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MOVING FORWARD WITH

RESEARCH FOR IMPACT

2023

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The views and opinions expressed in this publication are those of the authors, researchers, and interviewees and do not necessarily reflect the views of Stellenbosch University, its management, or governance.

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Prof Wim de Villiers | Photo by Stefan Els

FOREWORD

I have to acknowledge that there is a lot of turmoil in the world. But we must remain optimistic about the future, especially the future of Stellenbosch University (SU). I firmly believe in optimism, regardless of how dire circumstances may seem.

In his book *Our Long Walk to Economic Freedom*, one of SU's esteemed economics professors, Johan Fourie, cites the economic historian David Landes. At the end of his magnum opus, *The Wealth and Poverty of Nations: Why Some are So Rich and Some So Poor*, Landes writes: "In this world, the optimists have it, not because they are always right, but because they are positive. Even when wrong, they are positive, and that is the way of achievement, correction, improvement, and success. Educated, eyes-open optimism pays; pessimism can only offer the empty consolation of being right."

I've shared this quote before, but it holds true during these challenging times. The COVID-19 pandemic and its associated restrictions have compelled us to become more agile and innovative. We've had to transform obstacles into opportunities. This challenge also relates to securing funding for our scientific endeavours.

International funding, investment, and partnerships are instrumental in driving research and innovation in Africa in that it offers essential financial resources, access to advanced research facilities, capacity-building opportunities, collaborative research opportunities, and global recognition. In doing so, it enables the development of solutions to both local and global challenges, fosters economic growth, and contributes to the long-term sustainable development of the continent.

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

Knowledge exchange and engaging diverse audiences in the research conducted at SU can significantly impact how our research addresses questions, events, and problems. At SU, research is fundamental to ensuring a multi-dimensional impact that promotes academic excellence, societal well-being, economic growth, and cultural enrichment. It fosters a culture of knowledge creation, critical thinking, and innovation that benefits not only the University but also the community and society at large.

Our goal with doing research for impact is to create positive change and enhance the well-being of individuals and communities by extending our footprint beyond the academic realm to have real-world significance. In this publication, we share some of our scientific processes and outputs. We have included stories from all five of our strategic research areas to showcase the important initiatives and innovations happening on our campuses and in the field.

Some of the research efforts we chose to highlight led to the development of life-saving medical treatments, innovative technologies, policy recommendations, sustainable environmental practices, improvements in education, and solutions to social and economic challenges.

The University's vision for 2040 is to become Africa's leading research-intensive university, globally recognised for excellence, inclusivity, and innovation. We aspire to advance knowledge in the service of society.

Our commitment to contributing to society is rooted in social responsibility, a dedication to addressing pressing challenges, and a belief in the transformative power of education, research, and innovation.

We hope you find these articles enjoyable to read. Together, they narrate our scientific endeavours and progress in conducting research that makes a meaningful difference.

Prof Wim De Villiers

Rector and Vice-Chancellor, Stellenbosch University, November 2023

RESEARCH FOR IMPACT

The year 2023 has been filled with great successes for both our researchers and the University, despite some challenges within the higher education sector and the country as a whole. Loadshedding, dwindling funding for research and development, and the impact of these and other factors on equipment availability and research productivity are just some of the issues universities have had to deal with during this academic year.

Prof Sibusiso Moyo | Photo by Stefan Els

Recent trends in global geopolitics and their adverse impact on women, children, and vulnerable communities have also caused considerable threats to higher education and the sustainability of quality research. International events directly affect our partnerships — who we collaborate with, and to what extent. As such, Stellenbosch University (SU) and other higher education institutions must continuously engage with their regional ecosystems (including governments) to tackle local, regional, and global challenges in our sector.

Internally, of course, we continue to manage the change and adaptation needed to ensure our processes and systems at SU increase research efficiency.

Foregrounding equity

Within South Africa, inequality, poverty, and unemployment are key challenges affecting our citizens.

SU, as one of the research-intensive universities in the country, remains committed to producing knowledge that advances our understanding of the world and generates tangible, positive changes in society. As we strive to be socially relevant, many of our efforts are focused on enhancing the quality of life of individuals and in communities.

This commitment is aligned with the University's vision and mission, respectively, to be Africa's leading research-intensive university, globally recognised as excellent, inclusive and innovative, where we advance knowledge in service of society and attract outstanding students, employ talented staff and provide a world-class environment.

Research is a transformative activity with the power to change the world. Our academics, research fellows, and postgraduate students are breaking ground to build healthy, strong, and sustainable communities through their future-oriented and innovative ideas and work.

Research for impact

As a well-established research-intensive institution, SU contributes to broadening the global knowledge base. Our researchers are not only producing knowledge in their respective fields but making a real difference in society by delivering research for impact. The latter remains one of our institution's main priorities, as is evident in our *Vision 2040 and Strategic Framework 2019–2024*, where it is listed as one of our six institutional strategic themes.

These themes were developed against the background of the United Nations' Global Sustainable Development Goals and the African Union's Agenda 2063 goals. They furthermore align with the national priority areas set out in the 2019 *South African White Paper on Science, Technology and Innovation* and with the new *Decadal Plan 2021–2031*.

Doing research for impact implies optimising the influence of our research. To achieve this, interconnectedness and inter- and transdisciplinary approaches to research projects are essential.

Because we aim to be locally relevant and globally competitive, with regional impact, we need to continuously 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.

> The University wishes to pursue excellence, remain at the forefront of its chosen focus areas, gain standing based on its research outputs, and be enterprising, innovative, and self-renewing. This requires a careful balance between, on the one hand, continuity and consistency and, on the other, transformation and rejuvenation of our academic researcher cohort.

New research and innovation framework

At SU, we continue to push the boundaries of knowledge and possibility for the benefit of society, our country, and the planet, for which we are responsible.

In the blueprint for our new research and innovation framework, we focus on four dimensions: strategy and plans, people (our researchers), resources and infrastructure, and monitoring, evaluation, and impact. We have also updated our thematic research areas to include inequality, poverty, and unemployment as key themes to address in our efforts.

As mentioned, we have furthermore adjusted our existing thematic areas to align with the South African decadal plan, which sets out how the government intends to leverage the fourth industrial revolution to meet national imperatives.

To this same end, the National Research Foundation and the Department of Science and Innovation recently visited the University to help us determine our research priorities over the next few years. We believe this new framework will guide SU's research, innovation, and postgraduate studies strategy over the next few years.

Clusters of excellence

On an international level, SU has been approved to lead four clusters of research excellence and is participating in three others. A selection of African and European universities recently launched the joint Africa-Europe Clusters of Research Excellence (CoRE) initiative to transform collaborative research with the aim of finding practical solutions to major scientific challenges facing the two continents. The clusters foreground equity as a precondition for excellent, impactful research that addresses common societal challenges. Together, these clusters are set to make a meaningful contribution towards tackling critical issues affecting our continent.

Initiated in 2022 during a meeting of the African Research Universities Alliance and The Guild of European Research-Intensive Universities, this initiative is seeing partners from African and European universities working together in clusters of common interest.

The focus is on projects spanning at least a decade that will address the current priorities of the involved universities, while building the capacity of the next generation of researchers. The CoRE researchers have identified 17 interdisciplinary research areas that address Africa and Europe's critical challenges.

The CoRE research projects align with the AU-EU Innovation Agenda that set the leading themes for green transitions, green health, innovation and technology, and capacities for science.

The next steps require the cluster research leads to share the CoRE research opportunities within the University, to invite emerging scientists and students to be part of the initiative, to set a research agenda with tangible, measurable outcomes over a decade, and to prepare joint grant proposals to advance the various research areas.

Telling our stories

This publication highlights some of the high-impact research being done at SU. It contains a selection of the Research for Impact platform's digital content, which is available in full here.

Be it research on pandemic preparedness and response, forensic art and the preservation of our common humanity, the fostering of partnerships, or advancements in Parkinson's disease treatment, the work being done at SU is having ground-level impact.

The articles clearly show the researchers' dynamic and purpose-driven approach, and highlight the social relevance of their work, the interdisciplinary collaboration it takes, and and the importance of stakeholder engagement. Moreover, the articles showcase sound research practice in the form of ethical considerations, measurable outcomes, and long-term sustainability goals.

May the pages that follow inspire, provoke thought, and instil a profound appreciation of the transformative power of our research.

