have to develop and strengthen our collaborative structures. Interconnectedness and an interdisciplinary approach to research projects are important if we are to learn from people who have different skill sets and perspectives. I believe, and research has shown, that this is the best way to tackle the world's most wicked problems.

Our university does not exist in isolation. The context in which we do research is important. We have to ask ourselves not only what universities are good at, but also what they are good for. Is the work that we do, as our vision states, truly in service of society?

I am happy to say that the work reported on in this publication proves that we are indeed well on our way to achieving this goal.

Prof Wim de Villiers
Rector and Vice-Chancellor, Stellenbosch University, November 2022

When I took up my current position at SU in September this year, one of the first things I did was to read Michael Watkins' book *The First 90 Days: Proven Strategies for Getting Up to Speed Faster and Smarter.* It proved an interesting read.

Prof Sibusiso Moyo
Photo by Stefan Els

As such, I have spent the first three months in this job familiarising myself with the vast array of research-related activities and initiatives that our researchers have been busy with, despite the many disruptive effects of the COVID-19 pandemic on the teaching, learning and research environments. Our researchers do this work not only for the purposes of knowledge production in their respective fields but also to make a real difference in society by delivering 'research for impact'.

SU maintains its standing as one of Africa's leading universities, according to the Quacquarelli Symonds (QS) World University Rankings by Subject 2022, which ranks the world's top universities in individual subject areas, covering 51 subjects. Within the broad subject area category, SU improved its global standing in life sciences and medicine from position 269 in 2021 to position 265 in 2022. In addition, it was ranked higher than any other South African university in the subjects agriculture and forestry (attaining the 76th position globally), as well as in theology, and divinity and religious studies (rating within the world's top 100).

In April this year, SU was also ranked among the top 2 000 higher education institutions in the world by the Center for World University Rankings.

But rankings alone do not tell the story of SU's research for impact. Knowledge exchange through activities that engage different audiences in the research done at SU can help us make a real difference to the ways in which questions, events and problems are understood and addressed.

Over the next few years, I will prioritise building on existing efforts to create an enabling environment that will strengthen our research portfolio even further. We can do this by promoting interdisciplinary research and collaborations; supporting the innovation and entrepreneurship of our researchers in order to translate their research into relevant projects, services and products; and creating opportunities for emerging researchers to excel, even at undergraduate level.

In addition, we must optimise our postgraduate student experience, expand our postdoctoral fellowship programme, and engage in initiatives that ensure broadened access, diversity and transformation.

Indeed, at the time of writing, we have certain challenges that we must address as part of our institutional transformation journey. On the research and innovation front, we know that people, our people, play a significant role in setting the research agenda, providing training, and framing research to help transform and improve livelihoods.

We invite you to become a part of this journey. And what better way to engage with the work of our colleagues than by reading about some of our research highlights?

This year, we followed a digital-first approach in compiling our annual publication. The printed version contains a curated selection of unique online content and features some of the research for impact done at the University.

This publication provides us with an opportunity to engage a broader audience and foregrounds efforts to develop and strengthen specific transdisciplinary research projects and collaboration. It also showcases our work towards increasing our societal impact and the sustainability of our operations, and developing new expertise in emerging areas.

Finally, I would like to use this opportunity to thank my predecessor, Prof Eugene Cloete, who did a sterling job at building the research and innovation enterprise at SU over the last decade.

I would also like to thank my colleagues in the Division for Research Development, the Library and Information Service and all other support services at the University that ensure that our research environment and infrastructure remain excellent.

I trust that readers will enjoy the publication – I certainly did.

Prof Sibusiso Moyo

Deputy Vice-Chancellor: Research, Innovation and Postgraduate Studies, Stellenbosch University

RESEARCH FOR IMPACT

At SU, pushing the boundaries of knowledge and possibility is our focus. Our strategic research areas help ensure that our work connects the University with the rest of the world.

Dr Therina Theron
Photo by Erhardt Thiel

We support our researchers in executing their core [institutional] mandate, which contributes to socioeconomic development. SU's research mission is to stay future-focused and to maximise our impact.

This requires a careful balance between, on the one hand, continuity and consistency and, on the other, renewal. The transformation and rejuvenation of our academic researcher cohort is a priority at SU and provides us with exciting opportunities.

Strategic research areas and investments

SU has five strategic research areas that drive its institutional research agenda: the natural environment; health and human security; social justice and development; human creativity and social innovation; and systems and technologies for the future.

Together, these areas serve as the overarching 'umbrella' themes for our work. The challenge for us is to be locally relevant, with regional impact, but also globally competitive. To achieve this goal, we need to focus on the unique areas in which we have developed expertise over time and build collaborative networks with knowledge partners in South Africa, the rest of the continent and further afield.

In this regard, interconnectedness and an inter- and transdisciplinary approach to research projects are important. Our strategic research areas represent inclusive, broadscale areas of research expertise for the strengthening and development of specific transdisciplinary focus areas.

Recent investments in inter- and transdisciplinary research outputs at the University include the establishment of the School for Data Science and Computational Thinking and the School for Climate Studies. Institutionally, these structures stand alongside the 10 faculties. These new entities can be compared to skyscrapers towering over a bustling urban landscape. In a vibrant city, high-rise buildings often stand alongside smaller and older buildings, with roads and infrastructure crisscrossing in between. This urban landscape is diverse and constantly changing, just like our University.

Our academic 'skyscrapers' focus on inter- and transdisciplinary work beyond traditional faculty borders. Together, our research entities ensure our uniqueness, competitive advantage and research outputs. They also generate knowledge in service of society.

Benefits to society

In terms of SU's *Vision 2040 and Strategic Framework 2019–2024*, 'research for impact' remains one of our core strategic themes.

Doing research for impact implies optimising the scientific, scholarly, economic, social, cultural, technological and political influence of SU's research.

The University is engaged in efforts to establish credible, responsible measures for its research outputs. This means looking at all kinds of metrics and indicators to assess the impact of our work. But metrics alone do not tell the full story of the impact of our research and the merit of our scholarly endeavours. We are learning about knowledge exchange paths and impact outcomes at different stages of the research process. This is done by exploring the stories behind the research, which enriches our understanding of its impact and the processes that underpin it.

Research excellence is, of course, a defining measure of research for impact. The quality and quantity of research at SU are on an upward trajectory.

Knowledge transfer

Globally, the movement is towards knowledge transfer, which is a broader concept than technology transfer. For us to move more towards knowledge transfer, we also need to explore the impact of our research by doing research impact studies. Investment in research and development remains key to ensuring a vibrant higher education sector that is able to address some of society's most pressing challenges. Increasingly, SU's high-quality research efforts are generating significant investments in research collaborations.

At the Division for Research Development, we work hard to help build equitable funding partnerships between research collaborators, here and abroad. SU's income from research contracts has nearly doubled in the past 9 years, from about R500 million to R1 billion per year, of which 70% constitutes international funding. This kind of investment is an indication of the international footprint of our research.

Dr Therina Theron

Senior Director: Research and Innovation, Stellenbosch University

Research for impact, in numbers

DISTINGUISHED RESEARCHERS (2022)

44 research chairs, of which 23 are National Research Foundation (NRF) South African Research Chairs Initiative (SARChI) chairs, funded by the Department of Science and Innovation

493 NRF-rated researchers, of which 20 are A-rated

>350 postdoctoral research fellows

POSTGRADUATE STUDENTS

310 doctoral degrees awarded in 2021

4 960 master's students registered as at June 2022

1 611 PhD students registered as at June 2022

NETWORKS AND PARTNERSHIPS

320 bilateral partner institutions in 64 countries, across 6 continents

25 formal bilateral agreements with African universities

INNOVATION

27 Patent Cooperation Treaty (PCT) applications submitted since 2019 (more than any other entity in SA)

30 spin-out companies launched since 2014

35 SU innovations aligned with the African Union's Agenda 2063 goals

RANKINGS

2ND on the Times Higher Education World University Rankings' (THE WUR's) list of South African universities

24TH on the THE WUR's list of universities in emerging economies

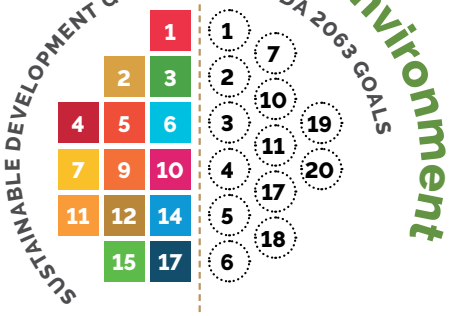
CONTRACTS

1 446 research contracts processed in 2021, compared to 956 in 2018 (a 66% increase in 4 years)

70 percentage of SU's research contract funding from international funders in 2022

SU's five strategic research areas

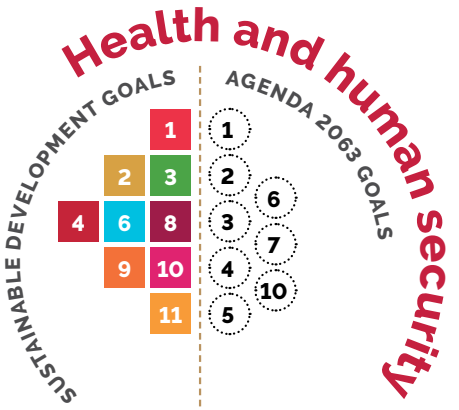
The natural environment



ASSOCIATED SU ENTITIES

- Centre for Invasion Biology
- Centre for Invasion Biology Research Chair: Managing Invasion in Protected Areas
- Centre for Renewable and Sustainable Energy Studies (CRSES)
- Stellenbosch University Water Institute (SUWI)
- SA Research Chair in Social-Ecological Systems and Resilience
- SA Research Chair in Integrated Wine Science
- SA Research Chair in Mathematical and Theoretical Physical Biosciences
- Scatec Solar Chair in Photovoltaic (PV) Systems
- SA Research Chair in Genetic Tailoring of Biopolymers
- Research Chair in Plant Health
- Postharvest Physiology Research Chair in Deciduous Fruit
- Hans Merensky Research Chair in Advanced Modelling of Eucalypt Wood Formation
- School for Climate Studies
- AIMS-Canada Junior Research Chair in Data Science for Climate Resilience
- Sasol Chair in Analytical Polymer Science

Health and human security

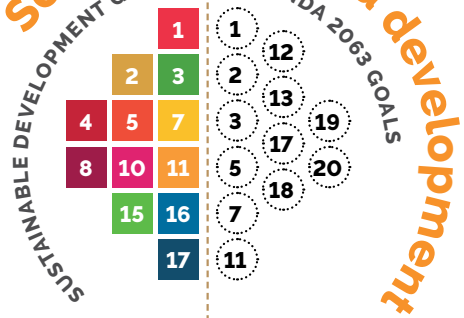


ASSOCIATED SU ENTITIES

- Centre of Excellence for Biomedical TB Research (CBTBR)
- South African Centre for Epidemiological Modelling and Analysis (SACEMA)
- Desmond Tutu TB Centre
- African Cancer Institute
- Institute of Sport and Exercise Medicine (ISEM)
- SA Research Chair in Innovative Rehabilitation
- SA Research Chair in Mycobactomics
- SA Research Chair in Food Environments, Nutrition and Health
- SA Research Chair in Posttraumatic Stress Disorder (PTSD)
- SA Research Chair in Paediatric Tuberculosis (TB)
- SA Research Chair in TB Biomarkers
- SA Research Chair in Animal TB
- SA Research Chair in Mechanistic Modelling of Health and Epidemiology
- Sarah Turoff Endowed Chair in Schizophrenia Research
- SA Research Chair in Integrative Skeletal Muscle Physiology, Biology and Biotechnology
- Rand Water Chair in Public Health
- Centre for Epidemic Response and Innovation (CERI)
- Centre for Food Safety

THE UNITED NATIONS' SUSTAINABLE DEVELOPMENT GOALS

Social justice and development



ASSOCIATED SU ENTITIES

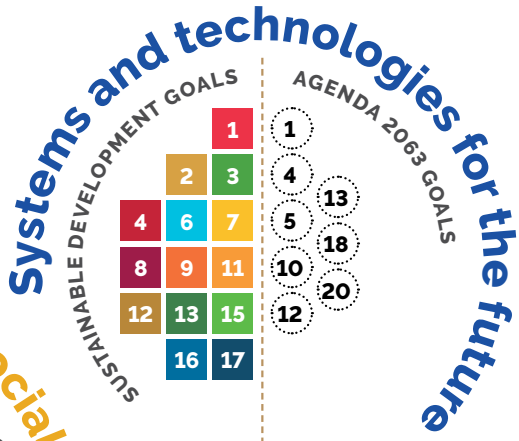
- HF Oppenheimer Chair in Human Rights Law
- SA Research Chair in the Sociology of Land, Environment and Sustainable Development
- SA Research Chair in the Economics of Social Policy
- SA Research Chair in Property Law
- SA Research Chair in Gender Politics
- SA Research Chair in Violent Histories and Transgenerational Trauma
- Bureau for Economic Research
- Africa Centre for Dispute Settlement
- Unit for Religion and Development Research
- Centre for Applied Ethics
- Centre for International and Comparative Politics
- Africa Centre for HIV/AIDS Management
- Anti-corruption Centre for Education and Research of Stellenbosch University (ACCERUS)
- Law Trust Chair in Social Justice
- South African Research Chair in Mainstreaming Gender for Energy Security in Urban Poor Environments
- Centre for Research on Democracy (CREDO)
- Centre for the Study of the Afterlife of Violence and the Reparative Quest (AVReQ)

Human creativity and social innovation

ASSOCIATED SU ENTITIES

- SA Research Chair in Science Communication
- Anton Mostert Chair of Intellectual Property
- Centre for Regional and Urban Innovation and Statistical Exploration (CRUISE)
- Centre for Science and Technology Mass Communication (CENSCOM)
- Africa Open Institute for Music, Research and Innovation
- Standard Bank Centre for Agribusiness Development and Leadership
- Stellenbosch Institute for Advanced Study (STIAS)
- African Wildlife Economy Institute
- Centre for Applied Ethics
- Ton and Anet Vosloo Research Chair in Afrikaans Language Practice
- Centre of Excellence in Scientometrics and Science, Technology and Innovation Policy (SciSTIP)

Systems and technologies for the future

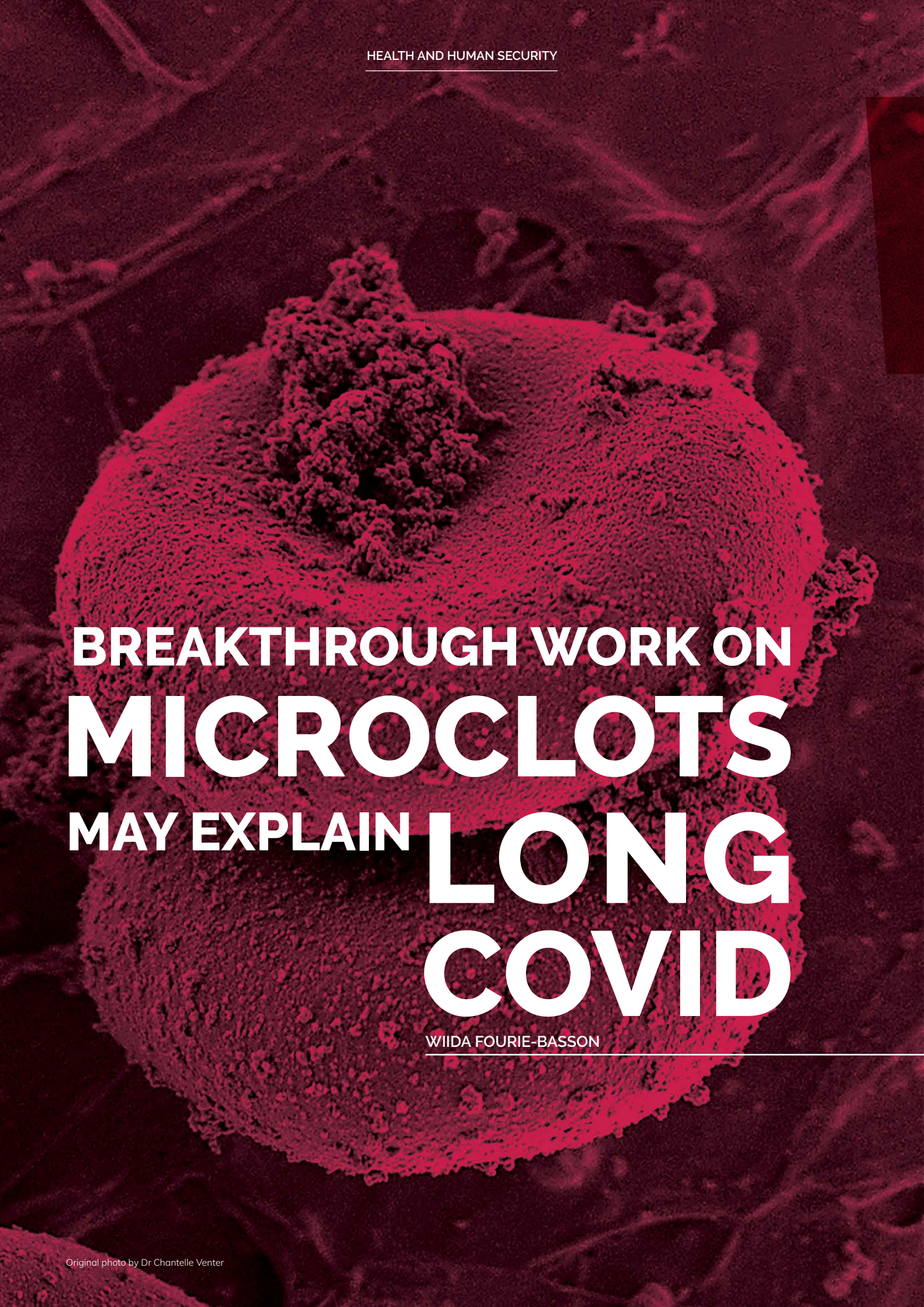


ASSOCIATED SU ENTITIES

- School for Data Science and Computational Thinking
- SA Research Chair in Sugarcane Biorefining
- SA Research Chair in Antenna Systems for the SKA
- SANRAL Chair in Pavement Engineering
- Chair of Computational Thinking for AI (CT4AI)
- SA Research Chair in Postharvest Technology
- Centre for Geographical Analysis (CGA)
- Institute for Futures Research
- Centre for Complex Systems in Transition (CST)
- Institute for Wine Biotechnology
- Institute for Biomedical Engineering
- Macrocomm Smart Utility Solutions Chair
- Research Chair in the Internet of Things (IoT)
- Rand Water Research Chair in Mechanical Engineering
- National Institute for Theoretical and Computational Sciences (NITHeCS)
- Research Alliance for Disaster and Risk Reduction (RADAR)
- AUDA-NEPAD Centre of Excellence in Science, Technology and Innovation (AUDA-NEPAD CoE-STI)
- Capitec Chair in Applied AI

THE AFRICAN UNION'S AGENDA 2063 GOALS

1. A high standard of living, quality of life and well-being for all citizens
2. Well-educated citizens and skills revolution underpinned by science, technology and innovation
3. Healthy and well-nourished citizens
4. Transformed economies
5. Modern agriculture for increased productivity and production
6. Blue/ocean economy for accelerated economic growth
7. Environmentally sustainable climate-resilient economies and communities
8. United Africa (federal or confederate)
9. Continental financial and monetary institutions are established and functional
10. World-class infrastructure crisscrosses Africa
11. Democratic values and practices, the universal principles of human rights, justice and the rule of law are entrenched
12. Capable institutions and transformed leadership are in place at all levels, cross-cutting with governance
13. Peace, security and stability are preserved
14. A stable and peaceful Africa
15. A fully functional and operational African peace and security architecture (APSA)
16. An African cultural renaissance is pre-eminent
17. Full gender equality in all spheres of life
18. Engaged and empowered youth and children
19. Africa as a major partner in global affairs and peaceful co-existence
20. Africa takes full responsibility for financing her development

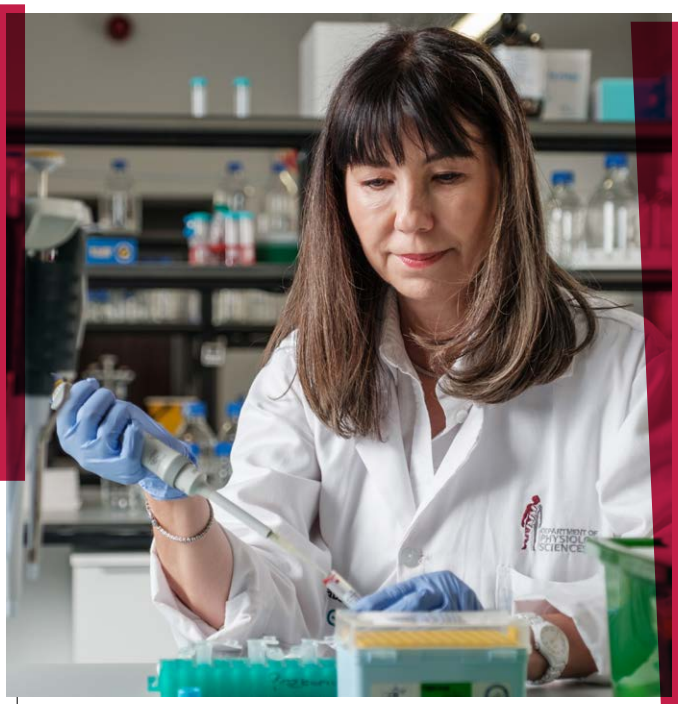


BREAKTHROUGH WORK ON MICROCLOTS MAY EXPLAIN LONG COVID

WIIDA FOURIE-BASSON

Original photo by Dr Chantelle Venter

Proteomics. Genomics. Systems biology. Machine learning. Researchers at Stellenbosch University (SU) are using all possible tools to figure out how exactly the coronavirus disease (COVID), caused by the SARS-CoV2 virus, develops into long COVID, which affects an estimated 1,2 million South Africans.