Prof Sibusiso Moyo

Deputy Vice-Chancellor: Research, Innovation and Postgraduate Studies

Research for impact, in numbers (2023)

DISTINGUISHED RESEARCHERS

46 research chairs, of which **21** are South African Research Chairs Initiative (SARChI) chairs, funded by the Department of Science and Innovation through the National Research Foundation

508 NRF-rated researchers, of which **21** are A-rated*

328 postdoctoral research fellows, of which **34** are consolidocs**

POSTGRADUATE STUDENTS

281 doctoral degrees awarded in 2022

5 013 master's students registered (as at June 2023)

1 594 PhD students registered (as at June 2023)

NETWORKS AND PARTNERSHIPS

341 bilateral partner institutions in **64** countries, across **6** continents

25 bilateral agreements with other African universities

INNOVATION

97 Patent Cooperation Treaty applications submitted since 2014 (more than by any other entity in South Africa)

29 spin-out companies launched since 2014

RANKINGS

3RD SU ranks 3rd in SA and 283rd worldwide on the Quarelli Symonds World University Rankings

2ND SU ranks 2nd in SA and falls in the category 251–300th globally on the 2023 Times Higher Education World University Rankings

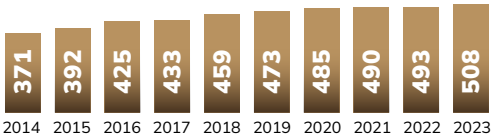
RESEARCH CONTRACTS

>1 450 research contracts processed in 2023, compared to 956 in 2018 (a 66% increase in 5 years)

70 percentage of SU's research contract funding sourced from international funders since 2018

NRF-RATED RESEARCHERS

Totals (2014 to 2023)



A-rated (2014 to 2023)

RESEARCH OUTPUTS

3 055 record number of articles in accredited journals (2022 publication year)

* Recognised by their peers as world leaders in their field of research
** SU doctoral graduates who receive a fellowship to spend a couple of months writing articles based on their doctoral research

INSTITUTE LEADS CUTTING-EDGE BIOMEDICAL RESEARCH IN AFRICA, FOR AFRICA

WILMA STASSEN

Illustration by Roulé le Roux

An investigator tracking the path of COVID-19, a scientist deciphering the body's own armour against antimicrobial resistance, and an immunologist studying the placentas of pregnant women for clues that can explain preterm births. These are but three of the African scientists at Stellenbosch University (SU) who are contributing to research for impact in Africa, and the world at large.

Lucious Chabuka | Photo by Wilma Stassen

Lucious Chabuka, Ewura-Esi Manful, and Dr Doty Ojwach are part of a growing cohort of SU students and researchers who are breaking new ground to find solutions to global medical and healthcare challenges.

Increasingly, African medical and health sciences research is playing a central role on the world's scientific stage. SU's Faculty of Medicine and Health Sciences (FMHS) is harnessing cutting-edge science to tackle some of Africa's most pressing health issues, with benefits for the entire globe.

A shining example is the efforts by FMHS researchers in the new Biomedical Research Institute (BMRI) who are involved in sophisticated genomic surveillance aimed at keeping one step ahead of disease outbreaks with effective tests, treatments, and vaccines.

A world-class biomedical research facility

In April 2023, the launch of the BMRI in the FMHS ushered in a new era for health research innovation and infrastructure in Africa. This advanced facility is on par with the best in the world and is unparalleled on the continent in terms of its facilities and research capacity. In fact, it is the largest and most sophisticated research complex of its kind in the southern hemisphere.

The research emanating from the BMRI has a decidedly African focus, with its researchers wanting to understand the genetic and biomolecular basis of diseases affecting the people of South Africa, and the rest of the continent.

This facility of R1,2 billion is situated on SU's Tygerberg Campus in Cape Town. As a key capacity-building site for biomedical research, it hosts more than 500 biomedical researchers, research fellows, and students. Among these are some of the world's foremost scientists in the fields of bioinformatics, tuberculosis (TB) research, neuroscience, and urology.

The work conducted at the BMRI builds on SU's commitment to impactful research that considers the natural environment, health, human security, and systems and technologies for the future.

"At the heart of our scientific endeavours is the challenge to be locally relevant and globally competitive," says Prof Sibusiso Moyo, SU's Deputy Vice-Chancellor: Research, Innovation, and Postgraduate Studies.

"Scientists at the BMRI are conducting research that translates into discoveries that help improve the prevention, diagnosis, and treatment of illnesses affecting the people of South Africa, and the rest of the continent at large," adds Prof Nico Gey van Pittius, Vice Dean: Research and Internationalisation of the FMHS.

Game changer for healthcare

The BMRI boasts numerous state-of-the-art facilities, including the largest (at 600 m²) biosafety level 3 (BSL-3) laboratory and fully automated biorepository in Africa; lecture and conference theatres equipped with the latest audio-visual technology; and large, modern dissection halls custom-engineered to minimise formaldehyde exposure. The biorepository is a facility that collects, catalogues, and stores samples of biological material for laboratory research.

"The investment in the BMRI will allow for significant human capacity development by offering training to some of the best students from the continent and exposing them to extensive national and international research networks, ultimately resulting in a next generation of successful scientists," says Prof Elmi Muller, the dean of the FMHS.

"The BMRI will be a game changer for healthcare in Africa and is true evidence of how breakthrough science can be used to improve lives."

The value of the BMRI was recognised even before its completion in 2023. High-profile visitors, including South African President Cyril Ramaphosa and some from the World Health Organization (WHO), came to view the facility in 2022.

Ewura-Esi Manful | Photo by Wilma Stassen

Its potential was further endorsed when the WHO selected SU's Centre for Epidemic Response and Innovation (CERI), located in the BMRI, as a partner-member of their first COVID-19 mRNA vaccine technology transfer hub. CERI is one of only two specialised genomic facilities in Africa, the other being the African Centre of Excellence for Genomics of Infectious Diseases (ACEGID) at Redeemer's University in Nigeria.

Preparing the region for the next epidemic

The BMRI is already attracting a cohort of emerging researchers and postgraduate students from across the continent who are making discoveries and bringing attention to crucial issues.

Lucious Chabuka, a laboratory technologist, is one of them, working relentlessly to finish his master's degree in molecular biology and human genetics. This native Malawian, a father of two, is eager to return to his family in Lilongwe. But his research, which considers the epidemic preparedness of eight countries in sub-Saharan Africa, will be vital for the health and safety of people in the region, if and when the next epidemic strikes.

"Africa is a breeding ground for many diseases, and African countries must be on guard and ready for any outbreak," he says. "These countries need the right equipment and skills to detect, track, and understand the [relevant] pathogen if public health officials are to make informed decisions for their countries," he says.

Chabuka has long been fascinated by molecular epidemiology. This field of study is concerned with how often and why diseases occur in different groups of people. The results are used for devising and evaluating strategies to prevent illness and to guide the management of patients already affected.

In 2020, Chabuka was a part of the laboratory team that detected the first case of COVID-19 in Malawi. He crossed paths with Prof Tulio de Oliveira, the director of CERI, when he was sent to South Africa to learn how to sequence SARS-CoV-2, the virus that causes COVID-19. De Oliveira is renowned for first detecting the Beta variant of SARS-CoV-2 in 2020, and then the Omicron variant a year later.

This encounter with De Oliveira crystallised a new path for Chabuka. He had been exploring opportunities to further his education, and during his training in South Africa, realised that his future lay in molecular biology with the CERI team. In 2022, he started his master's degree in the Division of Molecular Biology and Human Genetics at SU.

For the purpose of his degree, Chabuka is investigating how SARS-CoV-2 travelled between Malawi and seven of its neighbours (South Africa, Zambia, Kenya, Tanzania, Zimbabwe, Botswana, and Mozambique) during the pandemic. "I am using both epidemiological and bioinformatics data to try and understand how the virus moved in and around Malawi," he explains. "I'm looking at the number of infections and deaths, and the countries' capabilities to detect and track the virus, among other things."

But understanding how the virus moved between these eight countries is only one part of Chabuka's research. The next phase is to determine each country's expertise and resources, and to identify the gaps that make the region vulnerable.

Over the past year, Malawi has been battling one of the worst cholera outbreaks in decades. Health authorities in the region have been keeping a close eye on the unabating epidemic. Curious to understand the origin of this outbreak, De Oliveira and Chabuka enquired as to whether the pathogen had been sequenced. They found out that although Malawi has sequencing equipment, the cholera pathogen had not yet been sequenced due to a lack of technical expertise in the sequencing process.

Chabuka was sent to Malawi with the required reagents to sequence the cholera bacterium and to train Malawian laboratory technologists to do so with their own equipment. "After sequencing, we did the data analysis and tracked the specific cholera variant back to Pakistan," he says, "there being many immigrants from Pakistan and Asia coming to do business in Malawi."

Chabuka hopes to continue this work through means of doctoral studies, and to eventually return to Malawi with added knowledge and expertise.

A love affair with science

"I am deeply in love with translational science — converting what we are doing in the lab into clinical use," says Ewura-Esi Manful, who is completing her master's degree in molecular biology at SU. The language she uses to describe her research reads like a love letter: "I am fascinated by things on a molecular level and would love to combine both medicine and research. I am also passionate about infectious diseases."

Manful hails from Ghana, where she completed her undergraduate and honours degrees in biochemistry. The topic for her master's research — antimicrobial resistance (a pathogen's ability to defeat the medicine designed to kill it) — springs from a conundrum experienced during her childhood in the town of Sekondi in western Ghana, where malaria is endemic.

Every year, hundreds of millions of people are infected by this disease, and more than half a million people die, most of them in Africa.

"I have always been curious about why I had to take different medication every time I got malaria, even if I got it twice in the same year," she says. "The pathogens have become wise. They learn how to escape the body's defence mechanisms and fight off the current drugs. I found this disturbing, so I decided to see how I can contribute to this field."

With her research, she aims to tackle antimicrobial resistance in TB patients. To do so, she is investigating genes that can help a patient's immune system fight the disease. "All the existing drugs we have target the pathogen, which is becoming increasingly resistant to these drugs. As such, researchers are shifting their focus to the possibility of modulating the host [i.e., patient] response by targeting certain genes that can improve the host's defence against *Mycobacterium tuberculosis*," she explains.

With the South African Medical Research Council's (SAMRC's) Centre for Tuberculosis Research and the DSI/NRF Centre of Excellence for Biomedical Tuberculosis Research situated within her division at the BMRI, Manful is well-placed to explore this topic. "I chose Stellenbosch [University] because of its state-of-the-art facilities and also the high-calibre supervisors and mentors here." To her point, researchers in the FMHS are playing a leading role in finding solutions for the global TB disease burden.

Biology enthusiast with a heart for women and children

Dr Doty Ojwach's enthusiasm for all things biology is second to only one other, namely her dedication to alleviating the burden of disease in Africa's women and children.

This astute young researcher has combined her two passions in an already impressive scientific career during which she has tackled some of the continent's most pressing health problems, including HIV and malaria. As a postdoctoral research fellow in the Reproductive Immunology Research Consortium in Africa (RIRCA) laboratory based in the BMRI, Ojwach is now setting her sights on a new target: the foetal-maternal interface in the context of HIV. Ojwach grew up in the Kenyan capital of Nairobi. Her introduction to biology at high school lit a spark in her that still burns brightly today.

Dr Doty Ojwach | Photo by Wilma Stassen

After completing her undergraduate and honours degrees in biomedical sciences at Maseno University in Kenya, she worked as a research assistant at the Kenya Medical Research Institute on a project investigating HIV and malaria co-infection in women and children. She later relocated to South Africa, where she completed her master's and PhD degrees in virology at the University of KwaZulu-Natal. Currently at RIRCA, Ojwach is funded by an African Research Excellence Fellowship (AREF), the SAMRC's Self-initiated Research Grants Programme, and the National Research Foundation.

In her current work, she studies the placentas of pregnant women to look for clues as to why preterm births are more common among women living with HIV than among those without. "Pregnancies complicated by virus infections, such as HIV, are associated with pregnancy loss, preterm births, and developmental issues in the babies," explains Ojwach. "My study examines why the placentas are not coping for nine months. I'm trying to figure out if it has to do with the mothers' immune cells or maybe with antiretroviral therapy. Because that is what's different in women living with HIV, compared to those living without it."

Under the AREF fellowship, which enabled Ojwach to visit the universities of Surrey and Oxford, she characterised macrophages (large white blood cells in the immune system that destroy bacteria and other harmful substances) under renowned experts in macrophage immunology. "We subsequently hypothesise that viral infections activate placental macrophages, [inadvertently] leading to adverse outcomes," she says.

Ojwach is one of only 20 women worldwide to be selected for the 2023 Falling Walls Female Science Talents Intensive Track, which helps early-career female scientists pursue their career paths and supports them in building an international network of collaborators.

The above three personal stories illustrate how the BMRI is equipping African researchers with the necessary knowledge and expertise to be future leaders in their field; to form equitable, international research collaborations; and, ultimately, to help define the continent's health agenda and research priorities.

TB

A CROSS-SPECIES, GROWING THREAT

JORISNA BONTHUYS

Back in 2016, the death of a certain African elephant bull in the Kruger National Park (KNP) left researchers puzzled. Rangers found the animal's carcass near the Tshokwane camp in the southern part of the park. The elephant, estimated to be approximately 45 years old, had no external wounds or visible injuries, but its condition was poor.

Prof Michele Miller | Photo by Phillip du Plessis

Initially, scientists suspected the cause of death to have been bovine tuberculosis (TB), caused by *Mycobacterium bovis*. Bovine or animal TB is a significant infectious disease affecting livestock and wildlife populations. *M. bovis* was diagnosed in the park in 1990 and is now endemic to this conservation area.

But this case was different. Tests showed the elephant had suffered from human TB caused by *Mycobacterium tuberculosis*. This is the same TB bacteria that cause serious illness in humans worldwide. This was the first time researchers had identified a fatal case of human TB in a free-ranging African elephant. The finding suggested that *M. tuberculosis* could be a greater threat to wildlife populations in Africa than previously realised.

"We were puzzled by this," recalls Prof Michele Miller. "How is it possible for wild animals to get infected with human TB in the KNP?" Miller, who heads up the Animal TB Research Group at Stellenbosch University (SU), holds the DSI-NRF South African Research Chair (SARChI) in Animal TB.

To answer this and other questions, Miller and her team are investigating bovine TB in the KNP and other conservation areas, including the Hluhluwe–iMfolozi Park in KwaZulu-Natal. The researchers, based in SU's Division of Molecular Biology and Human Genetics in the Faculty of Medicine and Health Sciences, are determined to understand how exactly the transmission of TB occurs between wildlife, livestock, and people.

One of their research endeavours, for instance, is a surveillance programme that involves screening the KNP's elephants for mycobacteria. Since 2016, no more cases of human TB in elephants have been detected. Five elephants have, however, been diagnosed with animal TB.

A multi-host disease of concern

"TB is often thought of as a disease that affects only humans when, in fact, it is a multi-host disease [that affects many species]," Millers says. Also, there is not simply a single pathogen at work — several of the different species of mycobacteria that belong to the *Mycobacteria tuberculosis* complex (MTBC) could be responsible for causing the disease in animals. These pathogens include *M. tuberculosis* (the causative agent of human TB) and *M. bovis* (which causes bovine TB).

Currently, 25 wildlife species in South Africa — including rhinoceros, cheetahs, lions, and buffalo — are known to be affected by animal TB. Miller says the KNP offers "a real-world" example of how introduced TB bacteria can impact free-ranging populations of wildlife that interact with domestic animals and humans.

"It is a global problem, however," Miller says. "There are literally tens of thousands of TB-infected animals all over the world."

Old problem, new challenges

It is believed that bovine TB was brought to South Africa by colonial settlers importing infected cattle in the 19th century. "Primarily, it has been a disease among domestic cattle," Miller says. "It is only since the 1990s that we've really been aware that it can spill over from domestic animals into wildlife in the KNP." Centuries ago, as high as 20% of human cases of TB were caused by transmission from cattle, primarily via unpasteurised milk. This is one of the reasons why TB is, today, a controlled disease among animals.

"Although surveillance and monitoring programmes have reduced TB prevalence in cattle, animal TB is rearing its head again," Miller says. Several factors determine whether a population can maintain and spread animal TB infection. These include the presence of enough susceptible hosts, how long the bacterium infects its hosts without killing it, and whether the bacteria can remain viable long enough to find new hosts.

"What we are seeing," she says, "is that in a wildlife park, *M. bovis* crosses the border from buffalo herds to goats and cattle, to soil and water, and subsequently to humans. People with a high TB burden who, for example, care for captive elephants can also spread human TB to these animals."

Route(s) of transmission

There are many routes for transmitting TB among or between wildlife species. Some species are considered "reservoir" hosts of TB, which means they maintain the infection within their population and spread the disease to other species. On the other hand, "accidental" or "spillover" hosts typically contract TB through contact with a reservoir host.

Indirect spread may occur through contact with the mycobacteria in the saliva, nasal mucus, faeces, or urine of infected animals. This method of transmission usually occurs through close contact between individual animals, particularly in social species like African buffalo.

Moreover, *M. bovis* in animals' respiratory secretions can contaminate the environment since the pathogen is able to survive in moist soil in water holes and mud wallows. This may lead to its transfer between buffalo or to other species. (The prevalence of animal TB in buffalo is estimated to range up to 40% in some areas of the KNP).