Prof Resia Pretorius
Photo by Stefan Els

Leading this collaborative, multidisciplinary effort is Prof Resia Pretorius, distinguished professor and head of the Department of Physiological Sciences at SU.

The likely suspects

In 2021, Pretorius made a breakthrough discovery when she noticed insoluble microclots in blood samples from individuals suffering from long COVID. For the first time, it made sense why some individuals, long after contracting the virus, still complained of constant fatigue, brain fog, muscle pain and heart palpitations. Since then, Pretorius and a team of specialists and clinical collaborators have gone on to provide consistent evidence that COVID-19 is not a respiratory disease, as originally thought, but a complex multisystemic disease that causes widespread organ and tissue damage.

The latest report on long COVID from GAO, published in March 2022, identifies four potential causes of long COVID that need further investigation: the body's autoimmune response, organ damage, microclots and the persistence of the virus in the body. Except for the latter, says Pretorius, they have thus far provided evidence confirming all these causes. The journal *Science* recently listed microclots as one of the leading theories explaining the pathology of long COVID.

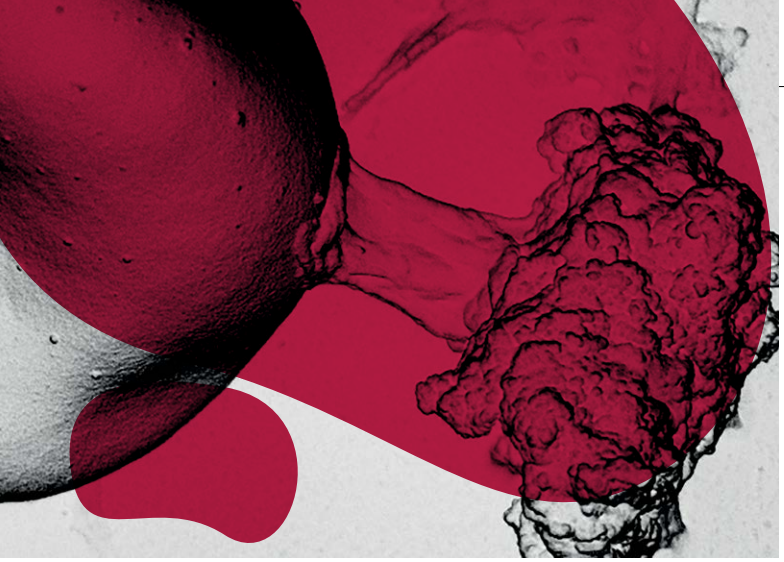
Making the link between blood clotting and long COVID

In 2020, when the dominant thinking was still that COVID-19 is a respiratory disease, Pretorius worked with two specialists in private practice at Mediclinic: Dr Jaco Laubscher, a vascular internist, and anaesthesiologist Dr Johan Lourens. The trio had a novel hypothesis: COVID-19 is a vascular disease, not a respiratory one. If they were correct, this would explain not only its effect on patients' lungs but also the prevalence of a wide range of symptoms related to clotting and bleeding that clinicians were noting in acute cases of COVID-19.

The group published various papers in 2020 to show clotting pathology in the acute phase, including a significant microclot load as viewed under a fluorescence microscope. In 2021, Pretorius turned her attention to those patients who had recovered from the acute phase but still suffered from lingering, debilitating symptoms that were not present before they were infected.

The first breakthrough in recognising that long COVID could be a valid medical condition occurred when Pretorius, again using fluorescence microscopy, found significant microclot formation in the blood samples from a small group of patients suffering from long COVID. Curious about the content of these insoluble microclots, she approached the proteomics laboratory at SU's Tygerberg campus to study their protein content. Working with the senior proteomics specialist in the Mass Spectrometry Unit at SU's Central Analytical Facilities, Dr Maré Vlok, they found an overload of inflammatory molecules 'trapped' inside the microclots.

According to the United States Government Accountability Office (GAO), long COVID presents as a collection of lingering symptoms that last 90 days or more after patients have recovered from acute COVID-19 infection. Some of the symptoms include fatigue, difficulty breathing, shortness of breath during daily tasks, joint pain and chest pain. By March 2022, long COVID was estimated to have affected at least 45% of the 2,7 million South Africans who had survived the SARS-CoV-2 infection. This means that over 1,2 million South Africans likely required further medical support for this very poorly understood condition. At the same point in time, in the United States of America, an estimated 7 million to 23 million people were likely affected.



Original photo by Dr Chantelle Venter

"The trapped molecules contained clotting proteins such as fibrinogen, as well as alpha-2 antiplasmin. We immediately realised that the presence of these proteins would significantly inhibit the body's ability to break down the clots," Pretorius explains.

Alpha-2 antiplasmin is a molecule that prevents the breakdown of blood clots, while fibrinogen is the main clotting protein. Under normal conditions, the body's plasmin-antiplasmin system maintains a fine balance between blood clotting (the process by which blood thickens and coagulates to prevent blood loss after an injury) and fibrinolysis (the process of breaking down the fibrin in the coagulated blood to prevent blood clots from forming).

The findings of this study were published in the journal *Cardiovascular Diabetology* in August 2021. Current thinking is that these insoluble microclots inhibit or even temporarily block blood flow to capillaries and subsequent oxygen transfer to tissue. The lack of oxygen in various parts of the body can account for most of the symptoms of long COVID. This theory was supported by Pretorius and her team's discovery that the Omicron variant caused significantly less blood clotting than the Beta and Delta variants and, therefore, less severe COVID-19 symptoms.

The replication problem

In the natural sciences, one of the most important indicators of the validity of your findings is the extent to which others obtain the same results, many times over, when replicating your work. But what happens when there is no widely available protocol for general practitioners or specialists to detect the microclots in circulation, which would confirm Pretorius' findings?

To address this problem, Pretorius set out to raise the necessary funds to duplicate the 2021 proteomics study on a much larger scale, this time working with blood samples from a cohort of 99 long COVID patients and a control group of 30 healthy individuals (instead of only 15 as in the 2021 study).

This larger proteomics study was funded by the Long COVID Research Charitable Trust, established with a donation from Mr Koos Pretorius from ENSafrica. The crowdfunding platform Kernls and the research foundation PolyBio in the United States enabled the purchase of a flow cytometer for the lab. Also, a donation from the COVID-focused scientific investment and direct gifting fund Balvi funded an automated system that fits onto the fluorescence microscope for studying platelet and microclot pathology. Proteomic analysis of blood samples is costly, but it was crucial to testing whether the findings of the 2021 study were indeed the rule and not an exception.

"Proteomics is the study of proteins, also called 'the building blocks of life'. Human and animal cells contain thousands of proteins with highly complex and diverse functions, from regulating development and reproduction to warning the immune system against invaders. Investigating how the body's immune system reacts is therefore crucial to understanding how the coronavirus disease develops," Pretorius explains.

It took 8 months to perform the proteomic analysis and analyse the nearly 130 samples. According to Vlok, this is the largest proteomic analysis he has ever performed. The results, published in October 2022 in the journal *Cardiovascular Diabetology*, again confirmed the presence of a significant number of large molecules known to significantly reduce the body's ability to regulate clot formation (coagulation), trapped in microclots in the blood samples from long COVID patients.

According to Pretorius, research groups from all over the world have recently begun to confirm their findings. This includes evidence of the increased presence of clotting proteins such as the von Willebrand factor (a prothrombotic molecule that favours clot formation) and alpha-2 antiplasmin (which inhibits the breakdown of clots) inside microclots in the blood of patients with long COVID. Importantly, researchers have also found a significant number of previously unidentified antibodies and autoantibodies that might be associated with or trapped inside the microclots.

'The clot thickens'

According to Pretorius, their study was the first to identify both antibodies and autoantibodies trapped, specifically, inside the microclots in the blood samples of patients with long COVID. The results are in line with other research groups' identification of antibodies and support the GAO's identification of the body's autoimmune response as one of the causes of long COVID.

Dr Arneaux Kruger, a medical doctor pursuing an MSc under Pretorius' guidance and first author of the aforementioned article in *Cardiovascular Diabetology*, says further research is needed to fully understand the significance of this finding: "The antibodies could have been formed in response to the infection, but they could also potentially be autoantibodies formed against the host itself or against the microclots we identified. In other words, it could be that, in people with long COVID, the immune system is trapped in a vicious cycle as it continues to produce autoantibodies in response to the antibodies trapped in the microclots."

The implications of this finding, as understood thus far, are far-reaching and confirm what Pretorius has discovered in over a decade of research on the link between dormant microbes and chronic inflammatory diseases such as Parkinson's, Alzheimer's and, more recently, the debilitating, poorly understood medical condition myalgic encephalomyelitis or 'chronic fatigue syndrome' (ME/CFS).

As far back as 1996, the systems biologist Prof Douglas Kell from the University of Liverpool predicted that more and more disease states would be found to have a microbial origin. In 2011, after reading each other's work, Pretorius and Kell started collaborating. In 2015, at a time when the general understanding was that blood in healthy organisms is a sterile environment, they coauthored a review paper in *FEMS Microbiology Reviews* titled 'The dormant blood microbiome in chronic, inflammatory diseases'. The two researchers have been collaborating ever since and are currently applying decades of knowledge and expertise in their attempts to make sense of long COVID, as it develops in real time.

In a recent webinar, Dr Mark Walsh, lead emergency medicine physician at the St. Joseph Regional Medical Center in Lewiston in the United States, stated that the foundational work by Pretorius, Kell and Laubscher has helped his team explain the clotting complications in patients with acute COVID-19: "We could not understand why patients would clot and bleed at the same time. We now have the pathophysiological foundation for a point-of-care bedside medicine approach, based on the foundations of excellent research." While the COVID pandemic has brought many dark clouds, there may be a silver lining: This renewed focus on post-viral diseases will bring relief to millions of people who have been silently suffering from ME/CFS and other chronic inflammatory diseases.

Bringing in the big guns: machine learning and genomics

Pretorius is also part of a multidisciplinary group of machine learning, physiology and genomics experts that will investigate the risk factors for developing complications after receiving the COVID-19 vaccine. This project is funded by a R3,3 million grant from the South African Medical Research Council.

"Although vaccination is our only hope to return to any form of normality, there are certain individuals that may suffer from adverse effects due to their genetic makeup or a general chronic inflammatory status, making them more prone to clotting pathologies and even death," Pretorius explains. This means that, after vaccination, some individuals may develop clotting pathologies even if they never had acute COVID-19.

"There is an urgent need to determine the overall risk factors for developing complications," says Prof Bruce Watson, principal investigator and holder of the Capitec Chair in Applied Artificial Intelligence at SU. The current understanding is that the origin of these risk factors is genetic and/or environmental, or related to the manner in which proteins are produced in the body.

Going forward, Pretorius and Dr Chantelle Venter from SU's Department of Physiological Sciences will be looking for clotting pathologies in the blood samples of healthy individuals who experienced complications after vaccination ('vaccination injury'), and in samples from individuals suffering from long COVID after acute COVID-19 infection, and from vaccination injury. The control group will consist of healthy, vaccinated individuals who have either never had acute COVID-19 infection or have fully recovered. Prof Maritha Kotze from SU's Department of Chemical Pathology will determine common genetic risk factors associated with inherited thrombophilia (a condition in which your body tends to form blood clots). Watson's team will make use of the latest machine learning methods to analyse associations between the various patient characteristics.

"Our approach is to build a dataset that includes patient characteristics such as their genetic, proteomic and environmental data, and their comorbidities. Using relatively sophisticated but well-studied machine learning methods, we will cluster participants to identify common features among unique clusters," he explains.

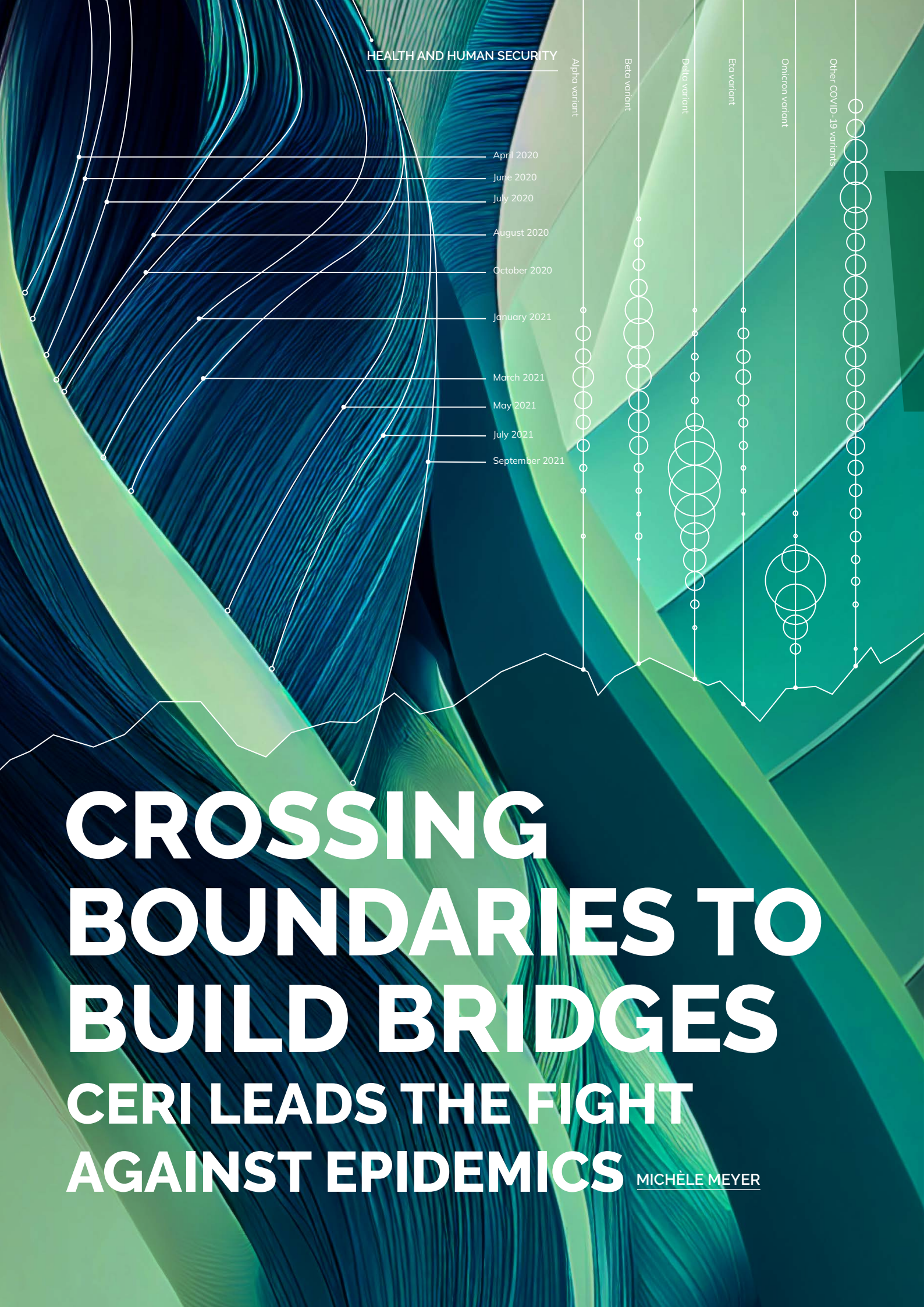
They will then use supervised learning methods to determine the relationship between blood markers, genetic and environmental factors, and those patients in the dataset with post-vaccine malaise. By taking these relationships into account, the team should be able to rank combinations of risk factors according to their impact on post-vaccine health. The results of the study may finally be converted into clinical guidelines for both pre- and post-vaccine patients.

The way forward

Pretorius and her team's microclot work is being replicated across the globe by teams such as the one at Dr Beate Jaeger's Mülheim Clinic in Germany and, in the United Kingdom, at the University of Sheffield Hallam and the University of Manchester. Also, the Balvi research foundation has funded a microclot detection system for Kell's laboratory at the University of Liverpool. In the United States, Pretorius will assist Prof David Putrino, Director of Rehabilitation Innovation for the Mount Sinai Health System, in establishing the microclot method in his laboratory.

"There is still a lot to learn about the pathophysiology of long COVID," Pretorius concludes.

It has taken 3,7 billion years for proteins to evolve into this complex immune system that we have today – no surprise then that we are still in the starting blocks of truly understanding it.



CROSSING BOUNDARIES TO BUILD BRIDGES

CERI LEADS THE FIGHT AGAINST EPIDEMICS

MICHÈLE MEYER

Prof Tulio de Oliveira
Photo by Stefan Els

At the Centre for Epidemic Response and Innovation (CERI), a team of dedicated scientists is crossing transdisciplinary boundaries in its search for information regarding global health threats, and in its interpretation of this data.