Although the mechanisms of transmission between herbivores such as rhinoceros are still poorly understood, they also relate to indirect interaction through the sharing of resources such as contaminated water holes and to the consumption of infected vegetation. Carnivores and scavengers, on the other hand, can be infected by eating infected prey. In addition, African lions have been found to transmit *M. bovis* through biting, causing infection in other lions. Recent evidence also suggests that lions and African wild dogs are shedding *M. bovis* in airborne particles through their respiratory secretions.

Wild animals kept captive in zoos, on game farms, and on wildlife ranches can also contract the disease. These infections can be caused by transmission within or between species due to the presence of infected animals or their human caretakers. Together, these and other transmission pathways enable TB bacteria to survive and spread among wildlife species.

> "We are finding that TB bacteria are really, really hardy," Miller says. "They can remain alive in soil or around water holes for days to months, depending on the conditions."

In areas where domestic livestock and wildlife share grazing and water sources, there is a higher risk of spillover (pathogen transmission from animals to humans) and spillback (pathogen transmission from humans to animals) within the wildlife population. Moreover, certain risk factors such as drought, increased population density, and animals clustering at artificial water and feeding sites can increase the likelihood of bovine TB occurrence in certain species.

SU researchers leading the pack

Researchers in SU's Animal TB Group are at the forefront of advances in understanding TB infections in wildlife. In 2022, they showed that about one in every seven rhinoceroses in the KNP was infected with *M. bovis*. Their findings indicated an estimated prevalence of bovine TB infection of 15,4% across both black and white rhinoceros populations.

The group also reported findings that the critically endangered African wild dog population in the park has a high apparent prevalence of *M. bovis* infection (82%), with associated mortalities. A recent surveillance study investigating antibodies against *M. tuberculosis* complex antigens in elephants estimated the level of infection in the KNP's population to be between 6% and 9%, suggesting that *M. bovis* and possibly *M. tuberculosis* infection are more common than previously thought.

The Animal TB Group is also part of a global consortium that received funding from the European Commission to expand genomics surveillance to include the main pathogens affecting people and animals in South Africa, Mozambique, and Kenya. This SU-led consortium aims to increase the use of genomic epidemiology to address public health issues such as TB, HIV-1, and antimicrobial resistance. The consortium will use a "One Health" approach to conduct early-warning testing in wastewater, and animal surveillance to detect emerging pathogens. The group is leading the consortium's work on environmental and animal sources of TB.

One Health approach

The Animal TB Group uses the collaborative, multisectoral, and transdisciplinary One Health approach, which aims to sustainably balance and optimise the health of people, animals, and ecosystems. A key area of research in the group is the development of molecular and cellular techniques for detecting infection in animals. This is important, given that bovine TB not only has a severe impact on the health of animals but also has major economic implications.

Miller says infected wildlife in South Africa is slaughtered rather than treated to avoid creating drug-resistant strains of the pathogen. "*M. bovis* is already naturally resistant to one of the key drugs used for treatment in people. The other reason is that we don't want to keep infected animals that can continue to transmit the disease around. So, generally, when you have a TB control programme for cattle, infected animals are culled to break the cycle of transmission."

Impacts on conservation

Animal TB not only has a direct impact on livestock, but also holds significant implications for conservation and wildlife ranching. Since *M. bovis* is a controlled disease, the movement of

potentially infected wildlife is restricted. Premises with confirmed cases of infection are typically subjected to quarantine measures that may restrict animal movements either completely or subject to approved testing. However, there are only a few validated tests available for detecting animal TB in wildlife. As a result, the translocation and reintroduction of certain species are impeded.

The discovery of *M. bovis* infection in the KNP's rhino population has, for instance, led to a quarantine of rhinos intended for translocation from the KNP to other protected areas. Miller says infected wildlife are generally not culled unless they are restricted to a small reserve and if management authorities are dealing with the first cases of TB infection in the area. "In some cases, you may want to test and then remove the infected animals, but in a very large system like the KNP where the disease is endemic, it's not effective or ethical."

Enabling early detection

Early detection remains key to stopping the spread of bovine TB. Species-specific reagents (for rhinos, elephants, and lions, for instance) are not commercially available. "The difficulty is that there aren't many tests for TB in wildlife species that have been validated and, therefore, are recognised by regulatory officials."

Moreover, conventional mycobacterial culture methods are time-consuming and expensive, with limited sensitivity. As such, more rapid direct methods are needed to detect the presence of TB bacteria, confirm infection, and evaluate the risk of transmission to other animals. The Animal TB Group employs whole-genome sequencing to bypass conventional mycobacterial culture tests. This technique allows the team to identify genetic markers associated with TB virulence, host adaptation, and antimicrobial resistance, thereby providing new insights for interventions.

Researchers in the group are also investigating the molecular epidemiology of TB in multiple transmission systems. Recent advances in the development of diagnostic tests for *M. bovis* infection have allowed for the testing of multiple species. This is done by collecting blood and other samples from anaesthetised animals and testing them for the presence of pathogens.

Repurposing existing technology

Researchers in the group have successfully developed various in vitro TB diagnostic immunological blood assays, DNA tests for detecting TB directly, and a novel mycobacterial culturing method for enhancing the growth of bacteria from difficult-to-culture respiratory samples. They have been modifying techniques originally used for human TB diagnostics, including a culture-independent rapid polymerase chain reaction (PCR) test used in human TB clinics. "This has been a wonderful piece of technology that can be used as a rapid screening tool across wildlife species," Miller says.

SU is taking testing to another level by looking at the epidemiology of the disease. "What's interesting is that different animals have different levels of resistance to *M. bovis*," Miller points out.

"We are looking at the population and systems level, trying to understand what it takes for the immune systems of some animals to clear infection, whether it is minimising animal density or purely genetics. This comparative biology enables us to investigate why, sometimes, when an animal gets exposed to TB, it doesn't develop the disease or, if it does develop the disease, it doesn't die." She says her team has not been investigating drug resistance in the *M. bovis* bacteria specifically. "What we are seeing, however, is that over time, the prevalence of animal TB in the KNP and particularly in buffalo is slowly increasing."

New frontiers

The Animal TB Research Group is using the KNP system as a model to figure out what happens when different infected species interact with each other and with their environment. "This can serve as a framework for us to go into communities, especially rural communities, where livestock and humans also live in close contact," Miller says. The team is also doing work on environmental samples taken from communities living close to protected areas, primarily in KwaZulu-Natal.

"There are literally no statistics about TB in humans caused by *M. bovis* in South Africa," Miller points out. "So, we don't know how big a threat animal TB is to humans in our country." Recently, SU researchers were involved in a pilot study, done in collaboration with the African Health Research Institute, which suggested that *M. bovis* DNA could be isolated from people in the area studied.

The researchers are applying surveillance techniques that were developed during the COVID-19 pandemic to track bovine TB in wastewater samples. This work, done in collaboration with the South African Medical Research Council, enables them to monitor a particular community or environment and could help them identify the potential downstream risk of TB contamination.

"The problem with TB is it is not a one-directional issue," Miller emphasises. "If we don't take care of the TB problem in our domestic animals and in our wildlife species, there will be potential spillover into humans, and that will add to the total TB burden.

"We have a unique situation here in the KNP, where [infected] animals are not being treated. What happens in a system when there isn't intervention? We're watching as this all unfolds.

"The fact that we have discovered infections in rhinos and elephants in the last seven years or so also suggests that TB is increasing in the environment and in wildlife populations."