Leading this team is Prof Tulio de Oliveira, director of CERI and the KwaZulu-Natal Research Innovation and Sequencing Platform (KRISP).

De Oliveira and his team earned worldwide recognition for detecting the Beta variant of SARS-CoV-2 in late 2020. In November 2021, a few months after De Oliveira joined the Stellenbosch University (SU) ranks as a professor in the School for Data Science and Computational Thinking, he and his co-workers also detected the Omicron variant.

Today, the CERI team is successfully using big data across a range of disciplines to address current epidemics and to prepare for possible future global health threats.

Big data for gigantic challenges

'Big data' is currently one of the hot topics in the war against global health threats such as the COVID-19 pandemic. This term refers to extremely large datasets that lend themselves to computational analysis. The latter reveals patterns, trends and associations, especially ones relating to human behaviour and interaction.

Given that we live in a time of information overload, big datasets can assist scientists in applying specific deductions or associations reached through computational analytics in the devising of smart solutions for a plethora of issues.

At CERI, big data is analysed to reveal links between seemingly unrelated factors in the interdisciplinary fight against epidemics.

De Oliveira explains: "We link all kinds of previously unrelated data. In the analysis of epidemics, we link data related to climate, temperature, humidity and rain levels with mobility data – which is collected every time someone uses a mobile phone – and with flight and epidemiological data. The latter entails the number of cases of infection and the genomes that we produce."

Linked epidemiological data such as this can reveal the environment's role in the spread of diseases, how diseases move, and how they are introduced around the world.

It is through this linking of data that the researchers at CERI came to understand aspects of the spread of COVID-19. The waves of infection during winter were associated with people spending more time indoors due to cold weather. The waves that followed in summer were associated with higher mobility – pleasant weather led to people spending more time socialising and travelling.

Similarly, linked data from CERI's work in Brazil and Africa has revealed that outbreaks of certain diseases transmitted by mosquitoes are more likely when the conditions for mosquitoes are ideal. Such conditions are normally associated with wet months and higher temperatures. "Here, the lesson is not only about how diseases are spread but, more importantly, about how to develop systems and tools to control or prevent them," De Oliveira says.

A truly transdisciplinary centre

CERI is based in the School for Data Science and Computational Thinking at SU but spans across another two SU structures, the Faculty of Medicine and Health Sciences and the Faculty of Science. According to De Oliveira, CERI is the first body to interlink different SU faculties and infrastructures in this way.

"Our work is transdisciplinary in nature. We have medical staff who see the patients. They are involved in clinical management and identification, sampling and ensuring proper medical care for patients. These staff members are part of the medical and biomedical team; they work on what we refer to as the 'bad side', close to the threat of infection through their interaction with patients. In the process, they learn and document as much as possible, while giving continuous assistance.

"In this manner, we build sample collections that can then move to our genomics laboratories where DNA data is produced. Our big laboratories are based in the Faculty of Medicine and Health Sciences on our Tygerberg campus. In addition to the data analysts at Tygerberg, we also link with the Faculty of Science. We strive to interlink various areas: biology, bioinformatics and ecology. It is essential to understand the environmental factors that drive epidemics."

> CERI also cross-links with contributors from more technical disciplines such as computer science and engineering. Electronic engineers are responsible for coding some of the softer applications needed for CERI's work, and for developing new mathematical formulae and applying them in the research process. This makes CERI a truly transdisciplinary centre.

Breaking boundaries to return to a universal view

Traditionally, academic institutions and universities are horizontally organised, with individual faculties representing clearly defined disciplines. CERI takes an alternative stand that challenges the concept of isolated disciplines within the University.

"What CERI does is groundbreaking, but we are not the first to do this at SU. The School for Data Science and Computational Thinking and the School for Climate Studies do groundbreaking work in their attempts to cut across different disciplines. These schools are partaking in a big movement currently occurring in the world's top scientific research laboratories and universities.

"Once we start breaking down the barriers between disciplines, moving the focus away from earning credit for a specific discipline towards answering the obvious scientific question, we rapidly boost the level of science."

In less than a year after its establishment, researchers linked to CERI have been published multiple times in some of the world's top scientific journals. The Centre's results have driven much of the global response to epidemics. Clearly, once the barricades between disciplines are removed, cooperation can lead to the answering of questions with a public interest.

"The best way to prove this is by producing high-level science that will convince other academics and university structures that transdisciplinary cooperation has its merits," De Oliveira says.

The past, present and future of epidemic research

Looking into the recent past at how the world responded to the coronavirus holds clues to how tracking new variants of the virus can prepare us for the next global health threat.

"It's not surprising that we were one of the global leaders in scientific response to the coronavirus because, during the last five or ten years, we became involved in responding to all the previous epidemics – HIV, TB, Zika, dengue, chikungunya, yellow fever, West Nile virus, Rift Valley fever. When the coronavirus hit, our team, involving both CERI and KRISP, was already used to responding to epidemics. As such, we could rapidly pivot our attention to the new epidemic."

Today, De Oliveira believes, it is more important to return our attention to the current epidemics faced by South Africa and Africa at large than to prepare for possible future epidemics. Much of the progress made in HIV and TB research in the last five years was lost during the pandemic. It is essential, he argues, that scientific resources and facilities be used for renewed research on these two diseases. In particular, their genomes must be generated and linked to big data in order to improve tailormade therapy.

Three current focus areas of the HIV and TB work done at CERI are understanding the transmission of these illnesses, identifying the correct interventions to decrease it, and explaining treatment drug resistance. Apart from HIV and TB, De Oliveira also identifies malaria, Ebola and hepatitis B, C and E as diseases in dire need of research attention in the African context. The latter hepatitis strain is fast becoming problematic, specifically in refugee camps.

Global south leads the fight

"CERI responds to current epidemics, pivots back quite strongly, but also prepares for future epidemics," De Oliveira emphasises.

"Towards the end of 2022, we will be launching a large global programme, Climate-Amplified Diseases and Epidemics (CLIMADE). The idea is to create a global consortium, led by the global south, that will identify the areas that are most likely to suffer from epidemics associated with climate change and global warming. The World Health Organization; Africa Centres for Disease Control and Prevention; a strong partner in Brazil, the Oswaldo Cruz Foundation (Fiocruz); and partners from the global north will also be involved. Countries from the global south should lead the programme because this is where these epidemics cause mass suffering. Through means of the consortium, the data can be collected and information disseminated swiftly, helping the entire globe to develop therapies and vaccines.

> "We expect 60% of existing pathogens to become more dangerous with global warming. There is much talk about pathogens associated with vectors such as mosquitoes and ticks, as well as climate (cold winters and hot summers), but also about waterborne pathogens that are associated with floods. Dozens of countries around the world are suffering unheard-of outbreaks of cholera," says De Oliveira.

To him, this is not surprising. With the global environment having been under severe strain over the past few centuries and with humankind's continuous nonchalant attitude towards the culminating devastation, outbreaks of epidemics are inevitable, he says. Sociopolitical and economic problems compound the effect.

Adding to our dilemma, De Oliveira says, is the global increase in antimicrobial resistance – a disease-causing microbe's development, through mutation or gene transfer, of the ability to survive exposure to an antimicrobial agent that was previously an effective treatment for the relevant disease. "Genomics plays a crucial role in antimicrobial resistance. If we are careless, the world can lose most of the antibiotics available to us within the next few decades. Overuse of antibiotics is a very real issue.

"In developing countries, in addition to epidemics caused by pathogens, we will see an increase in epidemics associated with lifestyle and the fact that people now live longer. Cancer, diabetes and high blood pressure are all examples. My concern lies with the masses of poor individuals suffering from not only high levels of violence, unemployment and mental health issues but also physical diseases."

Strength in unity

CERI follows a work ethic that emphasises teamwork. De Oliveira chuckles when asked about this methodology.

"Of course, teamwork is what produces high-level science. We have a truly transdisciplinary team that works in unison. Each sub-team consists of highly experienced individuals. Our clinical team understands diseases from a clinical perspective. We have a laboratory team that produces genomic data and diagnostics in real time. Our data analysis team is quite large, with around 20 individuals analysing data in real time. Each of them applies their specific expertise. Various engineers develop software applications. Someone with a strong biological background will do the evolutionary analysis, whereas someone with a mathematical background will do the mathematical analysis."

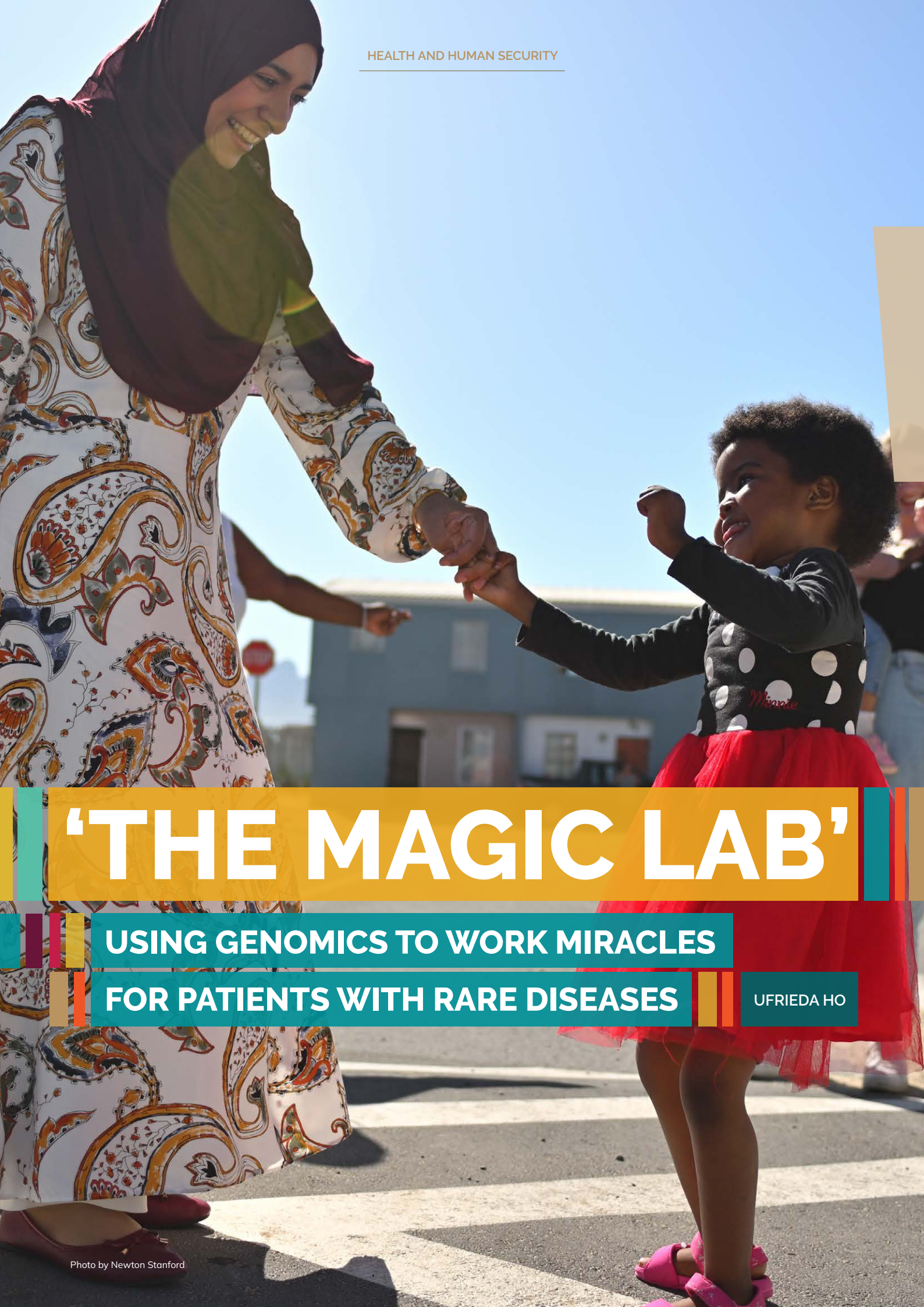
Since April 2021, CERI and KRISP have hosted over a hundred fellows from 33 different African countries. The aim is to teach these individuals how to produce and analyse data. After receiving training, they return home with all the protocols and scripts needed for data analysis. This allows for the analyses to be replicated in the countries that the fellows hail from. Recently, this fellowship programme was extended to Latin America. De Oliveira says there are also plans to expand the programme to countries in the southern and southeastern parts of Asia. All of this forms part of an effort to support countries from the global south.

"This may sound counter-intuitive, as if we are giving away our secrets. We are, however, building a very strong network of researchers who can work together. It also builds trust. Our fellows are individuals, not numbers."

Proof of this network is the paper recently published in *Science*, one of the top two scientific journals in the world. Over 300 collaborators from more than 150 institutions contributed to this paper on the genomic surveillance of the SARS-CoV-2 pandemic in Africa.

CERI has become a beacon of hope in a time of global health threats. Its role in relentlessly mapping out protocols and solutions for current and future epidemics is highly regarded. This international acclaim is evident from the fact that the Massachusetts Institute of Technology listed the Centre's work on identifying and tracking COVID-19 variants as one of the top 10 technological breakthroughs of 2022.

Dr Jennifer Giandhari inspects an Illumina MiSeq flow cell with Ethiopian fellows Rajiha Abubeker and Dawit Hailu during their genomics fellowship at KRISP in 2022.
Photo by Paul Harris



‘THE MAGIC LAB’

USING GENOMICS TO WORK MIRACLES FOR PATIENTS WITH RARE DISEASES

UFRIEDA HO

Photo by Newton Stanford

Prof Shahida Moosa and her patient, Anothando Kabingesi, in front of the new home Moosa helped secure for this rare disease sufferer and her family.
Photo by Newton Stanford

The Rare Disease Genomics research group at Stellenbosch University (SU), the first of its kind in sub-Saharan Africa, is at the cutting edge of genetic medicine and large-scale genomic sequencing research. The group searches for answers to deepen the value of science, and to make the unknown a little bit less scary.

Late one July night in 2022, head of the group Prof Shahida Moosa received a desperate message from the mother of one of her patients. The photos that were attached to the message showed the rat-chewed fingers of four-year-old Anothando Kabingesi. The toddler suffers from a rare condition, called 'Joubert syndrome', a disorder that affects brain development and hampers balance, coordination, breathing, eye movement and muscle tone. Given her condition, Anothando wasn't able to swat away the rats or cry out easily to her mother, Nonhlanhla Kabingesi. At the time, Kabingesi and her four children, on a housing waiting list for six years already, were living in a shack in Mfuleni. The toddler's missed milestones had been pushed back even further because of her living conditions.

Moosa first met Anothando at Tygerberg Hospital, where Moosa is also the head of Medical Genetics and the Undiagnosed Disease Programme. At that point, Anothando was just a few months old and no one had yet been able to pinpoint her condition. Based on Anothando's clinical features and on imaging analysis, Moosa had a differential diagnosis in mind. In order to definitively diagnose Anothando, Moosa referred her for genetic testing. (Tygerberg Hospital is currently the only public healthcare facility in the country to offer such testing.)

"I was praying to meet a kind doctor and then I found Prof Moosa," Kabingesi says.

Types of genetic testing

Genetic testing looks for changes, or or so-called 'mutations' or 'variants', in DNA – the unique 'instruction book' that makes up each individual human being. Genetic testing can take the form of a single-gene test, used when a doctor wants to confirm a specific condition or syndrome. There is also multi-gene panel genetic testing, which focuses on categories of medical conditions being investigated. Lastly, large-scale genetic testing constitutes exome and genome sequencing.

The difference between these two types of sequencing lies in the range of DNA coverage of the two tests used. During whole exome sequencing (WES), the tests look at those parts of the genome that contain the DNA code for making proteins. In the case of whole genome sequencing (WGS), all of the genome – both its coding and non-coding regions – is mapped. Large-scale genetic testing has become a powerful weapon for understanding the genomics of rare diseases. It is this type of testing that was conducted on Anothando.

Better the devil you know

The results indicated that Anothando, Kabingesi's youngest child, suffers from Joubert syndrome. Suddenly, having a name for the condition, everything seemed less of a terrifying mystery to Kabingesi.

"I used to be crying alone, but I knew I was going to put this name – Joubert syndrome – into my phone and I was going to find out more for my Ano," she says.

She adds that, prior to receiving the test results, she blamed herself for Anothando's situation.

"I had been asking myself all that time if I did something wrong when I was pregnant; maybe I ate something bad or it was because I didn't remove my [contraceptive] patch till two months after I found out I was pregnant. But Prof Moosa was very calm with me and told me not to worry. She listened to me even though English is not my tongue; she heard what was in my mind and in my heart – she always meets me half of the way," says Kabingesi.

Being able to name a rare condition is a huge step forward for the families of patients, says Moosa. Next, matching the known characteristics of a condition with the patient's individual situation means a course of treatment, intervention and support can start to take shape.

In Anothando's case, support involved Moosa developing a long-term patient-doctor relationship with the family. Moosa intentionally goes beyond the reach of science and medicine, understanding that human connection too is a cornerstone of well-being, especially in the case of children, her key focus. After seeing the horrific pictures of Ano's hands, Moosa was able to motivate the fast-tracking of the housing application for Ano, as a special needs child, and her family. Kabingesi says: "I don't know what Prof Moosa did, but in the next few days, I got a call from the housing people and they said I must come fetch my keys for my house in Eerste River. And now my Anothando is much better."

No money, no data

For Moosa, the true value of science lies in closing the gap between, on the one hand, cutting-edge research and technological advances, and on the other hand, its application, thereby protecting the most vulnerable patients.

"Our first problem, however, is funding," she says. "We have the technology and the machines that do the sequencing right here in the state-of-the-art Biomedical Research Institute at SU, and we don't have a shortage of people coming forward, wanting to have testing done. But I only have enough money to do tests on maybe half of the people that I would like to test at the moment." (WES testing costs between R7 000 and R10 000 per patient.)

Moosa's research is currently being funded by the Early Investigators' Programme of the South African Medical Research Council. The aim, she says, is to have more people tested and diagnosed, and to create a larger database that can constantly grow to widen the scope of understanding of rare conditions. This is a dire necessity in Africa – even as the cradle of humankind, host to the greatest genetic diversity on Earth, the region is under-researched.

"Most genetic research and testing is not being done in Africa. This means that when I read the exome of one child or the genome of another and I find some 'spelling error' [a variant in the ways the genes have been sequenced], I often don't know how to interpret it. Is it something that is present in healthy African people or is it something to worry about? We don't know because the variation is simply not represented in the limited databases that we have."

Moosa says it puts the continent on the back foot and at a greater risk of falling behind as genetic medicine reshapes the future of healthcare by offering targeted and tailored medical care for individuals. She adds that it will also be a missed opportunity for the continent if it fails to, early on, invest in and adopt technology that will cut healthcare costs in the long run.

The case for mainstreaming genetic testing

From the examples Moosa offers, it is clear that the impact of genetic medicine is far-reaching. It can take patients with an undiagnosed condition off the merry-go-round of doctor visits and testing-related hospitalisation. It can eliminate the trial-and-error treatment of conditions by matching someone's genetic profile with a targeted drug regime. It enables the accurate assessment of a patient's risk, the prescription of the correct preventative measures, and timely intervention to stave off the onset of severe illnesses like cancer. It even improves a doctor's prediction of how a particular patient about to undergo surgery will tolerate different anaesthetic drugs.