ADVANCES IN FORENSIC ART EXPLORE OUR COMMON HUMANITY

WILLEM DE VRIES

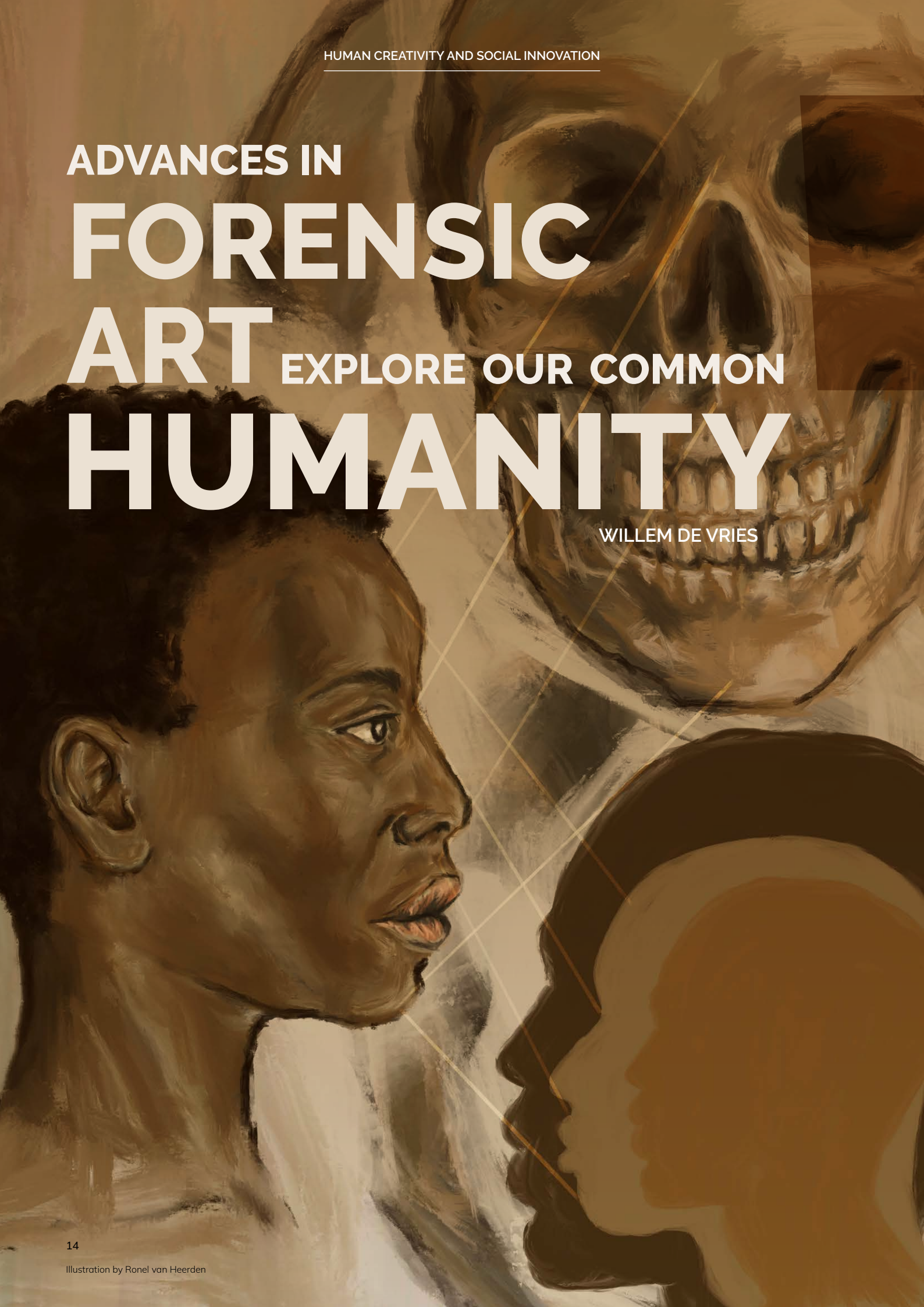


Illustration by Ronel van Heerden

Today, we understand more about the complexity of our genetic heritage through DNA, but both scientific cultures and popular perceptions need to catch up and get attuned to the full spectrum of what it is to be human.

Dr Kathryn Smith | Photo by Caroline McClelland

So says Dr Kathryn Smith, an interdisciplinary visual artist, curator, and Chair of Visual Arts at Stellenbosch University (SU). She also heads up VIZ.Lab, an imaging laboratory based in the Department of Visual Arts at SU. Smith launched the laboratory in 2021 and is today joined by Pearl Mamathuba, a forensic artist and SU PhD candidate, as a full-time postgraduate researcher.

Smith and Mamathuba are, to date, the only two South Africans to have completed the MSc in Forensic Art and Facial Identification at the University of Dundee in Scotland, the world's first institution to offer a full postgraduate qualification of this nature.

According to Smith, other universities offer short introductions to this field as a part of forensic anthropology or medical illustration modules. Some have special units offering research support, such as Face Lab at Liverpool John Moores University, where Smith is a visiting research fellow.

A first for the continent

SU is the first tertiary institution in Africa to offer research and casework expertise in forensic facial imaging, a critical tool in human identification. As the only two academically trained forensic facial imaging specialists on the continent, Smith and Mamathuba have a shared interest in working towards reinstating personhood through the lens of forensic art.

After being lauded as a Standard Bank Young Artist in 2004, Smith joined SU in 2006 as head of the fine art division in the Department of Visual Arts. Six years later, she realised a longstanding wish to formalise her interest in forensic cultures and procedures by immersing herself in her studies at Dundee's Centre for Anatomy and Human Identification. Here, she gained the skills and knowledge she intuited necessary to forge a career in what was to become a many-layered forensic art space.

VIZ.Lab draws on local and international expertise in its research projects at the interface of art and science. Here, knowledge of facial anatomy, biological anthropology, forensic pathology, and cognitive psychology is blended with cutting-edge technology to perform craniofacial analysis, reconstruction, and depiction for both forensic and archaeological applications.

Currently, Smith is working to grow VIZ.Lab's ability to host postgraduate researchers working with visual cultures of science, object-orientated ontologies, and digital imaging. She also hopes to welcome students pursuing research in fields other than forensic art, including anatomy and related sciences, with a forensic identification application.

Building relationships

Smith realised early in her career that if she wanted to do forensic art in South Africa, she would need to do so within a research environment because of the benefits it holds, such as institutional support and authority. She would also need to sign a service contract with the South African Police Service (SAPS) to be able to formally assist with any cases they receive. This realisation led to, among other projects, the formation of the Western Cape Cold Case Consortium (W4C).

"The W4C is a collaborative, ongoing research project that has proven to be one way of both working closely with Forensic Pathology Services [FPS] and getting cases directly referred from them. It involves exploring the possibilities of multifactorial analysis for complex identification cases within a research context, but with explicit application to the improvement of service delivery."

Smith notes that FPS, which is part of the Department of Health, and SAPS operate under a memorandum of understanding regarding unidentified cases, as each has a specific mandate. FPS investigates the death and is the custodian of the body; SAPS is responsible for its identification. "FPS and SAPS collaborate in order to do this work. Sadly, this relationship is full of challenges, although there are active attempts to enable better cooperation, especially in the Western Cape, which is also the only province with digitised FPS records."

Shaping a likeness

Smith is often asked the question, "How does one know, when creating a forensic likeness of a person, that it is accurate?"

In answer, she explains that forensic artists do validation studies of anatomical data and utilise medical imaging technologies.

"Because of the developments in technology, I could now conceivably put you in a CT scanner, scan your head, and then segment the scan to separate hard tissue from soft tissue, and process each set of data into virtual 3D models, a skull and a face surface. I would then hide the 'face' model so it doesn't interfere with my study and do a 'blind' reconstruction of the skull using existing methods, and then compare my reconstruction with the 'real' face model using 3D mapping to check how accurate my initial reconstruction was, from a shape-based perspective. These studies are common — that's how validation is done nowadays."

Smith has studied the relationship between shape-based accuracy and likeness extensively. "If we know that the currently available methods are accurate within two millimetres for 70% of the facial surface, that's pretty good. But it doesn't mean that the shape model is necessarily recognisable.

"A lot of the very sophisticated facial compositing software that is now available uses what is called 'evolutionary algorithms'. When we see faces, we don't encode them feature by feature. Our brains don't work like that. We encode faces holistically. These software packages are corresponding more and more to our cognitive face processing and facial recall capacity."

Technology, science, and art on equal footing

Forensic art is divided into two broad categories: the identification and depiction of living subjects, on the one hand, and the deceased on the other. "For living persons, artists are usually involved in developing composites of persons of interest from eyewitness memory," Smith says. "For the dead, artists reconstruct facial appearance to assist investigators when other conventional methods of identification such as fingerprints, dental records, and DNA aren't available.

"There are many contexts in which one might need to identify an unknown person that could be either dead or alive. Creating age-progression images, such as those you might do for abducted children or fugitives who have disappeared for various reasons, is the least scientific method. In such cases, there is a lot of guesswork involved.

"There are certain things, like juvenile facial growth and development, for which you have data from the maxillofacial field [relating to the mouth, jaw, face, and neck] to refer to. But the specifics of a particular face? There are so many differences, even with twins. Lifestyle can have a huge impact on how they've aged. Depictions of age progression may be the least scientifically supported of the forensic art techniques, but they play a critical role in prompting people to remember particular events and people, and leads can be called in decades later."

Technological and methodological advances expand the scope of forensic art, benefitting police work and heritage projects. Within this context, Smith considers the implications of artificial intelligence (AI): "For a long time, there's been an interest in automating facial reconstruction. There was also the idea that if we can computerise it, then it is automatically more objective. However, the limitations of AI have since been quite well illustrated in the realm of facial recognition technologies. It is essentially computer vision. You train your system on a data set. So, your system is only as good as the diversity of the data. And if you have a limited data set, you are going to get a limited output."

Increasingly, the importance of secondary identifiers, such as clothing and personal effects, are understood to have huge value in complex contexts, therefore Smith sometimes also needs to reconstruct objects. "It is in the heritage space, where a historical person may be shown wearing garments or with artefacts informed by the archaeological record, that this contextual reconstruction informs our understanding of an unknown individual's personhood."

Artist, curator, and collaborator

Smith prefers to look at art — her own and that of others — through the lens of curatorship.

"I normally make installation environments or curate exhibitions. I also extend my interest in curatorship to how I approach my own work. I put together lots of different things in order to explore unexpected relationships and the meaning or knowledge that may be created when unrelated things are made to connect, or familiar things come together in unexpected permutations."

Smith has participated in many projects over the years, notably as a co-curator of one commissioned by the Nelson Mandela Foundation for an exhibition called "Poisoned Pasts", which looks at the legacies of South Africa's chemical and biological warfare programme. The exhibition opened in 2016 at the Nelson Mandela Centre of Memory and travelled to several venues. It is currently at the Ditsong National Museum of Cultural History in Pretoria.

> "It's very much a social history exhibition, but it also asks questions around the dual uses of science — science for good or for bad," Smith says.

Smith's online artwork *Speaking Likeness*, which is also an artists' book, anthologises the diversity of her community of practice from a global perspective. This work was recently featured in an exhibition in Norway and is currently on display in Slovenia. She is working with Prof Pumla Gobodo-Madikizela to try to get the exhibition to Stellenbosch. Gobodo-Madikizela holds the South African Research Chair Initiative (SARChI) chair in Violent Histories and Transgenerational Trauma at SU and was a member of the Truth and Reconciliation Committee.

"The most exciting recent development, however, is my connection with the new SARChI SciComm chair, Prof Mehita Iqani. We are actively exploring how visual arts can contribute to her agenda of 'science communication for social justice', which is at the core of my forensic and heritage work but gains broader scope in her vision. It's telling that two of her postdoctoral research fellows are both visual artists, now situated in a science communication environment — in journalism."

Forensic art at a crossroads

Smith works in what she calls "the forensic humanitarian action space". She and Mamathuba do forensic identification "while being very conscious of the social biases built into the structural inequalities that make some bodies appear to matter more or less than others".

In forensic work, one is confronted with someone who has lost their identity through whatever circumstance. Smith explains: "You can't ever fully reinstate personhood, obviously, but it remains an ambition. With forensic imaging, you are trying to identify an individual, you're not trying to create a type of person. This is where assumptions based on legacies of data derived from physical anthropology, or 'race science', need very careful reassessment.

"There is a move among more progressive practitioners in the fields of biological and forensic anthropology towards rethinking the concept of 'ancestry' or 'population affinity', and towards not including it in biological profiles based on analysis of skeletal morphology. Biological sex also needs some critical reassessment, given that it may not accord with our gender identity or presentation. Yet, the convention is to only think in binary terms, and the forms we use to report this data don't offer a third space."

Forensic practice on two continents

Smith has looked at international examples of how forensic art, both academically and in practice, might benefit people.

"A colleague at the National Centre for Missing and Exploited Children in the USA does facial reconstruction training workshops in different American institutions, using actual cases. The reconstructions are made public at the conclusion of each workshop and, more often than not, at least one or two of the depicted persons are recognised. So, they use a skills-transfer opportunity to simultaneously generate publicity around unidentified people. I want to replicate this in our context, but getting access to the data is the first challenge.

"Compared to ours (South Africa's), American laws tend to have a more relaxed interjurisdictional relationship when it comes to applying forensic art to unknown decedent cases," Smith says. "For instance, the medical examiner's office could simply clear or make skulls available for such use. Forensic art is practised in a controlled context, led by an expert. In South Africa, however, there's a lot of fear surrounding mortal remains."

When asked about the impact of tighter regulation in South Africa, Smith says: "I think there's so often a lack of understanding within the biomedical ethics space. One of the principles in clinical research is the anonymisation of patient data. In the forensic identification space, however, we are working with already anonymised people who must no longer remain anonymous. We are trying to identify them, which is a requirement in our *Inquest Act*, and a basic human right.

"Often, it can lead to a very interesting conversation as we are ultimately trying to answer the opposite question: How can we 'undo' anonymisation in death? Taking into account the greater good, you can often argue that the benefits outweigh the risks, which is essentially what ethics tries to achieve."

A sense of urgency

Smith leaves little doubt that there is a dire need for forensic art skills internationally and also in South Africa. "This is only a back-of-the-envelope calculation because these statistics are not formally kept, but up to 10 000 people in our forensic medicolegal laboratories are left unidentified every year."

She emphasises the urgent need to develop the field due to societal implications. "For one, we need to create jobs in the sector before we start offering any degree programmes. Right now, I am trying to generate as much exposure as possible by talking to academic and popular audiences and looking at ways we can build on existing research networks and projects locally, internationally, and in Africa.

"There is so much scope for developing forensic facial imaging in neighbouring African countries with some forensic infrastructure, especially in parallel with the extraordinary work of the International Committee of the Red Cross and the new African Centre for Medicolegal Systems."

Ultimately, Smith sees connecting with and creating open lines of communication between various roleplayers as the first and most important tasks in the development of the field.

A SPICE AS MEDICINE

THE POSSIBLE ROLE OF TURMERIC IN TREATING PARKINSON'S DISEASE

ENGELA DUVENAGE

Illustration by Ronel van Heerden

In the past, Delia (a pseudonym) often used turmeric to provide colour and taste to rice, bobotie, and curries. Recently, however, she's also started adding a sprinkle of this yellow spice to fruit smoothies, milkshakes, and even coffee — in which case the flavour isn't always complementary. Fortunately, her homebrew's strong aroma helps to mask the bitter, mildly earthy taste of the spice.

Prof Soraya Bardien | Photo by Wilma Stassen

Delia always gulps her drink down quickly. After all, she isn't drinking turmeric for the culinary experience. She's doing it for her brain.

She recently read that the polyphenol curcumin found in turmeric has strong antioxidant and anti-inflammatory properties and that, in India, a paste made from the yellow spice is commonly applied to wounds. Moreover, she learnt that researchers are investigating its possible role in guarding against and treating Parkinson's disease (PD).

The burden of disease

Members of Delia's extended family have suffered from PD, a degenerative neurological condition that develops when brain cells stop producing enough dopamine, a brain chemical that coordinates movement. This so-called "movement disorder" is characterised by, among other symptoms, rigidity, resting tremors, sleep disturbances, and depression.

Delia had to watch her grandfather fade away from a headmaster who could mesmerise a school assembly to a frail old man who took ages to respond to questions, and then only in the softest of voices. Often, his hands shook so uncontrollably that he couldn't drink coffee without spilling. At other times, he would freeze to the spot, unable to shuffle down the passage to make it to the bathroom in time.

The experts called his increasingly slow, halting movements "bradykinesia". This, along with the tremors, is a typical symptom of PD, a disease for which there is still no cure. The only known therapy, the amino acid (or protein "building block") levodopa, is merely palliative and only temporarily enhances levels of the neurotransmitter dopamine in malfunctioning brainstems.

The effectiveness of levodopa wears off over the course of a day, and often over a patient's lifetime. It also comes with side effects such as lightheadedness, a loss of appetite, and even hallucinations. For some patients, the dyskinesias — the involuntary erratic writhing of one's face, trunk, or limbs — are worse than the PD symptoms themselves.

These symptoms start unobtrusively. A loss of taste is often the first sign of emerging PD, many years before symptoms such as a masked, unemotional face, tremors, or forgetfulness make their presence known in full colour.

Possible new therapy

Over the past decade, research groups from countries such as India, Pakistan, Italy, Mexico, Iran, and China have explored the use of curcumin as a pharmacotherapy to stave off PD, and possibly even cure the neurological damage it has already caused in patients who suffer from it.

Recently, in Stellenbosch University's (SU's) Faculty of Medicine and Health Sciences, members of its Parkinson's Disease Research Group have also started studying curcumin's use in PD treatment, and its role in gut-brain interaction.

This research is funded by the National Research Foundation and the South African Medical Research Council.

"Our studies are still in their very early stages, with tests so far only being done on cell lines and not even animal models yet," says Prof Soraya Bardien, head of the Parkinson's Disease Research Group in the Division of Molecular Biology and Human Genetics at SU's Biomedical Research Institute (BMRI).

Finding the root cause

Bardien says there are many theories about how and where exactly in the body PD starts. The strongest of these maintains that it's in either the gut or the brain.

In a 2021 paper published in the *European Journal of Neuroscience*, Bardien's team explains that a pathological

hallmark of PD is the buildup of toxic forms of presynaptic alpha-synuclein, a neural protein, in specific structures in a patient's gastrointestinal tract and brain called "Lewy bodies". This might be because the protein moves along the vagus nerve that connects the brain to the gut.