But medical health insurance companies and authorities need to wake up to this shifting landscape of medical treatment, Moosa urges. Alongside the lack of funding, this is the second major hurdle to bringing genetic medicine to the mainstream.

"Ultimately, it doesn't matter which area of medicine you're looking at, incorporating genetics brings down costs. We are realising more and more that genetics should actually feature higher up in differential diagnosis. We need to be able to get this across to the Department of Health and to medical aids – it serves their purposes as well as that of our patients."

According to the World Health Organization, around 400 million people worldwide are affected by rare diseases. In South Africa, the estimate is 1 in every 15 people, says the non-profit organisation Rare Diseases SA. This means just over 4 million South Africans are living with a condition that affects a small minority of people within the general population.

In South Africa, there are about 7 000 known rare diseases, children being the worst affected. According to Rare Diseases SA, about 70% of rare diseases arise from genetic factors and are considered congenital disorders. For many people, their condition is not identified at birth but manifests later on in life only.

Photo by Damian Schumann

More geneticists, please

There's also a third barrier to making genetic medicine more routine: the dearth of medical geneticists, genetic counsellors, laboratory geneticists and bioinformaticians in the country, and of universities that offer training in this field.

This deficit renders the Rare Disease Genomics research group a rare beast. Says Moosa: "We need very advanced computer clusters to handle the amount of data that comes out of our sequencing machines and once this happens, we need a very skilled person or group of people to analyse and interpret the data. So, the bottleneck is not the long time (of up to six months) that it takes to get a test result; it's finding enough skilled people to interpret the data. Currently, there are only about 12 medical geneticists in the country. This workforce is not nearly enough to meet the needs of the population of undiagnosed families searching for answers."

Addressing this problem starts with improving genetic literacy among doctors, nurses and the general public, Moosa believes. Being able to better identify candidates for genetic testing means fewer patients fall through the cracks, left to believe there is no hope for them. Showcasing the potential of genetic medicine is one way to raise awareness of this developing field. In turn, this awareness can attract more professionals to careers in genetic medicine and in its sub-disciplines.

Molecular biology honours student Jess Cormick is one of the newcomers to the field, majoring in human genetics. She tells how she was first introduced to the Rare Disease Genomics research group and its genetics lab in the Biomedical Research Institute, nicknamed 'The Magic Lab'.

Whilst going for interviews to narrow down her choices of a unit at which to complete her honours research requirements, she came across Moosa's unit. Upon her arrival there, she saw bright colours, balloons and fluffy toys everywhere, she remembers.

"I was just thinking, 'What is this place?' when the professor explained that they were about to have a rare diseases day in the hospital and were taking these 'rare bears' – fluffy toys made especially for children with rare diseases – to the paediatrics unit.

"I could hear the professor's passion; she's all about the people behind the diagnoses. She always asks things like, 'Is this child going to be safe at home with the diagnosis?' or, 'Where can we put them in school?' And that's what drew me to the unit. I never went into science for the data, I went into science to help, in my small way, the people behind the data," she says.

This attitude and purpose make Cormick a star science communicator, especially when schoolchildren visit the unit. She explains: "Recently, we had some grade 11s visit us and I explained to them that I am not a doctor, so I don't give medicine to patients. I'm more like Sherlock Holmes, a detective looking for answers, finding out what the problem is."

Cormick's work involves channelling data through a bioinformatics pipeline, using different codes and thresholds to set filters for the data and, at each step, honing in further on the parts in the sequencing that point to a rare disease.

"We would filter, for example, for pathogenic variants, rare variants and other filters that come from existing databases," she says.

The value of an answer

Cormick contributes her findings to genetic data libraries and, ultimately, the field's global knowledge base so that other researchers and clinicians can lean on the documented information in their quest for answers. And when it comes to illness, an answer matters. Some people wait 15 or more years for a diagnosis – this is why Cormick believes genetic testing must become accessible as a part of mainstream public health services. For her, the true value of science becomes clear when she sees the young patients in the paediatrics ward simply being kids and their caregivers confident in knowing that they are not alone. "I couldn't imagine doing anything else," she says.

In Kabingesi's words: "As a mother, you sometimes know that something is wrong, but you don't want to go to the clinic because you are scared. But I want to say to others, 'It's better to know than not to know because it's only then that your child can be helped.'

"There are people who don't trust, but I ask God to give me strength and I trust the doctors because I can see that Anothando is walking now in this new house because she can hold onto the walls. It's like Prof Moosa says, I can see miracles with this child."

DIGITAL ADVANCEMENTS EXPAND

KNOWLEDGE OF AFRICA'S ECONOMIC HISTORY

WILLEM DE VRIES

Since the launch of the Laboratory of Economics of Africa's Past (LEAP), its projects have contributed to widening the scope of the economic and social history of Africa. The research group at the heart of this laboratory has done so in a systematised and innovative way, using quantitative tools to uncover facts and trends that inform a larger narrative, and breathing life into marginalised histories.

Prof Johan Fourie

Prof Johan Fourie is the coordinator of LEAP, which is hosted in the Department of Economics at Stellenbosch University (SU). He sees the group's work as representative of the renewed global interest in economic history since the early 2000s.

LEAP's first project (on the economy and social history of the Cape at the time of the Dutch East India Company, the VOC) ran from 2015 to 2019 under the leadership of Fourie and Dr Erik Green from the University of Lund in Sweden.

"This project started out with much less funding than is the case today. However, its potential was apparent, so we later received a grant from the Bank of Sweden's Jubilee Fund Foundation." According to Fourie, this grant of approximately R51,84 million (SEK29,4 million) is, to date, the largest amount awarded to a project of this nature in Sweden.

Telling our own stories

People absorb facts more easily through narratives, Fourie says – much more so than through statistics.

"When we think of history, we think of our own stories and how we fit into the bigger story. The challenge for economic historians is that we typically work with averages and not outliers, which is what traditional historians and biographers tend to focus on. However, to tell these stories – those of the average person at a certain time – you still want to write as if it were the story of an individual. It's an interesting challenge."

The large amounts of data LEAP analyses and then uses to calculate average trends give different answers to those offered by traditional historiography. "It also answers different types of questions," he points out.

"If you have a question about the average income of a person, you can't really find out more from newspaper articles, letters or the like. You need other techniques. And this is where we make an important contribution. Also, the book I wrote is a way to capture these broader trends in the stories of individuals so that they can serve as an example of the rest."

In *Our Long Walk to Economic Freedom,* published in 2021, Fourie examines lessons from economic history that span 100 000 years of human history, and engages with the question of what contributes to and detracts from creating wealth.

In writing the book, Fourie prioritised bringing African perspectives from the continent itself, rather than from elsewhere, to the economic history of Africa.

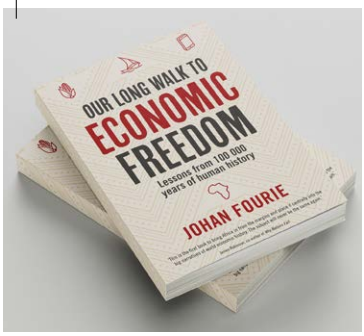
Since the start of 2022, author and historian Karen Jennings has been conducting postdoctoral work at LEAP. Her historical novel *An Island* was longlisted for the Booker Prize in 2021.

Jennings now aims to turn her research at LEAP into a narrative about the emancipation of slaves in the Cape. "This kind of work brings statistics to life and makes it a part of larger conversations. I'm very excited about it," Fourie says.

He is joined at LEAP by two other permanent staff members, Prof Dieter von Fintel and Dr Calumet Links. In addition to master's and postdoctoral students, an extensive group of collaborators, co-authors, and two extraordinary professors from the universities of Utrecht and Arizona are also involved in LEAP's research projects.

The group's interdisciplinary work shows that a topic such as the economic history of South Africa in the colonial era has substantially more to it than can be claimed by research done in a single traditional subject area. Moreover, it shows that such topics can now be unlocked on a scale previously impossible.

Our Long Walk to Economic Freedom is Johan Fourie's guide to global economic history, told from an African perspective.



Karen Jennings' novel *An Island* was longlisted for the Booker Prize.

Kathryn Smith and Pearl Mamathuma (artists) and Karl Bergemann (researcher), Fugitive, 2021. Digital facial composites and digitally remediated advertisements. Digital print on 300 gsm Innova paper.

More comprehensive research, faster

For LEAP's researchers, unlocking big data from the past requires the systematic analysis of various archives using techniques from the digital humanities. Academics working in this mode are expanding their existing research tools to include image recognition software, algorithms that help with text analysis, and programs that easily process large datasets.

> The digital humanities hold far-reaching implications for the pace and scope of research, as well as novel opportunities regarding its presentation and interpretation.

Part of LEAP's work is to equip the historians of tomorrow with knowledge of the new techniques through which sources can be analysed.

Explaining LEAP's work, Fourie says the physical source documents are first made available digitally, then transcribed. "One can do the transcription by hand. However, there are more and more machine learning techniques that can help you do that automatically."

"It is important to emphasise that LEAP is not saying the study of history as it is currently done, should be done away with. What we are saying is that some of the questions about history simply cannot be answered using traditional methods," he clarifies.

Attending to questions

"We at LEAP want to contribute to an international conversation. We have strong connections with some of the leading universities in the world. There is also a lot of overlap with other research units, notably with Research on Socioeconomic Policy (ReSep), the development economics unit in the Department of Economics here at SU. They ask the same question about poverty that we do about wealth. We learn a lot from one another.

"These high-quality research projects focus on a very complex society. As researchers, we especially want to bring to light the parts of history that were not fully illuminated before."

For example, how was wealth created in the Cape during the time it was governed by the VOC?

For the past seven years, this has been a central research question posed by the economic historians of the Cape of Good Hope Panel, LEAP's flagship project.

Tax returns reveal colonial history

The Cape Panel, funded until 2026, studies the development of the VOC's maritime service station in the Cape of Good Hope, as well as the region's economic growth in the ensuing years.

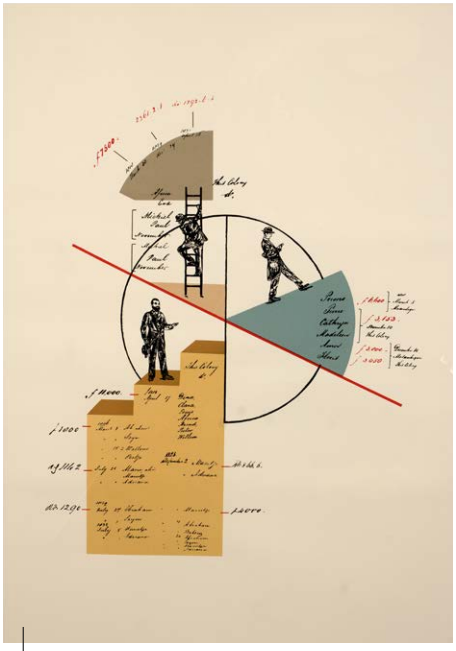
For the Cape Panel project, researchers have been focusing on the annual tax censuses that the authorities in the Cape collected between the 17th and 19th centuries. The archival documents that the researchers study and transcribe are kept in the Cape Archives in Cape Town and in the National Archives in the Netherlands. The latter also offers access to digital sources.

The Cape Panel constitutes a dataset documenting a complete settler population over a period of more than 150 years – the largest such dataset in the world, tracking multiple generations. Apart from settler numbers, the tax documents also provide insight into the economy of the settler population and that of the indigenous Khoesan population during the period 1652–1795.

By using tools and techniques of the digital humanities, the researchers involved have gained previously unprecedented access to data that reveals a detailed account of the economic development of South Africa at the time.

For the purposes of this project, LEAP is utilising the expertise of academics across subject areas, thereby broadening the base of their empirical work.

Fourie says the researchers of the Cape Panel will eventually have all the annual census data on the Cape's settler population available at the level of individuals and households. "The richness of this data is something that no one has been able to unlock before anywhere in the world. You can now follow people over time, generations even."



Chelsea Ingham (artist) and Kate Ekama (researcher), Men Who Mortgage Men, 2021. Colour hand-pulled silkscreen print on Arches paper.

Stephan Conradie (artist) and Kelsey Lemon (researcher), Mens Sana in Corpore Sano, 2021. Mixed media assemblage.

Usha Seejarim (artist) and Amy Rommelspacher (researcher), Reserved for Special Occasions, 2021. Enamel paint on enamel plate.

Different sources to complete the story

In addition to tax documents and family and slave registers, the LEAP researchers also have access to, among other things, estate inventories.

"Using all these documents, you start uncovering networks," Fourie explains. You can see who was at the auction of, for example, the French Huguenot Louis Fourie's estate after he passed away and who in the district attended it. You can find these people, in turn, in the tax documents. This research shows you dynamic networks over time."

Fourie says LEAP's projects increasingly utilise large collections of archival records to deepen the understanding of the South African past.

In one such project, titled 'Biography of an Uncharted People', researchers are piecing together data from administrative records to reveal the life stories of those who were typically excluded from conventional archival sources.

The Uncharted People project is currently funded by the Mellon Foundation and undertaken in conjunction with SU's Department of History.

The quantitative resources that LEAP investigates are not typically considered in qualitative historical research. The stories of individuals and families that get retold are enriched by the use of both types of data. Technology used in the Uncharted People project helps researchers bring to light previously unexplored lives of those that were marginalised and overlooked. Before, entire communities served as a static backdrop to the history of politics and the powerful few. Now, however, the researchers at LEAP intend for a multitude of individual stories to become accessible.

Creative spaces between the humanities and computer science

During the COVID-19 pandemic, LEAP paired 14 researchers with 14 artists to create visual interpretations of the research done for the Uncharted People project, thereby bringing to life the stories uncovered through quantitative research. PhD art student Clara Babette was the curator of the 'Charting the Uncharted' exhibition.

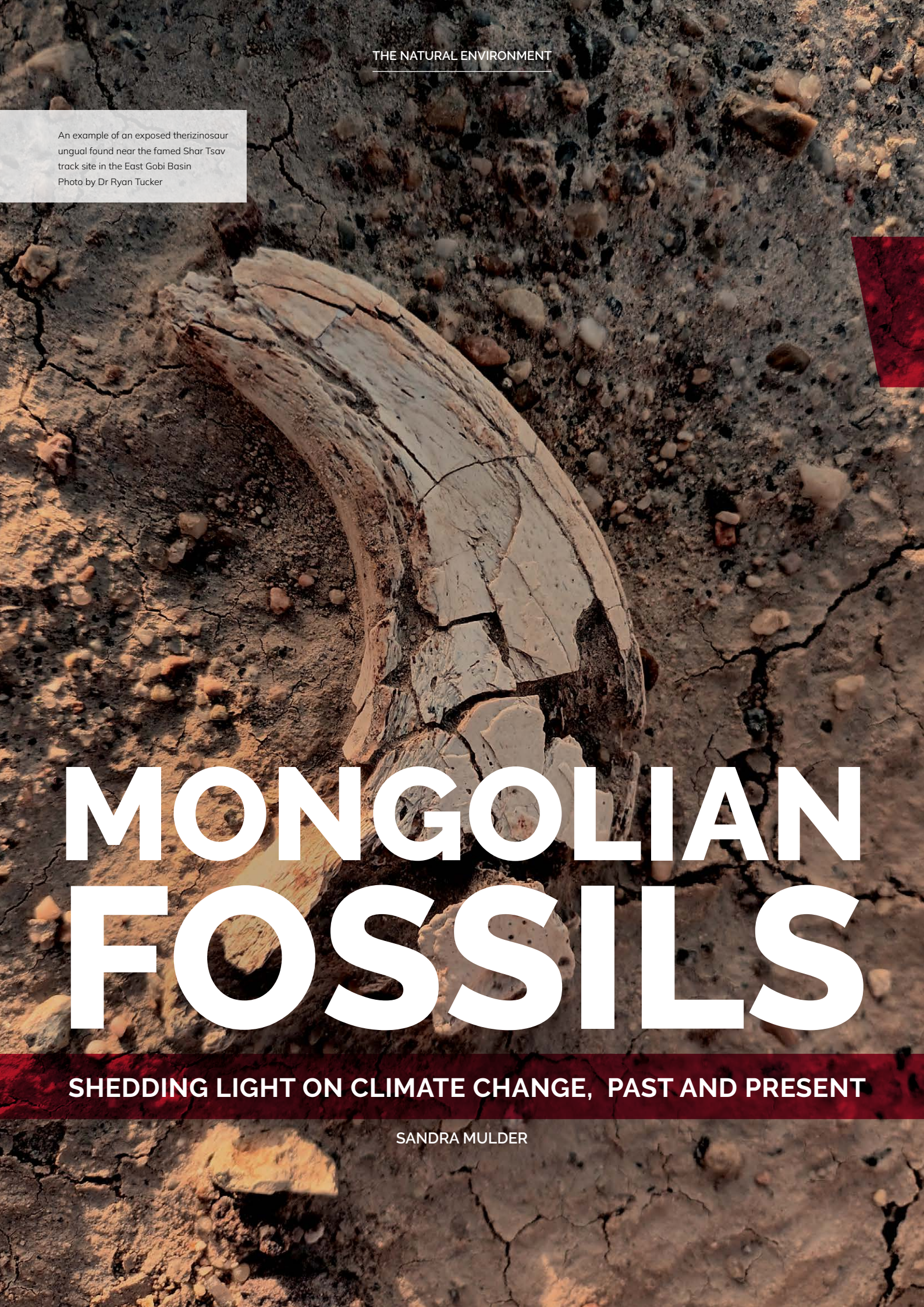
Its success led to the Dutch Embassy and consulate-general requesting five more commissioned works, which were exhibited in Cape Town's Castle of Good Hope as a part of the #cocreateIDENTITY Experience in June 2022. A selection of artworks was nominated as a digital humanities project finalist at the World Economic History Congress in Paris in July 2022.

Research into slavery in the Cape Colony

From the overall response to the Uncharted People project, there is clearly interest in research on slavery at the Cape, Fourie says. Yet, he points out, the study of slavery currently receives little attention at South African universities.

Personal and collective histories are cracked open by investigating large collections of archival records such as the slave emancipation records that detail the amount of compensation each slave owner received at emancipation. Dr Kate Ekama, a postdoctoral fellow at LEAP, is currently leading investigations into the period of slavery at the Cape.

Quantitative History and Uncharted People, to be published by Bloomsbury in the first half of 2023, offers an overview of the Uncharted People project.



An example of an exposed therizinosaur ungual found near the famed Shar Tsav track site in the East Gobi Basin
Photo by Dr Ryan Tucker

MONGOLIAN FOSSILS

SHEDDING LIGHT ON CLIMATE CHANGE, PAST AND PRESENT

SANDRA MULDER

Prof Ryan Tucker excavating a partially preserved hadrosaur from the upper Mussentuchit Member of the Cedar Mountain Formation
Photo by Dr Lindsay Zanno

The recent discovery of multiple fossil assemblages and ash deposits in the East Gobi Basin in Mongolia could provide new knowledge of the dinosaurs and extreme climate conditions on Earth 120 to 80 million years ago.