With time, as more such Lewy bodies accumulate, patients start experiencing problems with thinking, movement, behaviour, and mood. The starting point for the movement of alpha-synuclein seems to vary from patient to patient. This could explain why people with PD experience different symptoms and clinical versions of the disease. Some often experience gastrointestinal problems, for example, while others do not.

Evidence is still scant on whether surgical alterations of the vagus nerve or operations to remove gut-associated lymphoid tissues, such as the appendix and tonsils, provide protection against PD.

Curcumin as toxin magnet

Researchers are interested in testing whether curcumin can bind to specific parts of alpha-synuclein, specifically its non-amyloid-beta component. The idea is that, if curcumin can work like a "magnet" to attract and then bind with alpha-synuclein, the molecules will be quickly excreted from the body in tandem. Ultimately, this will prevent the protein from building up in the body to the point of toxicity.

A drawback is that curcumin is excreted quickly, and in great quantities. This makes it difficult for the body to take up enough of this polyphenol for it to be of any real value, and for it to cross the brain-blood barrier and target the brain cells that are lost in disorders like PD, Bardien explains. Even if proven helpful, it is likely that curcumin will have to be taken as a lifelong complementary supplement.

Two of Bardien's PhD students, Jessica Burns and Amy Buck, are investigating whether it is possible, and helpful, to cover curcumin granules with nanoparticles made from organic and biodegradable materials.

The point of their work is to determine whether this technique will help slow down the excretion of curcumin, improve its crossing of the blood-brain barrier, or both — thereby boosting its ability to provide neuroprotection to people living with PD.

Burns says their studies are motivated by others that have shown the use of nanoparticle-encapsulated curcumin to provide better results in the treatment of diseases. They are currently working with commercially acquired neuroblastoma cell lines, but hope to also do tests on the cells of people with genetic forms of the disease. Burns and Buck's studies focus specifically on the mitochondria of brain cells, which they believe play an integral role in the development of PD.

Could genetic factors be at play?

PD is the fastest-growing neurological disorder in the world. This is likely also the case in Africa, although this remains to be shown. The environmental and genetic factors possibly linked to the disease have been studied widely in various populations across the globe, but similar investigations among African populations are still few and far between. In point of fact, the Parkinson's Disease Research Group at SU is the only one of its kind on the continent.

Established in 2000 by neurologist and movement disorder specialist Prof Jonathan Carr, this multidisciplinary group studies the genetic basis of and molecular mechanisms at play in PD development. Despite having been discovered in Western medicine some 200 years ago, the exact causes of PD are still not quite known, Bardien says. An interplay between environmental factors and genetic causes is most possibly at its root.

"So far, genetic factors have only been linked to 10 to 15% of all cases of PD, and are often associated with families with a history of early-onset PD," she notes.

Patients with early-onset genetics-related PD are often diagnosed in their twenties or early thirties, whereas others tend to receive their diagnosis around retirement age only.

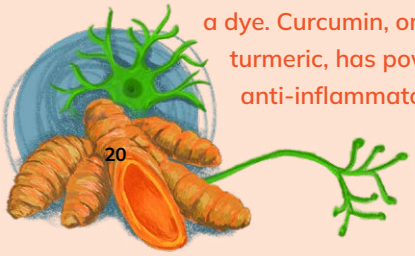
One of the important findings from the work of Bardien's research group so far is that there may be a founder effect for PD in some Afrikaner families, dating back to the 1660s. The term founder effect refers to the reduction in genetic variation that occurs when a new population is founded by a very small subset of a large population. This often increases the occurrence of otherwise rare inheritable diseases in the new group.

Also, as part of an international collaboration, neurologist Dr Riaan van Coller was able to identify a novel pathogenic variant in the PTRHD1 gene in a specific Xhosa family with a history of early-onset PD and intellectual disability.

These findings are the result of studying DNA samples gathered since 2006 as part of the South African Parkinson's Disease Research Collection database, housed at SU.

Spiced gold

Bright yellow turmeric powder, also known as "Indian saffron" or "the golden spice", is made from the ground roots of a rhizomatous, herbaceous perennial native to tropical South Asia. Apart from being a major ingredient in curry powder, it is also used as a dye. Curcumin, one of the components of turmeric, has powerful antioxidant and anti-inflammatory properties.



"Parkinson's is a real disease. It affects at least 3% of the population worldwide. There are many people suffering from it in South Africa, but it's not always properly diagnosed. It's a horrible disease. People who have it are often not understood, possibly because of the movements that go along with it. They suffer from depression and apathy. It's often not seen as a disease. Some people think it's witchcraft, or something else. They think people can snap out of it. We really need to raise awareness about the disease." — Prof Soraya Bardien, head of the Parkinson's Disease Research Group at SU

Most of the work on these samples has been concerned with specific single-gene variations previously identified by other researchers as being linked to the development of PD.

"By looking at these single genes that others have identified, we've found that the pick-up rate in the South African population is very low. That means that we are not finding the same pathological gene variations in families with two or three generations of PD as we do elsewhere in the world, for instance in America or Europe. It makes me think that if we have a pathogenic variant in these families, it's in a yet undiscovered gene," Bardien notes.

She considers studies on the genetic differences between Southern African populations to be of great importance. "We know the genetics of populations in sub-Saharan Africa to be the most diverse globally. Because the genetics of PD in these populations has not been well studied, it is vital that these populations be investigated to determine whether they have novel genetic causes of this disease."

The GP2 as research booster

"Funding in South Africa for PD research is very limited, given all the infectious and cardiovascular diseases we have. We've never been able to do sequencing of the whole human genome, in search of possible new variations specific to our unique South African population," Bardien explains.

As such, she is excited about her research group's involvement in the Global Parkinson's Genetics Program (GP2), and what it could mean for the study of the genetics of PD in African populations. Funded by the Michael J. Fox Foundation, the GP2 is an ambitious initiative to genotype 150 000 volunteers around the world to better understand the genetic architecture of PD.

Bardien says the endeavour, which provides free whole-genome genotyping and sequencing to participating countries, is a "game changer" and already includes 100 research teams from around the world.

"The idea is to do genotyping in underrepresented populations in especially Africa, Asia, South America, and pockets of Europe where such research cannot be done; to help them recruit study participants; and to do whole-genome sequencing for free if the necessary genetic labs aren't locally available," she explains. "To my knowledge, this has not been done for any other disease at this scale before."

Identifying and characterising carriers of specific genetic variations involved in the development of PD is "imperative in light of related gene-targeted therapies increasingly being developed", Carr and 106 other researchers wrote about GP2 in a 2023 paper published in the journal *Movement Disorders*.

Data for Africa

Bardien is excited about what SU's involvement in GP2 could mean for local and global PD science.

"We might get some real answers about the genetics of South African people with PD. We might even find, through this consortium, that there is a bigger genetic component worldwide to PD than the cases that we currently know of. Sequencing is done for free. The data is then used to do global analysis. At the same time, we receive our own data back, which we are allowed to analyse and publish on our own."

After only a few months, Bardien's team has already received back their first batch of genotyping and whole-genome sequence data. It is now up to PhD student Kathryn Step and human genetics MSc student Abigail Braun to analyse this data in detail, in search of possible new variants in specific South African individuals and their families.

"Populations in Africa are some of the oldest worldwide, therefore our genetic diversity in the causes of PD could also be the greatest," Bardien notes. "Already, the consortium has had to adapt some of its protocols to be able to better analyse the ancestral makeup of participants from the South African population."

Did you know?

- Parkinson's disease is a brain disorder that affects 7 to 10 million people worldwide, most of them men.
- The disease is vastly understudied in Africa.
- Most people who develop Parkinson's are over 60, but one in ten are under 50 years of age.
- The Global Burden of Disease Study 2015 estimated that there may be nearly 13 million people with Parkinson's by 2040.

RESEARCHERS CONSIDER MECHANICAL SHUDDERS ON POLAR VESSEL

JORISNA BONTHUYS

Photos by James-John Matthee

Prof Anriëtte (Annie) Bekker, a vibration science expert at Stellenbosch University (SU), is willing to brave harsh conditions in pursuit of new knowledge. Her interest lies in how data from mechanical sensors and engineering models on board a polar vessel can help seafarers make more informed decisions towards safer ship operations. More specifically, she marvels at the sounds caused by vibration on such a vessel and gets excited about the research opportunities they offer.

Prof Annie Bekker | Photo by James-John Matthee

Bekker holds the Gibela Engineering Research Chair in SU's Department of Mechanical and Mechatronic Engineering. After joining the department in 2011, she became its first female professor in 2020, and today also heads up its Sound and Vibration Research Group (SVRG).

Over the last decade, Bekker and members of the SVRG have investigated noise and vibration in the shipping and engineering industry. Their work now includes rotor and structural dynamics, and a role in the operational deployment of digital twin technology. (Put simply, a digital twin is a virtual replica of a physical object, process, or person that can be used to simulate their behaviour to support decisions through information.)