This is according to Dr Ryan Tucker, a sedimentologist and taphonomist (fossilisation expert) in the Department of Earth Sciences at Stellenbosch University (SU). Tucker is a member of the international team of scientists MAADEx (the Mongolian-American Alliance for Dinosaur Exploration) who undertook the expedition that led to the exciting discovery in September and October 2022. Under the leadership of Dr Lindsay Zanno of North Carolina State University (NCSU), the MAADEx team focuses on finding data on climate change in Earth's deep time, specifically the Cretaceous period (between 145,5 and 65,5 million years ago).

Tucker cannot reveal too much information about the discovery, as much of the recovered material belongs to new species yet to be named. "But in broad strokes, we found the fossils of a rather unusually large ankylosaur, what could be an allosaur-type theropod, several new dromaeosaurs (raptors), and one site locality with numerous preserved eggs and egg nests – all roughly from the middle Cretaceous period.

The Cretaceous period, in geologic time, is the last of the three periods of the Mesozoic era, having followed on the Jurassic period. During the Cretaceous period, oceans formed as land shifted and one big supercontinent broke into smaller ones. Though dinosaurs ruled throughout this period, the dominant groups shifted and many new types evolved.

The Cretaceous period began 145 million years ago and ended 66 million years ago, giving way to the Paleogene period. Spanning 79 million years, it represents more time than has elapsed since the extinction of the dinosaurs, which occurred at the end of the period.

Sources: National Geographic, Natural History Museum, and www.paleoportal.org

"We are exceedingly happy with the data discovered," he says.

During the five weeks spent at the Gobi site, the team was surprised to find ash beds, something that had never before been identified in the East Gobi Basin. "This will significantly improve our understanding of Earth's temporal framework, which currently spans a possible 40 million years. With these specific ash beds, we could improve that age estimate to within the span of 1 million years, which would allow us to meaningfully compare similar dinosaurs, both locally and globally," Tucker says. "The data found at the site will provide insights into what we possibly need in order to adapt to climate change in our present time and in the future. We try to compare the Mongolian fossil assemblages and ecosystems to those of Utah in the USA to test global patterns," he adds.

Exploring the past and present global climate crises

The recovered fossils, ash deposits and rock material are now at various laboratories in America, Stellenbosch and Mongolia. Scientists are determining, among other things, their age and climate proxies (preserved physical characteristics that enable scientists to reconstruct the climatic conditions, such as the average temperature, humidity and rainfall levels, during a specific time period). The expedition to Mongolia formed part of MAADEx's Cretaceous Terrestrial Ecosystems Project, which aims to fill knowledge gaps by exploring the impact of a global climate crisis on Northeast Asia's Cretaceous ecosystems. Previous research has found that Earth's climate is impacted by the ongoing tectonic processes (earthquakes and the movement of land) and changes in the planet's crust. Significant historical climate shifts have been linked to these factors.

Recent research indicates that substantial climate change occurred roughly 30 million years ago. Global warming was so intense that rainforests flourished on the South Pole. During this time – dubbed the 'mid-Cretaceous Thermal Maximum'

(CTM) – Earth's inhabitants experienced environmental and climatic disruptions due to movements in the planet's crust. More specifically, these changes resulted from the separation of the northern and southern hemisphere landmasses, Laurasia and Gondwana (which later respectively split into North America and Eurasia, and South America, Africa, Antarctica and Australia).

> Tucker states that the detrimental effects of climate change currently being felt globally could be linked to both natural causes and humans' alteration of the natural environment, but more research is needed to confirm it.

"Therefore, our team seeks to fill these knowledge gaps by exploring the impact of a global climate crisis on Northeast Asia's Cretaceous ecosystems. If we are successful in obtaining sufficient research funds, our research will allow us to better understand the effects of the CTM event in the East Gobi Basin of Mongolia, allowing us to capture palaeoclimate environmental proxies for global comparisons in a modern or future context."

High risks, high rewards

Tucker plans to return to Gobi next year with postgraduate students, who will benefit significantly from prospecting there. "Besides helping to explain the region's cryptic geology, they will also be prepared for a very successful and rewarding career because of the unique nature of the fieldwork and the complexity of the geology there. I hope to find funding to take the students to Mongolia next year and for many years to come. It holds such a special place in my heart now," Tucker says.

The Mongolia project team seeks 'high-risk, high-reward' areas to do their prospecting. "With the aid of historical geological maps and satellite imagery, we assess areas with good rock exposure and high relief, and lacking human modification," says Tucker. "In these areas, the risk of not recovering any fossil material is high, but so is the reward if we do find something because it will typically be new to science."

The East Gobi Basin is one such a site. According to Tucker, there is still a wealth of data to be found there. "We've just scratched the surface, and we've barely covered a fraction of the geographical area we intended to. We've seen very little of what there really is."

Tucker's life calling

Tucker's desire to do the work he does today arose when he was a young boy in a kindergarten in Montana, America. "I have always been fascinated by dinosaurs and similar forms, and vividly remember telling my kindergarten teacher I wanted to dig up dinosaurs." At age five, Tucker realised his love for the carnivore *Tyrannosaurus rex*. "My parents took me to the Denver Science Museum. As the doors opened, a newly mounted *T-rex* was in the foyer. I stood there for an hour, unable to move, in awe of what I saw. At that exact moment, I knew it was my calling to do work on dinosaurs.

"A few years later, I was lucky enough to take part in a local palaeontological dig at the early age of nine. After that, in my teens, I was able to work in the famed Morrison Formation of Southern Wyoming with Dr Robert Bakker and, after that, the Hell Creek Formation in Montana with Dr Luis M Chiappe of the Los Angeles County Museum of Natural History, a person who set the foundation for my future career in the palaeosciences," Tucker remembers.

A shift in his interest and move towards sedimentology came about when he, as a teenager, still worked at the Montana site where the famous 'Thomas the T-Rex' was excavated. "A geologist from the American Museum of Natural History came and conducted a geological assessment of the locality where we were working," Tucker recalls. "Dr Lowell Dingus [renowned palaeontologist and author] started to paint an environmental picture around the *Tyrannosaurus* skeleton we were excavating. The remains were entombed within a river channel, with bones sorted based on size and weight due to the energy of the current. Lowell pointed out the riverbank, which had preserved evidence of bioturbation (worms and insects churning up the sediment), and the adjacent floodplain filled with the remains of a complex ecosystem of flora and fauna. The picture he painted that day got me hooked and has stayed with me ever since," Tucker says.

The experience on that landmark day made him realise that a fossil's environment holds just as important information as the fossil itself, sometimes even more. "It's enthralling to assess a fossil assemblage as a crime scene by using clues left out in the rain for tens of millions of years."

Building a career

Palaeontology and similar disciplines are competitive fields, with most job opportunities being at universities, museums or companies that conduct monitoring services during construction in sensitive areas. "A few jobs require an MSc, but most require a PhD or postdoc experience. Recently, however, positions within media companies have become more common due to the public's fascination with dinosaurs, which has been akin to pop culture since the early 1900s," Tucker says.

According to him, it is a bit easier to develop a career in sedimentology as the field has a broad application in environmental studies and applied geology. "Even financial companies will seek out sedimentologists or geologists as they can work with incomplete data sets and still draw meaningful conclusions or formulate estimates," he explains.

Since he started working for SU eight years ago, teaching students has become another highlight of Tucker's career. "I can think of no better feeling than seeing a student's 'lightbulb' of understanding go on when they're learning a complex concept or principle within sedimentary geology. Every time that happens, I feel like I've accomplished something meaningful," he says.

But the career of a sedimentologist and taphonomist holds its challenges. Fortunately, Tucker is geared toward them and has a positive mindset. "For the most part, the challenges of the job are minimal, because I'm doing what I love. The old saying, 'Do something you love and you'll never work a day in your life' is very true. I've spent much of my life dreaming about doing exactly what I do now. I feel very fortunate. I'm still the kid in the sandbox digging up a dinosaur."

Doing fieldwork, staying in remote areas in a tent with no bathrooms, kitchens, shops or people nearby is the easy part of his job, says Tucker. "As long as I have good coffee in the morning, that is." To him, the biggest challenge is not surviving fieldwork in remote areas but securing the necessary funds to do their work. "Travelling to and staying in remote areas is a perk of the job. I try to be outdoors as much as possible. I feel very fortunate that, for a part of the year, my office is in some of the most remote places on Earth. It's pretty special to have that in this day and age."

Other international expeditions

In 2013, Tucker was still completing his PhD, which focused on the middle Cretaceous sedimentary record of northeastern Australia, when he first met Dr Lindsay Zanno at a Society of Vertebrate Paleontology meeting in Los Angeles.

"Over tacos and drinks, Zanno and I discussed, at length, the lack of knowledge concerning critical points in the evolutionary history of terrestrial life in the Mesozoic era, especially the Cretaceous period," Tucker says. According to him, despite years of ongoing research, the Cretaceous period remains an enigmatic phase of Earth's rock history, filled with global warming and cooling, sea-level rise and fall, drifting continents and cataclysmic extinctions.

"As such, we decided to start collaborating on two key projects. I was invited to join Dr Zanno's crew on a new project involving the Mussentuchit Member of the Cedar Mountain Formation in Central Utah."

At the same time, Tucker motivated Zanno to join a new project he had recently initiated, relating to similarly aged sedimentary rocks in the northeast of Thailand and in west-central Laos, a region known as the 'Khorat Plateau'. The partnership has also resulted in collaboration with NCSU, which is successfully bringing together a broad network of educators, administrators and scientists to implement citizen science projects in classrooms around the Western Cape.

"As a result of this collaboration between SU and NCSU, we developed complementary programmes, including the Palaeosciences Peer Mentorship Programme, or 'PPMP'. All SU's postgraduate students in Earth Sciences are involved in the PPMP, which comprises collaborative projects for especially SU students who gain support, advice and educational assistance in navigating their academic journeys," says Tucker. The PPMP also involves SU's Sedimental Research Group (SRG), a collaboration between SU staff and students that focuses on providing students with opportunities to investigate continental fossil assemblages preserved in the sedimentary rock record, and to participate in a dynamic, global research network.

"Through my work with Lindsay and our team, I have learnt how valuable it is to be part of a team that you can always count on, especially in the thick of it, both in and out of the field," says Tucker.

While the specific collaborators change depending on the project, there are three core teams that Tucker engages with:

The Mid-Cretaceous team, based in the USA, includes Drs Celina Suarez and Glen Sharman (University of Arkansas), Dr Pete Makovicky (University of Minnesota), Drs Rich Cifelli and Rick Lupia (University of Oklahoma), Dr Marina Suarez (University of Kansas), Dr Ethan Hyland (NCSU), and Dr Ryan King (Western Colorado University).

The PasSaGE (Thailand and Laos) team: Drs Lindsay Zanno, Terry Gates and Ethan Hyland (NCSU, USA), Dr Wasinee Aswasereelert (Kasetsart University, Thailand), Dr Ryan King (Western Colorado University, USA), Dr Rattanaphorn Hanta (Suranaree University of Technology, Thailand), and Dr Apsorn Sardsud and Sasa-on Khunsubha (Department of Mineral Resources, Thailand).

The Mongolia team: Dr Lindsay Zanno (NCSU, USA), Dr Ryan Tucker (SU), Drs Junki Yoshida and Ryuji Takasaki (Hokkaido University's School of Science, Japan), Drs Khishigjav Tsogtbaatar and Tsogtbaatar Chinzorig (the Mongolian Academy of Sciences' Institute of Paleontology), Dr Celina Suarez (University of Arkansas, USA), and Dr Marina Suarez (University of Arkansas, USA).

Photo by Dr Lindsay Zanno

SYSTEMS AND TECHNOLOGIES FOR THE FUTURE

PUTTING DATA AVALANCHES TO WORK TO SOLVE THE WORLD'S PROBLEMS

ENGELA DUVENAGE

Prof Kanshukan Rajaratnam
Photo by Stefan Els

By the end of this year, the world is expected to have produced 94 zettabytes of data and have 4,95 billion active social media users, all creating more data on a daily basis. Some might feel engulfed by this avalanche of data, but others see it as an ideal opportunity to mine for solutions to the world's problems, quite literally bit by bit.

The School for Data Science and Computational Thinking, a transdisciplinary research and teaching entity at Stellenbosch University (SU), falls into the latter opportunistic group.

As it states on its website: "Artificial intelligence, robotics, the Internet of Things, autonomous vehicles, 3D printing, precision medicine and quantum computing hold the promise of radically changing all aspects of society. At the core of these advances are the rapidly developing fields of data science and computational thinking."

As founding director, Prof Kanshukan Rajaratnam is helping lay the strong foundations on which the School is being built.

Years ago, Rajaratnam had the misfortune of having to dig his car out under a metre of unexpected snow on the American East Coast. The snowstorm made the Sri Lankan-born systems engineer seriously rethink his career options in the USA, so much so that he decided to carve himself a niche in his adoptive country of sunny South Africa.

What followed was work in the South African banking and finance sector, in research and in academic administration, all before he was appointed as the director of the School for Data Science and Computational Thinking in 2020.

At its launch in 2019 already, SU rector and vice-chancellor Prof Wim de Villiers described the School as "a game-changer in higher education, both in South Africa and beyond" and as "a vehicle for SU to help enhance South Africa's competitiveness in the Fourth Industrial Revolution."

Rajaratnam revels in his leadership role, proud of the contribution that distinguished experts associated with the School have already made towards understanding quantum computing, cybersecurity, conflict resolution, conservation and health matters, including the distribution, epidemiology and long-term effects of COVID-19.

Rajaratnam's systems engineering training helps him maintain a multidisciplinary perspective on the School's organisational matters, short courses and projects.

"We must constantly think how we impact Africa," he says. "Its problems are big – from governance, food security and energy issues to emerging diseases and the impact of the climate. There are great opportunities for data scientists to help provide solutions by working with people who are domain experts."

He believes the field of data science will increasingly contribute to personalised and precision medicine, and help develop pharmaceutics tailored to people from specific demographic groups.

Where humans and data meet

About the SU Rectorate's vision to build the School into a world-class institution for data science and computational thinking in and for Africa, Rajaratnam boldly notes: "If we can figure out Africa, we can figure out the rest of the world. And that's an opportunity."

He sees it as a major benefit that much of the input and investment needed to make this endeavour a success is "highly cerebral" and people-driven, rather than necessarily hardware and infrastructure intensive.

> "Data science is in some sense a cheap way of working because computers, cloud infrastructure and fibre links have become much more accessible and pervasive across the continent."

Rajaratnam foresees many job opportunities opening up for Africa's bright, entrepreneurial and increasingly tech-savvy youth looking to play a role in their communities and countries. Also, the continent is free of the drawback of legacy infrastructure and can therefore adopt the most suitable technology to solve the blizzards of known and emerging problems.

"Our biggest challenge is to stay relevant yet innovative, also in terms of capacity, and to constantly consider how we impact Africa. One way of doing so is to pivot one's research from one space to another. This is, for instance, what biomathematicians and epidemiologists did when they moved from studying the HIV pandemic to COVID-19, and now also other emerging diseases."

Transcending boundaries

The School's appointment structure reflects its non-typical, transdisciplinary way of doing business. Most staff members hold joint appointments at the School and at an academic faculty such as that of science, engineering, and medicine and health sciences.

In the name of research and training in the data sciences, the School is purposefully moving away from independent research silos. Rajaratnam explains: "Joint appointments involve multiple relationships. We are learning on the job how best to manage them. It starts with a conversation to see what's possible."

By late 2022, there are already 11 academics and 10 postdoctoral fellows in the School's ranks. Among them are the renowned quantum scientist and interim director of the National Institute for Theoretical and Computational Sciences (NITheCS) Prof Francesco Petruccione, the AIMS-Canada Junior Chair in Data Science for Climate Resilience Dr Emmanuel Dufourq, the Capitec Chair in Applied Artificial Intelligence Prof Bruce Watson, and Shane Josias and Dr Sydney Kasongo, co-leaders of the Standard Bank Lab.

A sterling example of the calibre of researchers associated with the School is that of Prof Tulio de Oliveira, director of Africa's largest genomics centre, the Centre for Epidemiological Research and Innovation (CERI). He holds joint appointments in the School, SU's Faculty of Science and its Faculty of Medicine and Health Sciences.

De Oliveira, internationally credited for sequencing the Omicron COVID-19 variant, was named one of *Nature*'s 10 most influential scientists of 2021. In addition, the prestigious Massachusetts Institute of Technology's *MIT Technology Review*

listed his work towards identifying and tracking COVID-19 variants as one of 2022's top 10 technological breakthroughs.

Rajaratnam views the support De Oliveira has received from the South African government as being grounded "in deep respect for the quality of open science" that De Oliveira and other scientists in South Africa advocate for.

Another joint appointment is that of Prof Brian Ganson of the Stellenbosch Business School's Centre on Conflict and Collaboration (formerly the 'Africa Centre for Dispute Settlement'). His team is collaborating with the Copenhagen Business School and the University of Pennsylvania to develop a business and conflict barometer. This tool uses publicly available social media posts, reports and news articles to assess and advise on conflict situations in African countries in real time, ideally before conflict erupts.

"It's about confronting the myriad ways that the private sector is implicated in the creation and maintenance of conflict, and about finding pathways to address them," explains Ganson.

Adds Rajaratnam: "All of science is increasingly moving into a multidisciplinary, transdisciplinary space, even more so in the data science and computational thinking world. You'll never use lab methods from the biological sciences in economics. But data is data. Data science can bring multiple disciplines and groups together by sharing the methods used to handle data and do modelling, and by talking about how each discipline handles issues of privacy and ethics."

To circumvent the potentially costly affair of creating new data, these issues must be top of mind whenever data is shared between projects.

But is it ethical?

Rajaratnam predicts the emergence of novel job types such as data auditors, data ethics specialists and data legislators – all career paths in the tech domain that also involve the humanities. He foresees business project teams having at least one ethics specialist in an oversight role similar to that of a research ethics committee that considers the implications and possible human rights infringements of projects.

"Ethics already quite helpfully allows one to think about whether something is morally right or wrong, even when legislative frameworks are not yet in place. Questions about when personal data can be used for the greater good, for instance, are increasingly important philosophical questions."

Ethical considerations relating to artificial intelligence and the upskilling of people in digital citizenship were among the first topics tackled in online workshops and short courses presented by the School's teaching arm, the African Data Science Academy (ADSA). There have also been a number of introductory short courses on data science and the use of R, a particularly powerful software program for data analysis and graphical representation.

"Through ADSA, the School builds capacity in data science not just in South Africa and Africa, but across the world," says Rajaratnam. He adds that the School also develops and supports bespoke courses for industry and academic partners.

During the course of 2022, Rajaratnam delivered a presentation on equity, ethics and legalities in the digital world as part of an online graduate seminar on digital citizenship, run in collaboration with KU Leuven (Belgium), SU, Waseda University (Japan) and Venice International University (Italy). In November

2022, the programme culminated with a week-long, in-person event in Venice, where Rajaratnam again presented.

In conjunction with Praelexis, the School will also be hosting an in-person machine learning summer school in Gordon's Bay in January 2023.

Moreover, SU researchers in the School and in the Faculty of Medicine and Health Sciences are currently collaborating on a data science, artificial intelligence and medical ethics project funded by the National Institute of Health.

Rajaratnam is heartened that, in universities across the globe, data science is becoming both a study field in its own right and a focus area within other fields, and that the big data space in countries such as Rwanda and Ghana is expanding. He also feels privileged to have provided input into the plans and business models of big data initiatives at other institutions.

"We build on each other. The question is how we leverage this relationship to build something even better."

TYGERBERG AT FOREFRONT OF SURGICAL TRAINING WITH

DA VINCI ROBOT

SUE SEGAR

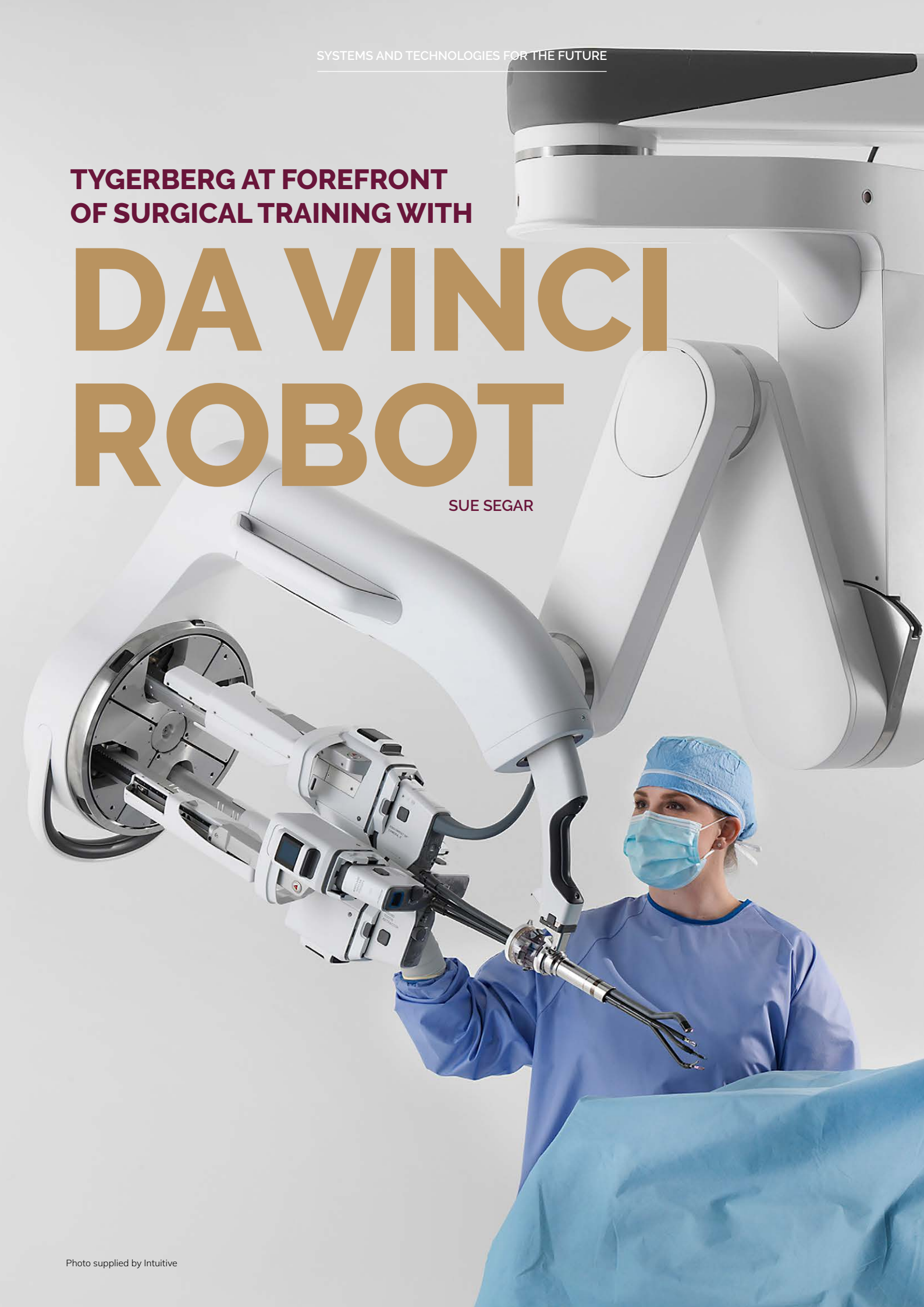


Photo supplied by Intuitive

The future of advanced surgery undoubtedly lies in technology and, increasingly, in using robotics for complicated surgical procedures. As such, it was a big moment for Stellenbosch University's Faculty of Medical and Health Sciences (FMHS) when, in February 2022, the first operation using the newly acquired Da Vinci Xi robot was performed at Tygerberg Hospital in Cape Town.

Since then, dozens more operations have been successfully completed using this highly sophisticated robotic system. It is currently being used across multiple platforms – in general surgery, urology and gynaecology – to perform a wide range of procedures.

The Da Vinci Xi is the most advanced surgical robot in Africa, and one of only two such robots in use on the African continent. (The other one is used at Groote Schuur Hospital, also in Cape Town.)

> This robot allows surgeons to operate remotely, using four dexterous 'arms', and is controlled in real time via an immersive 3D console.

Tygerberg Hospital's acquisition of the Da Vinci Xi robot means that public-sector patients now have access to the best surgical technology available anywhere in the world.

Dr Tim Forgan, a colorectal surgeon at Tygerberg Hospital and a lecturer in the FMHS, says the availability of this robot offers a valuable opportunity to illustrate the high levels at which state hospitals can function.

Forgan was the leader of the surgical team at Tygerberg Hospital that performed South Africa's first robotic gastrointestinal surgery procedure at a public hospital when they removed a cancerous rectal tumour from a patient. He says the robotic system means public-sector patients "will now be able to return to their previous lives that much sooner."

The robotics training programme

In tandem with acquiring the robot, the FMHS also developed a robotics training programme with the aim of upskilling hospital surgeons and senior trainees in the use of modern surgical systems across multiple disciplines.

"Surgery is progressing rapidly on the high-tech front, making it safer and more efficient. Tygerberg already has some of the most advanced, minimally invasive surgical skills in the country at its disposal. So, being able to promptly apply these skills to the robot is very beneficial for patients, and substantiates the reputation of Stellenbosch University for producing excellent surgeons," says Forgan.

"The robot arrived at the hospital in October 2021. We set up a robotics training programme as there is a steep learning curve for trainees to learn to use these machines," he says.

Training in the use of the Da Vinci Xi robot consists of three consecutive phases: the development of basic coordination skills, in-service training on how to use the robot, and hands-on surgical training.

"Once the trainees have been through these phases, they are accredited as robotic surgeons. Each branch of surgery has its own requirements for the number of cases to be done before the surgeons are accredited," explains Forgan.

According to him, a new case has been performed every week since the first operation with the robot. "For us, it has resulted in the incremental development of our skills. We have been doing laparoscopic surgery in our department for 30 years. The robotic process uses similar techniques, with nicer tools. It is a natural evolution in our skill set."

Forgan says the integration of robotics into medicine to enable minimally invasive surgery is becoming more and more commonplace. "As it does, the price will come down, so access will be improved. Hopefully, this kind of surgery will become the norm, resulting in better patient outcomes.

"Our goal is to improve the quality of our surgery, with the aim to better results and, in the long term, expand this to more and more patients, and more and more branches of surgery or patient care."

"Incredible benefits for patients"

Prof Elmin Steyn, head of the FMHS' Department of Surgical Sciences, says the acquisition of the robot has put Tygerberg Hospital at the forefront of surgical training in South Africa and Africa at large.

She stresses that, by the time the robot arrived, the colorectal team had already been performing advanced surgical techniques and were well prepared for the new challenge. "The robot enables us to showcase the capabilities of a state hospital, and enhances subspecialist training in the FMHS.

"As surgeons, we are so excited when we get new toys – and, of course, they bring incredible benefits for patients too. The fact that patients are discharged earlier is good for the state hospital system and much more cost-effective, but the real benefit lies in risk reduction and the potentially improved surgical clearance of cancer tissue," she emphasises.

"It is a huge privilege to have this equipment. We are highly aware of the responsibility to make the best possible use of it, training as many people and benefitting as many patients as we can."

ROBOTIC SURGERY WITH A HUMAN TOUCH

Photo supplied by Intuitive

LINDSEY SCHUTTERS

The Da Vinci Xi robotic system has put Stellenbosch University (SU) at the cutting edge of minimal access surgery in Africa. This type of surgery is performed through one or more small incisions rather than a single large one.

The operating room of the future will still include surgeons, but they will have been trained to pilot machines like the Da Vinci Xi across a range of minimally invasive procedures, within their specific discipline. The performance of the country's first six robot-assisted total hysterectomies at Tygerberg Hospital in June 2022 constituted the first exciting step into this future.

Learning to wield a robot

Robotic surgery training is very different to regular surgical training because the manufacturers have developed specific training modules for each type of operation. Proficiency in traditional laparoscopic procedures (which involve inserting a long, thin tube into an incision in the body so as to perform an examination or surgery) is attained in three steps: first observing procedures, then assisting in them and finally performing them. Surgeons using robotic instruments, however, must complete the full certification process associated with each individual procedure.

This process includes training on the specific type of surgery, followed by simulated operations on animal models and cadavers, and then assisting in real procedures. The final step is having a proctor assist with and oversee a certain number of surgeries to evaluate the surgeon's mastery of the instrument for the final certification.

"Surgery is all about simulation, training and practising. Training to use a robotic instrument is no different. You can compare it to flight simulation because the shared goal between aviation and medicine is to ensure safety," says Dr Viju Thomas, head of the Faculty of Medicine and Health Sciences' programme in minimal access gynaecological surgery.

The Da Vinci Xi robotic system was under his control during the first of the three groundbreaking hysterectomy procedures performed at Tygerberg.

"Remember, we're not learning a new procedure, because we are trained surgeons," he clarifies. "We're learning how to use the instrument to do the procedure, and making sure our support staff are also well versed in working alongside the instrument."

Robotic surgery could potentially be performed remotely, with the surgeon operating the robot from another location. However, Thomas cautions that – while there would probably be no technical limitations such as lost data connection and high input lag – there are concerns around the patient experience.

> "SU recently hosted a South African Society of Gynaecological Endoscopy congress where we did the first live surgical broadcast from Tygerberg Hospital. Doing so, we trained about 200 surgeons on laparoscopic surgery and introduced them to the concept of robotic surgery."

Academic institutions have an important role to play in exposing surgeons to advanced techniques such as these, while demonstrating the correct ethics and principles to follow. While the high acquisition, maintenance and operational costs of the Da Vinci instrument limit its widespread use across a variety of procedures, the University is maximising its use to deliver as much value as possible to the Western Cape Health Department, its project partner.

"While we are not expecting it to dramatically affect public health in the short term, you will be surprised how high-level technology can impact primary healthcare," says SU Dean of Medicine and Health Sciences Prof Elmi Muller.

"If you leave out advanced medicine from the healthcare ecosystem, you will soon find yourself in a position where you've capped what you can do for healthcare in the country. That cap results from losing high-level specialists but can also be from not keeping up with technology. Either way, your healthcare industry stagnates or moves backwards."

Who reaps the benefits?

Muller also highlights the potential for these advanced technologies to drive interest and, importantly, promote intensive research. The latter aligns with the University's goal of being the continent's premier research-intensive institution.

While the instrument itself and the associated maintenance and training are major expenses, the benefits of using the Da Vinci Xi include shortened hospital stays (which, in turn, lowers costs) and an overall improvement in recovery times. Ultimately, it could mean better access for a wider range of patients. It is with this in mind that Muller warns against siloed thinking and encourages a more holistic view of the robotic surgery programme's overall impact.

SU is using research on minimally invasive surgery as an opportunity for collaboration across departments with a view to engaging and developing the entire employment and skills ecosystem that supports the functioning of a robotic instrument like the Da Vinci Xi.

The University is exposing tomorrow's medical technicians to the latest technology, which will positively impact their careers. This makes SU an attractive learning destination for global talent.

"Minimally invasive surgery techniques have an extraordinarily positive effect on patient well-being," explains Muller. "Pain functions differently in muscle tissue than it does in skin, so reducing the size of the incision has a dramatic impact on patient comfort and has shown to reduce hospital stays as well."

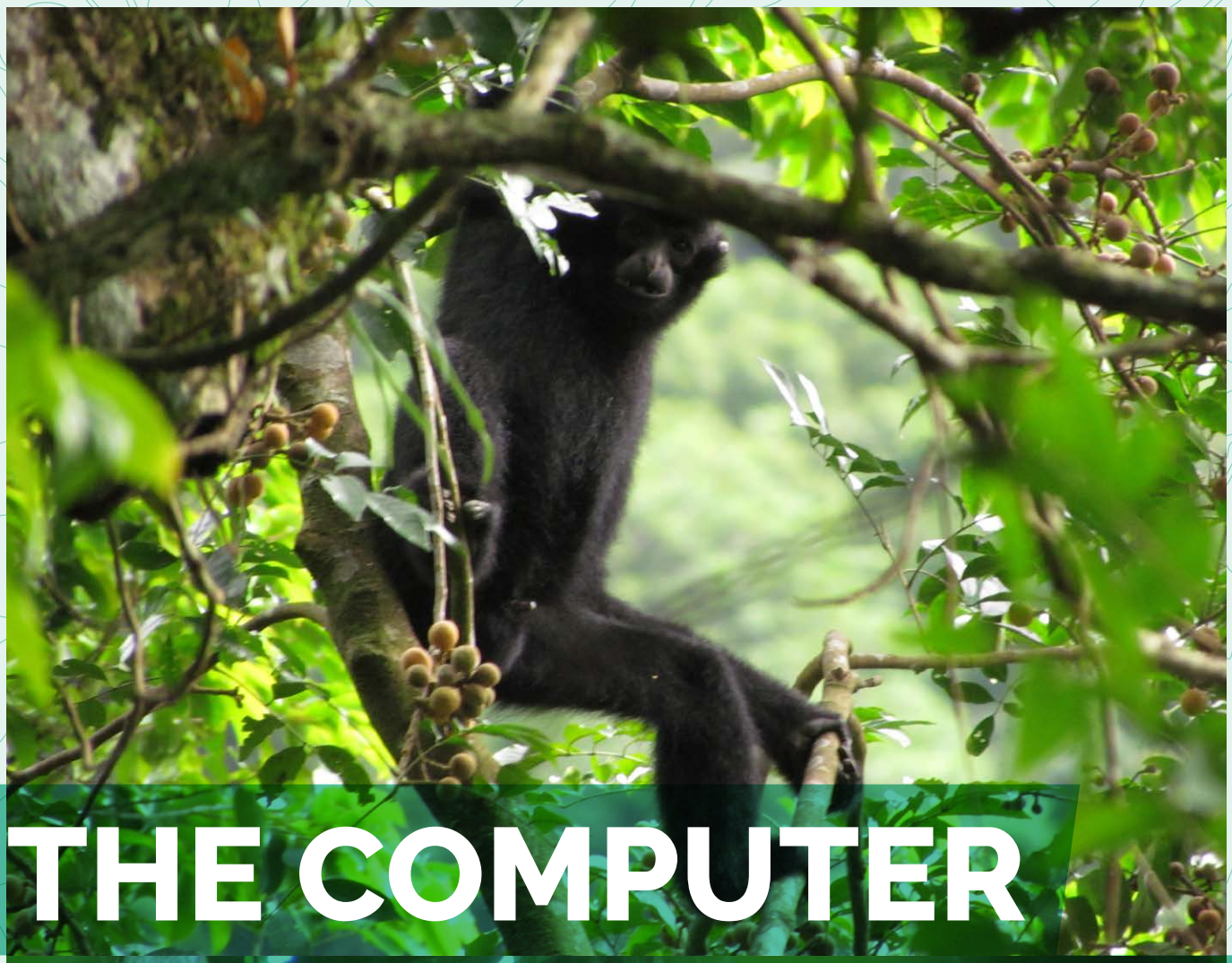
The combination of attracting highly skilled individuals and the networking effects of working with advanced technology can only increase the value of the robotic surgery programme to the University.

Muller believes there is also potential for the programme to increase faculty revenue, should the University actively seek out additional funding to empower more medical professionals. Moreover, additional funding to purchase another instrument could increase the University's research output.

With modern communication technology, it is now also possible for surgeons to receive live, on-the-job remote training from international experts.

"Surgery is a very interesting thing. Even if you're very experienced, it's still sometimes daunting to be in a situation on your own when you know you must approach something difficult and don't have a senior person with you," explains Muller.

"These operations with remote surgeons open up possibilities for people to feel supported, and it exposes them to global best practice."



THE COMPUTER CONSERVATIONIST

ENGELA DUVENAGE

Photos by Jessica Bryant (Zoological Society of London)

Dr Emmanuel Dufourq has never seen one of the last 30 remaining Hainan gibbons on Earth, but he knows very well what their calls sound like, or at least what a spectrogram image of the highs and lows of their chatter looks like.

"Their calls are very singsong. They sing individually and then, at some point, they sing together. It's a very pleasant sound," says Dufourq, the African Institute for Mathematics Sciences (AIMS) Junior Chair in Data Science for Climate Resilience and a lecturer in Stellenbosch University's (SU's) School for Data Science and Computational Thinking and its Department of Industrial Engineering.

Hainan gibbons (*Nomascus hainanus*) are considered the rarest apes on Earth, and among the world's most threatened mammals. Most of these gibbons live in two square kilometres of forest on Hainan Island in the South China Sea. A gibbon weighs about as much as a human baby of a few months. Males are almost completely black in colour, while females sport a combination of golden to buff fur and black patches on their heads. The nearest Dufourq has come to visiting the home of these rare apes was in 2013 when he visited Vietnam to present a paper on his MSc work. The latter focused on using genetic programming for data classification, a technique in the field of artificial intelligence.

"My journey has evolved from wanting to be a computer scientist to wanting to do something impactful. And then I found ecology," explains Dufourq, an avid nature photographer.

These days, he is something of a 'computer conservationist'. As the leader of the Data Science for Eco-Systems (DS4ES) research group at SU, Dufourq uses his computational skills to make it easier for conservation ecologists to analyse the large volumes of animal sound, video and photo footage that they capture for their research. His group's mission is to do this one keyboard stroke, one algorithm at a time.

> "We are trying to use all the tools we have in the fields of mathematics and machine learning to support conservation ecology projects, and to assist field rangers," he explains.

"We are one of the few research groups in Africa using machine learning for ecological outcomes. It's really rewarding to know that, in the process, we are developing students to improve the combination of these two fields," says Dufourq, who works with collaborators at, for instance, AIMS, the University of Cape Town, the University of KwaZulu-Natal, the University of Lisbon in Portugal, the University of St Andrews in the United Kingdom, and various non-profit organisations around the world.

Dufourq's interest in bioacoustics and the manner in which it can be used to conserve the planet and its inhabitants was first piqued in 2019. He was finishing his PhD in applied mathematics at the University of Cape Town when a statistical ecologist told him about an interesting conundrum faced by a group of British ecologists.

"The Zoological Society of London, along with their collaborators, had collected a very large dataset of about 1,5 terabytes of gibbon call recordings – hours' worth – but did not have anyone to process it."

To easily transform these recordings into something truly useful to researchers became Dufourq's mission during his postdoctoral years. His work has since shown that methods such as data augmentation can be used to automatically and quite accurately convert sound recordings into spectrograms, which are in turn automatically classified as images.

"Our best model converted acoustic recordings into spectrogram images on the mel frequency scale, using these to train a convolutional neural network," Dufourq and his fellow researchers wrote in a 2021 article on this topic, published in *Remote Sensing in Ecology and Conservation*.

"Our model is a time-saver of note", he says. "A post-processing step that identifies intervals of repeated calling managed to reduce an eight-hour recording, for the purposes of manual processing, to an average of only 22 minutes. Moreover, it did not miss a single calling bout over the 72 hours of test recordings."

Dufourq believes the model can be adapted for use in the analysis of other animal sounds too. He and his students have since started working on algorithms to automatically monitor animal behaviour captured in large datasets of video footage and images. The specific focus of the students' work ranges from the body language of endangered African penguins to the calls of Indian humpback dolphins in False Bay, understudied beaked whales, spotted hyenas, endangered birds in Malawi, and the critically endangered black-and-white ruffed lemurs in Madagascar. Some are developing an algorithm to identify and count the birds caught on webcam footage in South Africa's national parks.

Much effort is being put into compressing the sound files that researchers collect so that it is easier to analyse in real time, as opposed to only after the recordings have been made. The conservation of the planet is top of mind in all these efforts. "Model development and implementation must always be informed and guided by ecological objectives," Dufourq emphasises. "We cannot solve climate change, but we can at least solve the problem of ecologists wasting 6 months of work on processing 10 terabytes of data, when we can do it in 10 minutes."

RECKONING WITH THE TRAUMA OF THE PAST:

THE AFTERLIFE OF VIOLENT HISTORIES AND THE WORK OF REPAIR

JORISNA BONTHUYS

Illustration by Doret Ferreira

In April 1996, during the first week of the Truth and Reconciliation Commission's (TRC's) public hearings in East London's City Hall, Nomonde Calata uttered a cry, piercing and haunting. It burst out with such a force that it threw her torso backwards and then forwards.

Prof Pumla Gobodo-Madikizela
Photo by Stefan Els

"It was a scream that really indicated the pain that came from not just deep within her body, but from deep within the body and history of a community with wounds that go back several generations," says Prof Pumla Gobodo-Madikizela, the director of the Centre for the Study of the Afterlife of Violence and the Reparative Quest (AVReQ) at Stellenbosch University.

Long after Calata broke down during her testimony, the sound of her pain echoed beyond the walls of the packed colonial-era building on Oxford Street.

"That scream still haunts many of us who were present on that day," Gobodo-Madikizela recalls. "Ms Calata was screaming at a past, calling up deeply buried emotions that reverberated over several generations." Her cry also signalled an emotional rupture, a "second wounding" that those present bore witness to, she adds.

Gobodo-Madikizela holds the South African National Research Chair in Violent Histories and Transgenerational Trauma and she served on the TRC's Human Rights Violations Committee. Her scholarly endeavours include making sense of the 'transgenerational trauma' phenomenon that occurs over generations, using the South African context as a backdrop. In her current work, she wants to understand why the prospect of repair and national reconciliation, which framed the work of the TRC, no longer holds any promise amidst the violence of present-day South Africa.

In this context, in which the 'born-free' post-apartheid generation has come of age, she has been developing a new conceptual framework for understanding transgenerational trauma, which manifests when the violence experienced by particular groups is relived by the generations that follow them. To explore this area of her work, she is revisiting a selection of testimonies and iconic TRC moments, including Calata's cry, which has been described as "the defining sound of the commission" and "symbolic of the start of the human rights hearings".

Calata's emotions boiled over while she was testifying about the death of her husband, Fort Calata, a decade earlier at the hands of the security police under the apartheid regime. At the time of his death, she was 26 years old and 7 months pregnant with their third child. Fort Calata (28) was assassinated in June 1985, along with fellow anti-apartheid activists Matthew Goniwe, Sicelo Mhlauli and Sparrow Mkhonto. In death, they became known as the 'Cradock Four'.

Gobodo-Madikizela is asking the same question posed by T.S. Eliot in his poem 'Gerontion': "After such knowledge, what forgiveness?" She is investigating whether the notions of forgiveness and reconciliation carry the same meaning for today's post-apartheid generation as they did during the transition period after the end of apartheid.

Making sense of forgiveness

Gobodo-Madikizela's scholarly journey in trauma research started with her PhD. In her dissertation, she focused on case studies of collective violence (specifically, the burning-tyre 'necklace murders' in the Eastern Cape) and the violence inflicted by Eugene de Kock, former commander of Vlakplaas, a counterinsurgency unit responsible for numerous clandestine assassinations in apartheid South Africa.

During the TRC hearings, one of the first observed expressions of forgiveness for the atrocities committed during the apartheid era occurred after the testimonies of widows of the police officers murdered in the 'Motherwell bombing' in 1989. Two police officers, Warrant Officer Glen Mgoduka and Sergeant Amos Faku, as well as an 'askari' (a police informer), Sheperd Shakati, were killed in a car bomb explosion that was orchestrated by former apartheid security police. De Kock appeared at the amnesty hearing of the security police as an 'implicated witness'. He linked the bombing to the murder of the Cradock Four. At the end of his amnesty application, De Kock appealed to meet the family members of the murdered men. Two of the widows agreed and, in a private meeting with De Kock, offered him their forgiveness.

"At the time, I was really taken aback by this," Gobodo-Madikizela recalls. "It was so counter-intuitive. I wanted to really understand this notion of their forgiveness of such unforgivable acts and its true meaning.

"For a long time, there was this belief that in the face of radical evil, or 'the banality of evil' as the philosopher Hannah Arendt called it, some crimes are unforgivable because they are so far beyond human imagination. It was believed that some crimes are so humanly unacceptable that they are just unforgivable. My interest in the phenomenon of forgiveness was very much a personal one. But as a trained psychologist, I was also interested in the meaning of De Kock's expression of remorse. Was it witness-stand remorse or was it genuine, deeply felt regret for his deeds?"

Over a period of six months, Gobodo-Madikizela interviewed De Kock in jail. These meetings culminated in her critically acclaimed book, *A Human Being Died That Night: A South African Story of Forgiveness*, about her insights into what causes a moral person to become a killer.

"It was such an important time for me, those encounters with Eugene de Kock," she recalls. "Until then, in all my reading of studies on perpetrators of the Nazi Holocaust – at the time, the only available comprehensive studies on perpetrators of unspeakable atrocities – I had not encountered a single example of remorse for doing so much evil."

A novel approach

The repercussions of violent histories – including slavery, and colonial and apartheid-era violence – extend far beyond the victims and survivors who experienced these traumatic events directly. The 'afterlives' of these traumas can echo across generations, leaving imprints on individuals and communities, she says. Such transgenerational imprints have been documented across the globe, including in countries like Rwanda, Germany and the United States.

"There is something unfinished about past traumatic experiences," Gobodo-Madikizela explains. "And when this 'thing' is unfinished, what happens in its state of being unfinished is that it becomes fragmented; it becomes dissociated from the original trauma. In other words, what is remembered are fragments of the past." Instead of integrating these memories into a meaningful narrative context, traumatic experiences are often relived and 'acted out' in a range of behavioural repetitions of the events.

Gobodo-Madikizela and others at the AVReQ are exploring the concept of violence and its effects on the lives of victims, survivors and their descendants, on the one hand, and perpetrators on the other. The centre is involved in interdisciplinary projects in collaboration with trauma researchers from across the globe. In her own work, Gobodo-Madikizela explores a novel approach to making sense of the transgenerational transmission of historical trauma. She is working on a book tentatively titled 'Triadic Memories: Aesthetics of Trauma and Narratives of Repair'.

In the 'tri-telescopic perspective' on intergenerational trauma that she proposes, trauma memories cross and re-cross past, present and future temporalities. "For many people, the lived experience of intergenerational trauma reverberates across space and time into their lived experiences in the here and now." She believes this perspective "offers a lens through which the repercussions of multigenerational collective trauma can be identified as a lived reality that exists beyond phantoms [of the past]."

> **"We should not be thinking about transgenerational trauma as something that only happens at one specific point in the past and then has a unidirectional impact on the present," she says.**

The testimony of Calata, for instance, illustrates this "telescoping of traumatic violence through both oral and wordless testimony. Ms Calata's cry not only told a story about our violent past but foreshadowed how intergenerational trauma and violence would affect our society today," Gobodo-Madikizela says.

"I argue that the return of historic trauma is a more ambiguous space that points backwards – not just to a single traumatic event but to multiple generations past – and forwards in a prophetic foretelling of traumatic violence that is to recur in the future."

Gobodo-Madikizela says that the concepts 'post-colonial', 'post-apartheid' and 'post-slavery' should also not be seen as designating an end in the sense of a clear break with the past and a demarcation between an era of human rights abuses and the present. In contexts with long histories of oppression, inherited inequality and poverty shape the way that the past is remembered.

The lived memory of the past

Understanding intergenerational trauma in South Africa is as relevant today as it was during and immediately after the TRC hearings, Gobodo-Madikizela believes. In a recent article, she describes South Africa as a country at war with itself, ridden with mass protests, racial tension, vigilante killings, domestic violence, gender-based murder and the mutilation and dismemberment of women's bodies. "These events point not at closure and healing but rather at a question screamed into the future: 'When will it end?'

"When you think about that scream [of Nomonde Calata], the pain that was embodied in that scream was foretelling. It was almost

a prophetic scream that foretold that all will not be well in this future." In South Africa, the problem of the translation of the past into cycles of transgenerational re-emergence of violence is exacerbated by the continued disempowering conditions of racism, inequality and poverty.

The transgenerational suffering of the previous generation(s) is lived by the current generation within their families, communities and society, Gobodo-Madikizela says. Also, a disillusioned generation of 'born-free' South Africans is buckling under the burden of economic hardship they inherited from generations before them.

As a result, many young people still live in abject poverty and are exposed to extreme levels of inequality, like their parents before them. They are also part of a generation on the receiving end of the 'violence of corruption', caused by state capture and the misappropriation of public resources.

Apartheid's violence casts a long shadow on the generation born after its demise, Gobodo-Madikizela says. "In our post-apartheid society, there is also a rupturing of hope and a violent disintegration of the vision of a peaceful future imagined by the generation of South Africans who fought to end apartheid. It is as if the present – the future that was imagined – is the past of the violence of colonialism and apartheid braided together and then rewound."

Changing the discourse of the past

"Many people feel a deep sense of betrayal by the post-apartheid government," Gobodo-Madikizela says. This is evident in the stories she and her colleagues collected in Langa, Worcester and Bonteheuwel and then collated in the digital exhibition titled 'Through the Eyes of Survivors of Apartheid'.

The exhibition consists of excerpts from the stories of 29 storytellers who feature in the book *These Are the Things that Sit with Us.* "The notion of betrayal came out so strongly in our interviews with the younger generation – the idea that they feel a deep sense of betrayal. People are arriving at this moment [in time] where they're supposed to be free with an inheritance that is empty. It's almost like the coffers of their future have been emptied of resources, and the current post-apartheid generation feels robbed of the future they were promised. We are a society with a complex, unresolved trauma history stretching back hundreds of years," Gobodo-Madikizela explains.

"The stories we carry with us are also often the stories that define us. We carry these stories with us and pass them on [to future generations]."

The unfished business of the TRC

"Some people believe that the commission 'failed spectacularly'. However, I don't believe this is an accurate assessment of the work of the TRC. The commission did offer hope and a sense of possibility. But the hopeful aspects of the TRC soon dissipated for a number of reasons.

"Clearly, there were certain things that should have been done during the TRC hearings; there were certain missed moments. We were blinded by the vision of reconciliation. We didn't think long enough about how deep these wounds go and what it would require to address them."

Today, more than 25 years later, the country is seeing a resurgence of racism, racial conflict and intolerance, Gobodo-Madikizela says.

"A big problem now is the violence of corruption. In South Africa, it has reached phenomenal levels; it is unbelievable. It is just beyond human understanding how the same people who fought for freedom can work so hard to destroy the futures of so many South Africans who suffered under apartheid, and that of their descendants. Corruption is a gross human rights violation.

"Also, the wealth created during apartheid was skewed in favour of white people. As we move into the next generation, the inheritors of that wealth are still today mostly white people. Black people have inherited poverty, they've inherited disability, and this inequality is a continuity of the apartheid past. But it's also a consequence of the failure, the drastic failure, of our government."

The reparative quest

Gobodo-Madikizela believes it is essential to follow through with the recommendations for repair outlined in the TRC's final report. "The project of reconciliation begins with the articulation and acknowledgement of what it is that is being reckoned with, with reflecting on how different groups are positioned in relation to the past. This is why I think our work at AVReQ on the 'reparative quest' is so important. Restoring the human bonds that were broken between the wounded, the victimisers and their descendants require the engagement of what I call 'reparative humanism' as an alternative to the notions of 'healing' and 'closure'."

CHANGING CLIMATES

JORISNA BONTHUYS

Photo by Gallo Images/ Brenton Geach

Dealing with the twin crisis of climate change and biodiversity loss requires enormous collective effort, and now demands novel academic support across 'traditional' academic silos.

The world is facing cascading and intersecting crises, warns Prof Guy Midgley, who heads up Stellenbosch University's (SU's) School for Climate Studies. "We need to change how we work, live and sustain our energy needs, while pursuing socioeconomic development," he adds.

Midgley, a distinguished professor in SU's Department of Botany and Zoology, is considered one of the world's most influential climate scientists. In addition to being responsible for getting the School for Climate Studies up and running, he is also the acting director of SU's Centre for Invasion Biology.

"Dealing with the planetary emergency we currently face requires swift and informed responses, both from a mitigation and an adaptation perspective," Midgley says. "Nothing less than fundamental paradigm shifts are needed to tackle climate change, biodiversity loss, and their effects on our world and our society."

How to save both nature and jobs

According to Midgley, the cumulative effects of global socioeconomic development threaten the stability of planetary systems that sustain life and livelihoods. These effects are now causing the beginnings of dangerous interference with Earth's climate system. Scientific assessment has found that the impacts of compounding climate-related threats are most profound for people and societies already exposed to multiple socioeconomic stressors, he says.

"As a society, the solutions we embrace to deal with the climate changes underway must balance the need for very necessary socioeconomic development with the sustainable use of environmental resources. Also, the kinds of transitions needed to deal with the effects of climate change are amongst the most challenging ever faced by modern society.

"This is a challenge of epic proportions," Midgley says. "The good news is that we have the science to understand much of it. But the question now is: How do we get to our solutions?"

SU's scientific community has much to offer in terms of finding solutions to some of the most pressing climate-related challenges. Researchers at the University are already generating new, transdisciplinary knowledge in diverse fields, including botany, law, medicine and engineering.

A school for change

The School for Climate Studies has the status of a faculty but its work transcends the boundaries between the University's 10 faculties and 77 departments.

Affiliated researchers are combining their efforts to improve our understanding of the changes underway, and of how best to deal with climate-related risks and unfolding realities. The research partnerships enabled by the School are also helping them unlock funding in the highly competitive higher-education sector, conduct research for impact, and play a strategic role in various regional and global consortia.

Currently, SU scientists are working on several projects that support appropriate climate mitigation and adaptation responses in South Africa and elsewhere on the continent. These responses include efforts to understand ecological changes on land and in the Southern Ocean, to explore legal tools and mechanisms to mitigate climate change, and to prepare a new generation of medical experts for dealing with climate-related impacts on human health, including the burden of disease.

The Development and Rule of Law Programme (DROP), for instance, focuses on how climate adaptation and mitigation efforts should connect with a broader sustainable development agenda. This programme — linked to the Stellenbosch University Water Institute (SUWI) — focuses on sustainable development law and policy.

Midgley's own research group, the Global Change Biology Group, tracks the functioning of important species in diverse southern African ecosystems, such as fynbos, savannas, open oceans and estuaries, and links the resilience of these systems to climatic drivers.

In addition, SU conservation biologists have identified which areas need to be protected for the persistence of thousands of species that support the ecological infrastructure upon which we all depend. Researchers have also been involved in efforts to assess protected area vulnerability to climate change in South Africa's national parks.

In the Department of Botany and Zoology, experts are calculating the biodiversity risks of climate change by projecting

South Africa's energy sector is still the most carbon-intensive among G20 countries. The residents of Vosman (Emalahleni) who live near several coal-fired power stations are breathing some of the country's most polluted air.
Photo by Alet Pretorius

its impacts on plant and animal species in the near future. Climate models predict that, if global greenhouse gas emissions are not drastically reduced over the next decade, there will be significant changes in the distribution of ecosystem types on land, and an increased risk of extinction for 10% to 20% of endemic species.

It is more than just the loss of individual species that is at stake — reductions in species diversity and their interactions due to habitat degradation and fragmentation generally result in reduced ecosystem functioning. Midgley adds that, from an adaptation perspective, gaining new knowledge in this field is valuable in that it can inform land use and development planning and conservation.

Unprecedented changes and challenges

In 2022, a sober assessment of our planet's future was released by the United Nations' (UN's) Intergovernmental Panel on Climate Change (IPCC), a group of scientists whose findings are endorsed by the world's governments. This assessment, which SU scientists contributed to, is considered the most comprehensive overview to date of the physical science of climate change.

The recent changes in Earth's climate are widespread, rapid and intensifying, not to mention unprecedented in thousands of years. Earth is also warming faster than previously thought, and the window to avoid catastrophic outcomes is closing. With every 0,1 °C of global warming, there are clear increases in the intensity and the frequency of a large number of extreme event types. This means that every bit of global warming matters.

The IPCC's report indicates that, without swift international action on energy transitions, the crossing of the 1,5 °C threshold in temperature rise (compared to the global average temperature in pre-industrial times) may occur from the 2030s.

Moreover, the IPCC's authors say the current rate of warming could put Earth at risk of crossing dangerous climate 'tipping points' with higher levels of warming. This, in turn, may cause major disruptions to planetary systems, triggering large-scale singular events, such as the collapse of Antarctic ice sheets or Amazon rainforests. The scientific consensus is that climate change is a 'threat multiplier', meaning it increases the likelihood and severity of extreme events.

Some of the strongest projected global drying trends are to be found in southern Africa. The region is warming sharply, at about twice the global rate of warming. Along with higher temperature levels and increased evaporation, the implications of droughts and climate change for surface runoff and the long-term assurance of water supply are serious. For example, the recent severe multi-year drought in the Western Cape (2015-2017) was three times more likely to occur because of the human influence on climate change.

"That is why our region is so vulnerable and why it is regarded as a climate change hotspot. When an already dry and warm region becomes even drier and warmer, the options for adaptation are greatly limited," Midgley warns. This situation ups the urgency of implementing effective plans for increasing local climate resilience and biodiversity management.

Understanding risks and vulnerability

Over the next few decades, South Africa will face significant climate-related challenges across many social and economic sectors.

> "Improving the resilience of different sectors to rising shocks and stresses under climate change is vital," Midgley says. "Resilience is dynamic, socially contingent and often context specific."

Through the SUWI, studies have explored how irrigated agriculture in the Breede River catchment in the Western Cape was affected by the recent multi-year drought in the province. These and other studies at SU have investigated links between implications at the individual farm scale, where efficient irrigation scheduling and appropriate technologies are applied, and implications at regional scales. Efforts are also underway to build hydrological expertise in the School for Climate Studies that can inform appropriate regional adaptation responses and ensure that ecological benefits keep flowing from catchments. Understanding the impacts of climate change on a local and regional level requires the development and refinement of hydrological modelling tools, Midgley says. However, data scarcity hinders how and where the models can be used outside of South Africa. This causes uncertainty about the accuracy of the models' results, especially in sub-Saharan Africa.

In this regard, the SUWI's Dr Andrew Watson and others have been considering how climate extremes in the Western Cape influence conceptual rainfall-runoff model performance and uncertainty. In 2022, Watson and his collaborators published their research findings on hydrological variability in the province, calculated by means of a multi-catchment approach (for the Verlorenvlei, Berg, Eerste, Breede and Bot River catchments).

Midgley says this kind of research is considered important for reducing uncertainties in modelling. It helps researchers achieve more credible simulations of regional water balances and hydrological processes amid climate change.

Climate change and health hazards

Increasingly, SU researchers are also exploring the link between climate change and future health hazards. Climate change is considered the greatest threat to human health in the 21st century, Prof Bob Mash, head of SU's Department of Family and Emergency Medicine, recently highlighted in an online public lecture series. According to Mash, there are three important factors in the nexus between climate change, human health and health systems: the impacts of climate change on the burden of disease, the impacts of the burden of disease and climate change on health facilities and services, and the contribution of health systems to the problem of climate change.

Some of the effects on human health are predictable and we are already seeing many of them. Malnutrition will, for instance, be a problem for many communities as climate change reduces food production in our region. The prevalence of vector-borne infectious diseases will also change, while outbreaks of water-borne diseases are expected.

The number of pandemics is already increasing, and humanity is yet to encounter many more viruses. At least 10 000 viruses currently circulating in wild animals have the ability to affect humans. In some regions, the rise in virus outbreaks seems to be linked to global warming. This was pointed out by Prof Tulio de Oliveira, the director of the Centre for Epidemic Response and Innovation (CERI), at the first African Regional Forum on Climate Change. In 2022, SU hosted this event in cooperation with the Global Alliance for Universities on Climate (GAUC).

Climate change increases cross-species viral transmission risk, De Oliveira indicated. In recent years, countries in Latin America have been hit by multiple, concurrent arboviral epidemics (such as dengue and yellow fever, chikungunya and Zika virus disease, all spread to humans by infected arthropods such as mosquitoes).

Given that rising global temperatures are causing an expansion in the areas in which mosquitoes thrive, the predictions are that Africa may be the next place to be affected by such epidemics, he pointed out. De Oliveira also warns that outbreaks of over half of all known human pathogenic diseases will increase due to global warming. Moreover, over the next few decades, thousands of new viruses will spread among animal species as a result of climate change.

Building networks

The School for Climate Studies has joined and also initiated several innovative research and teaching projects to promote research for impact. One example is its collaboration with the South African Environmental Observation Network and German university partners to measure ecosystem functioning in all major South African biomes under different land uses.

Another collaboration that is gaining momentum is a project to model climate risks related to hydrology and biodiversity at UNESCO heritage sites in southern Africa.

In addition to promoting 'new thinking' within the University about the need for interdisciplinary climate-related studies and growing SU's research networks (here and abroad), the School is also playing an important role in enabling climate teachers. As one of the 15 members of the GAUC, the School leads some of the organisation's pilot projects on climate and climate policy training.

The concept of planetary health is also gaining traction in teaching in the Faculty of Medical and Health Sciences. Since 2021, environmental stewardship has been embedded in the undergraduate MBChB curriculum. Dr Christian Lueme, a lecturer in planetary health in the faculty, is helping drive systemic change through his teaching. His position is part-funded by the School.

Collaborative crunch time

The science is clear: To avoid crossing the dangerous climate change thresholds beyond which our planet will become far less inhabitable, we need to reduce global human-caused carbon dioxide emissions by almost half (45%) by 2030 and to almost zero by 2050, and then into negative emissions (net uptake) for some decades. Midgley says: "We are climbing up the risk scale from moderate to high risk, which means it is not only the direct environmental impacts we're worried about but also the risks that come from accelerating CO_2 emissions reductions and carbon capture." The future will look very different no matter what. Both mitigation and adaptation efforts are essential. Midgley says sound and creative academic work across disciplines and traditional academic 'borders' is already helping to inform a climate-resilient, just and equitable development path for the southern African region and to build a low-carbon society. He concludes: "The science to inform appropriate and timely responses is vital. We have an important role to play."

THE LONG ROAD TO CURING TB, TOGETHER

UFRIEDA HO

Photo by Damian Schumann

A centuries-old disease still stalks humankind today. What is becoming increasingly clear, though, is that the answer may lie in researchers, scientists and patients first finding their common humanity.

Humans have travelled a long journey with tuberculosis (TB) – since the first centuries after people abandoned nomadic lifestyles to settle down. But after 9 000-odd years of known contact with the bacterium, exactly how to leave TB in our past still eludes scientists.

Finding solutions to curbing TB in our modern era demands equal parts scientific and technological advancement, advocacy to raise the profile of the disease burden, and acute awareness of the societal inequalities that make the poorest communities the most vulnerable.

The TB disease burden

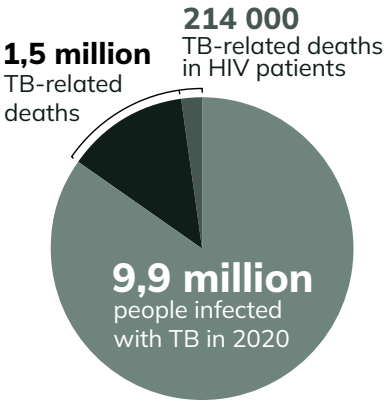
Prof Gerhard Walzl, clinician scientist and head of Stellenbosch University's (SU's) Immunology Research Group, believes that TB is still far from being eradicated, having claimed the lives of 1,5 million people in 2020, according to the World Health Organization.

"We have huge problems with TB, starting with its diagnosis. The diagnostic process is too complicated for the settings in which TB occurs in South Africa, which are resource-poor areas in which our healthcare system cannot deal effectively with the infection load," Walzl says. For context, he adds that 85% of the South African population is reliant on the country's ailing public healthcare system.

Other challenges he mentions include long clinic queues, staff shortages, the poor sensitivity of sputum tests, bottlenecks in sending samples off to laboratories for testing, and the need for a follow-up clinic visit for test results to be acted upon.

"We know that about 25% of people just don't come back for their test results. And many more don't ever get diagnosed and so continue infecting others. That's why we talk about TB's 'missing millions'," he says.

Prevention mechanisms have also become dated, Walzl points out. The bacillus Calmette-Guérin (BCG) vaccine, while still in use, is over 100 years old and has been shown to mainly protect against disseminated forms of TB, predominantly in children under the age of five years. Also, it does not ensure lifelong immunity.



Yet another barrier to TB eradication, he says, is that TB treatment regimens still require daily antibiotic treatment for a full six months. Many people fail to complete their treatment course once it starts to make them feel better. To make matters worse, incomplete treatment is adding to the problem of a rise in drug-resistant TB strains.

"For the last 10 years or so, we have seen a worrying increase in drug-resistant TB, extensively drug-resistant TB, and totally drug-resistant TB, which is an untreatable form of tuberculosis," he says.

Turning the tide on TB will come down to the use of multi-pronged approaches, Walzl believes. He says the "pleasant noises" made about taking TB seriously need to translate into balanced funding, investment in research, and the political will to put TB on everyone's agenda. According to him, truly tackling TB will demand vigour similar to that which drove the COVID-19 pandemic response in recent years and the HIV response in the late 1990s and early 2000s, which both dominated public attention.

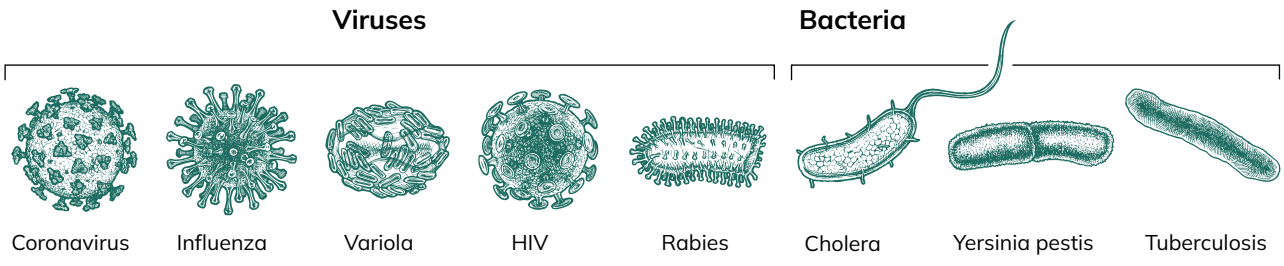


Photo by Damian Schumann

Hope in the dark

But Walzl also highlights some promising leaps forward: “There have been major successes in molecular diagnostics following the use of the polymerase chain reaction (or ‘PCR’) test that can detect TB genetic material in a sputum sample and deliver a result within two hours. This means you don’t need to culture the bacteria. The PCR-machines have also become smaller and smaller so they can be placed in clinics. We just need to make them more widely available.

“We have also seen new drugs that promise to shorten treatment time and we have a number of vaccines being trialled right now. Even though the trials are expensive and take a long time to be completed, it’s still significant,” he adds.

Feeding his optimism further is the strong foundational knowledge in South Africa and the continent at large, along with growing collaboration.

“Within the University, we have a wide portfolio of TB expertise, ranging from that in paediatric tuberculosis, adult tuberculosis, microbiology, vaccine testing, drug development and immunology to that in genetics. We also do a lot of social impact work that tries to inform the population about symptoms and risks, and foster a greater understanding of the problem,” Walzl says.

Cracking the code

For Prof Marlo Möller, head of the TB Host Genetics Research Group in SU’s Division of Molecular Biology and Human Genetics, the latest genetic research is revealing previously unimagined clues that deepen the understanding of the TB bacterium and the complex pathways of TB infection in its hosts. In turn, this gives clues to susceptibility, immunity, and how and why different patients metabolise and respond to treatment differently.

> “Scientists have been trying to cure TB for a long time, but we want to speed things up. With genetic research, even in the case of a complex disease like TB, we are finding out things we didn’t know before,” says Möller.

“For instance, there is one genetic region that has been coming up during testing in several populations, and it’s actually one of the first genetic associations linked to TB. This is the human leukocyte antigen (or ‘HLA’) region. In these immune genes, we get thousands of single-base-pair changes in the DNA, so it’s really very complex,” she says.

The HLA region, found on chromosome 6, regulates immunity and plays a role in assessing the success of organ transplants. HLA is also an important determinant of the outcome of TB recovery and survival.

“It’s a very complex region of the genome because the HLA genes are many, they’re small and they differ a lot between individuals and in different populations. So that’s one aspect that we would definitely like to investigate further,” says Möller.

Her and her team’s work on this research has already enlarged biobanks in South Africa so that meta-analysis can now be undertaken between South Africans and other Africans. Collecting the genetic samples of more people for libraries of genetic data is a core building block for advancing personalised medicine of the future. This is because metadata as reference allows the increased refining of genetic testing, which in turn heightens the possibility of targeted treatment and support for individual patients.

“Improving our understanding of the human genome and how it works means that at some point, we will be able, for instance, to predict who will get TB and get sick.

“TB genetics is, of course, complex, because we have evolved together for so long. It’s not just one gene contributing to an outcome; we’ve seen that several immune genes can contribute,” Möller explains.

While cracking the codes of this complexity is certainly at the forefront of cutting-edge scientific research, Möller is cognisant of the fact that any research in this regard should ultimately be to the tangible benefit of the communities that are most affected by TB. Her division has set up programmes to ensure that their key research results are taken back to the communities in which they work. “I love those meetings [between researchers and community members] because you have such great conversations,” she says.

Diagnosing TB requires looking at a patient's clinical picture, as well as the results of certain tests. Here, an unidentified patient and doctors discuss the results of a chest X-ray to determine treatment. Photo by Damian Schumann

Better testing tools not the sole solution

South Africa's TB burden is weighed in the 60 000 known deaths that resulted from this disease in 2021. It's a chilling wake-up call, says Prof Novel Chegou of SU's Department of Biomedical Sciences.

"TB is still the disease of the poor," he says in explanation of why it is still not being sufficiently prioritised. This is what drives Chegou's focus on tools, treatments and services that improve access to TB tests, as well as their ease of use.

"We are working on finding biomarkers [biological indicators] in bodily fluids other than sputum, like blood or urine, because sometimes people can't give a sputum sample or the TB is not present in the lungs. So, we are trying to develop more sensitive TB tests and bring down the cost of the test kits," he says.

Encouragingly, Chegou says they already have nine patent applications. Protecting the intellectual property is not for the purposes of commercial gain, he says, but to ensure that the products developed truly serve the interests of the most vulnerable.

"In the next 10 years, I think we're going to have a lot of tools for testing and understanding TB. What we'll need more than tools, however, is commitment from politicians and policymakers. Even if we have the tools, if those who are supposed to make the laws [related to their use, distribution and access] don't make them, then the tools are of no help to anyone," he says.

It's a remark that reconnects the fight to eradicate TB with its original intent: to support people, not profits or politics.

POLIO IN SA: ASSESSING THE RISKS

ENGELA DUVENAGE

In her 2020 book *Outbreaks and Epidemics,* science journalist and CNN health editor Meera Senthilingam described how the worldwide polio eradication programme had managed to reduce the global number of cases from 350 000 in 1988 to only a handful at the time of print.

She explained that two of the three immunologically unique strains of wild (naturally occurring) poliovirus were certified as having been eradicated: type 2 in 2015 and type 3 in 2019.

Regarding a third wild type, WPV1, she noted: "Wild poliovirus type 1, still circulating in Pakistan and Afghanistan – no new cases have been detected on the African continent since 2016 – is the final hurdle."

Unfortunately, this optimism about the situation in Africa was short-lived: six cases of WPV1 were reported in Southern Africa by mid-2022, one in Malawi and the rest in Mozambique. These cases were noted after the patients suddenly experienced some form of paralysis or weakness in their limbs (in medical terms, 'acute flaccid paralysis' or 'AFP').

Also in 2022, the USA, Israel, Yemen, the UK and 11 African countries reported cases of circulating vaccine-derived poliovirus 2 (cVDPV2). Albeit extremely rare, this strain can spread from someone who has been vaccinated to individuals in undervaccinated communities who have not received protection.

Smartening up to see the bigger picture

"Given that AFP cases represent only roughly 1 in 200 WPV1 infections, the cases observed in Malawi and Mozambique may suggest widespread circulation of the virus in the southern African region," warns epidemiologist Prof Juliet Pulliam, director of the DSI-NRF Centre of Excellence in Epidemiological Modelling and Analysis (SACEMA) at Stellenbosch University.

Consequently, SACEMA's Modelling and Analysis Response Team (SMART) has launched a modelling project to help health authorities keep their fingers on the pulse of potential polio outbreaks in Southern Africa.

SMART will also determine the value and input of potential preventative measures and/or interventions, in collaboration with the National Institute for Communicable Diseases.

"We have begun to develop a transmission-dynamic model of what poliovirus circulation could look like if the virus were introduced into South Africa," says Pulliam, leader of SMART.

The team's work can be used to project the time it would likely take between the introduction of the poliovirus and its detection on grounds of AFP cases.

The team also plans to take stock of the impact of reactive vaccination programmes put in place when polio cases emerge, and to assess the efficacy of these programmes depending on timely implementation. They will then compare the relative success of reactive vaccination to that of pre-emptively giving people extra doses of the polio vaccine to keep the number of infections to the absolute minimum.

"Our model will be run for specific populations, based on a characterisation of its age structure and vaccine coverage, and on how efficiently surveillance is being done in a given area."

"We hope this work will encourage the government to act quickly towards reducing the polio risk," Pulliam notes.

Mathematical models inform epidemic responses

The World Health Organization (WHO) warns that as long as a single child is infected with the poliovirus, children in all countries remain at risk. Unless the virus is eradicated from its last remaining strongholds, we may still see a global resurgence of the disease, they caution.

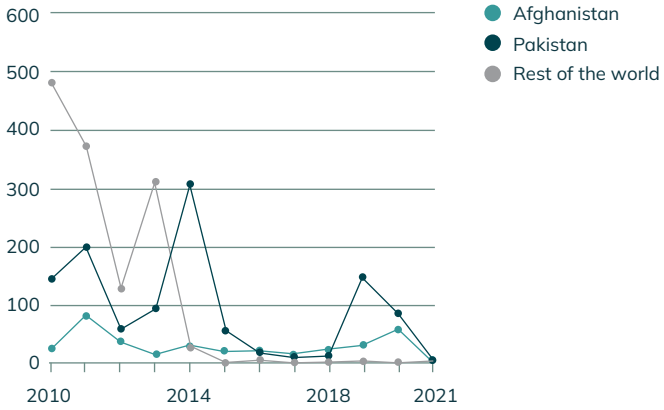
In 2020, the WHO unfortunately had to adjust its worldwide polio eradication programme in order to address the COVID-19 pandemic that was sweeping across the globe. This resulted in various polio vaccination activities being postponed for months. In the African region, 60% to 70% of the WHO's resources earmarked for the polio eradication programme were reassigned towards fighting the pandemic.

According to Pulliam, SMART will be using many of the valuable techniques, best practices and lessons they have learnt from modelling the pandemic and other diseases such as HIV and malaria in times of crisis.

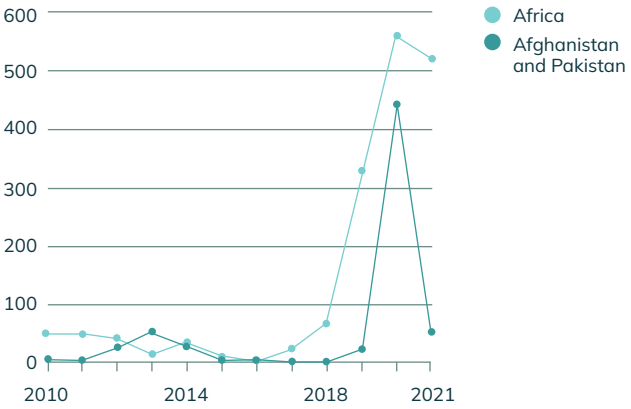
> "Mathematical models remain a really important tool for epidemic response," she says. "In some contexts, they are the only way to ask questions about the potential impacts of different factors."

"Any time someone makes a prediction or advocates for one intervention over another, there's a mathematical model being used to back up what they're saying. The value of mathematical modelling is that it makes those assumptions explicit. It formalises it, seeing as it's a formal tool for making predictions and comparisons. It helps us think more clearly about what's happening."

Wild polio cases



Vaccine-derived polio cases



www.polioeradication.org

"We cannot change a weather prediction with our actions. We can be prepared and take an umbrella, but we can't say that we don't want a hurricane to come. But in epidemics, you can actually change the outcome by using interventions that make a difference."

POLIO FACTS

Polio (*poliomyelitis*) is a highly infectious disease caused by a **virus**.

One in every 200 infections leads to irreversible paralysis.

Children under the age of five years are the most vulnerable.

Up to 10% of paralysed patients die because they struggle to breathe when their breathing muscles become affected.

99%

Cases caused by wild poliovirus **decreased by over 99%** from an estimated **350 000 cases in 1988** to **140 in 2020**.

Only **5 cases** were reported in **2021**, all in Afghanistan and Pakistan, where the virus is endemic. However, thus far in **2022**, **9 cases** have been reported. in **Africa**, **20 in Pakistan** and **2 in Afghanistan**.

Source: https://www.who.int/news-room/fact-sheets/detail/poliomyelitis