Wired for sound

Bekker discovered her passion for the vibration of structures as a third-year student in mechanical engineering. But her fascination with sound started much earlier, as a young girl growing up in Benoni. Her parents, a mechanical engineer and a doctor, are passionate about engines and classical music, and instilled a similar interest in sound in Bekker and her two brothers. "In the mornings, my father drove us to school in what can be described as a daily vehicle performance test, which sparked my interest in the topic. In the evenings, I practised playing my violin with my mother, who plays the piano.

"Music, like engineering, is a science of precision; it has rules," she says. "But the sequence of notes can change in character in the skilled hands of a musician. Mechanical forces — be it the pressure of fingers on piano keys, or waves crashing onto a ship's hull — give rise to vibrations, some of which are transmitted to the air and experienced as sound. I am curious about the nuances that give sound a special quality and the science that allows us to pinpoint these qualities."

For Bekker, the versatile field of engineering has served as a springboard for her diverse research into topics such as dynamic seat comfort in automobiles and the prediction of bone fractures in occupants of vehicles caught in landmine blasts.

She has led multi-sensor measurement campaigns on the heavy mobile equipment fleet for Richards Bay Minerals, as well as on polar vessels. Her work now centres around the vibration of machinery and structures.

Research aboard a polar vessel

Over the last decade, Bekker and 34 of her students and collaborators have benefited from exposure to scientific work on the *SA Agulhas II* — Africa's only polar supply and research vessel, which offers unique research opportunities for scientists.

In particular, Bekker and her students have focused on how the vibration of this vessel, caused by ice and waves, impacts its hull structure and propulsion system, as well as the humans on board.

Doing research on a working polar vessel of this kind requires researchers to go the extra mile, Bekker says.

Antarctica is the coldest, driest, and windiest place on the planet. Recent studies focused on this continent and the Southern Ocean have provided crucial insights into our changing world.

The polar regions are experiencing significant shifts, with ice loss and rapid ocean changes being observed. The west coast of the Antarctic Peninsula has, for instance, been warming at an alarming rate over the past 50 years. This warming trend is not limited to the land but can also be observed in the Southern Ocean. These and other ecological changes in the region have widespread impacts on the rest of the globe, affecting nature and humans in various ways.

Polar supply and research vessels, such as the *SA Agulhas II*, are vital platforms through which researchers investigate the physical and biological marine environment.

Digital transformation

Over the past decade, the *SA Agulhas II* has been equipped with an "engineering nervous system" of sensors in order to create a digital version of the vessel in operation that can serve as a prototype for Vessel 4.0.

This project, which entails taking engineering measurements on a polar ship in operation, kicked off in 2012. Today, the *SA Agulhas II* has more than 200 engineering and monitoring sensors to measure the impact of ice and waves on the vessel, the bending and twisting of her hull, and human responses to mechanical vibrations on board.

Bekker says these sensors help pinpoint impacts and shudders as the vessel interacts with her ever-changing environment. The digital transformation of the hull also supports improved decision-making by both its captain and its owner — the Department of Forestry, Fisheries, and the Environment.

"This research positions our group to collaborate internationally and to explore the practicalities of Vessel 4.0 by developing a digital vessel," Bekker says. Funding from the South African National Antarctic Programme has been pivotal in the group's efforts.

In search of a famous wreck

SU's involvement in the digital transformation of the *SA Agulhas II* enabled Bekker and a team of researchers to participate in expeditions in search of Sir Ernest Shackleton's famous shipwreck, the *Endurance*, in 2019 and 2022.

The crew and researchers on board the *SA Agulhas II* aimed to navigate their way to the exact location in which the ship sank during Shackleton's Imperial Trans-Antarctic Expedition, which took place in 1914 to 1915.

In 2022, the South African vessel embarked on the Endurance22 Expedition to the Weddell Sea. This was her second attempt to find the missing wreck of the *Endurance*, which — after being stuck in ice for months — was finally crushed by its sheer force in 1915.

Apart from mapping sea ice from space, representatives from the South African Weather Service, Drift+Noise, the Alfred Wegener Institute, the German Aerospace Center, Aalto University, and SU researched the ice floes, sea ice thickness, and weather conditions during the expedition. Experts from the institutions involved spent hundreds of hours conducting climate change- and vessel-related studies.

Bekker, the late James-John Matthee, and Ben Steyn provided insight as to the impact of the encountered environmental conditions on the ship hull and propulsion system.

"While the vessel navigated through sea ice, we investigated propeller vibration and how the vessel handled the ocean crossing," Bekker says. They monitored vessel performance throughout the expedition. "We measured acoustic emissions on the bearings," she says. This work was done with collaborating researchers at RWTH Aachen University.

In March 2022, after more than a century, the almost pristine wooden wreck of the *Endurance* was located on the ocean floor at a depth of 3 000 metres.

Going with the (ice) floe

During the expedition, the vessel had to navigate ice floes (thick, pancake-like ice structures), a crucial step in ensuring a polar ship's safe voyage.

"In ice, a ship's propeller blades interact with ice debris when it gets pushed under the hull and stern area," Bekker explains. "Milling or single impacts of ice on the propeller cause twisting loads on the propeller, which are transferred onto the propulsion shaft as vibration." Working in these conditions puts extreme pressure on any vessel, even the *SA Agulhas II*, which was designed and built for seafaring in harsh conditions, she says.

Considering that the hull is ice-strengthened, the limiting factor in the vessel's ice-going ability is the propulsion system, Bekker explains. "Our job was to see if we could measure the propulsion loads [caused by ice impact]. In this case, our main challenge was to collect and make sense of data, and make it available in real time to decision-makers on board."

Several research outputs followed from the expedition. For instance, a new model for the inverse estimation of ice-induced propeller moments (i.e. twisting loads on the propeller) on ice-going vessels has been developed based on modal superposition. In a 2022 paper on this topic, PhD candidate Brendon Nickerson outlined the loads experienced by the propellers of ice-going vessels.

A whipping problem

Although the *SA Agulhas II* was designed with ice considerations in mind, the vessel spends most of her working days in open water. Her spoon-shaped hull enables her movement in both sea ice and open water, Bekker explains. This hybrid design also means the vessel is predisposed to wave slamming.

Slamming is rather unpredictable on ships and can affect some of the oceanographic instruments being deployed. "When you expose ships to slamming, it creates a jelly-like motion and fatigue to the [vessel] structure, called 'whipping'."

Bekker believes the engineering sensors that have been installed on board can help provide valuable data on this phenomenon.

Damage caused by whipping increases when a vessel navigates in storms. "Our research shows that if the ship is stationary with waves approaching from behind, up to 98% of the fatigue damage to the hull structure of the *SA Agulhas II* is caused by whipping. We noticed cracks on parts of the ship that require constant repairs. These findings are relevant to ice-going hull designs with mission profiles that cross stormy oceans, such as research and tourist ships that operate in Antarctica," Bekker says.

The *SA Agulhas II* has served as a case study of the International Ships and Offshore Structures Congress subcommittee on structural longevity, which aimed to review novel developments in and challenges for predicting and monitoring vessel fatigue. As a result, Bekker has become a member of this subcommittee, which consists of experts from 15 countries.

Learning from digital twins

Technological advances have given rise to the possibility of advanced condition monitoring of a vessel through a digital twin, which involves feeding operational data into an engineering model.

The twin is constantly updated with real-time data from sensor feeds on the ship structure and machinery, and with data about her environment, which means that the state and behaviour of the physical counterpart can be accurately reflected.

"Over the past decade, we have performed full-scale measurements on this vessel," Bekker says. "Together with our collaborators at Aalto University [in Finland], we have created the world's most comprehensive open source data set on polar vessel operations, based on long-term operational measurements."

According to Bekker, their results show that the vessel operated "close to her safety margins" at times during the Endurance22 Expedition. She says their research can assist navigators with situational awareness based on the ship's structural margins, calculated using measurements and algorithms.

The SVRG is also involved in the HealthProp project, which is aimed at developing systems that can monitor the performance of a vessel under ice impact, and predict its lifespan. Funded by the MarTERA cofund scheme under the European Union's Horizon 2020 programme, in collaboration with the South African Department of Science and Innovation, HealthProp focuses on improving the reliability and operational safety of ships' propulsion systems.

Bekker says there is a clear need for full-scale measurements of ice impacts on ship propellers. "Although there are several tools available that provide information on ice conditions, navigators still need help quantifying actual ship operations' structural safety margins," she explains.

For the purposes of this project, SU researchers are partnering with the Norwegian University of Science and Technology, Hamburg University of Technology, RWTH Aachen University, Otto Piening GmbH, and EDRMedeso.

Mariner 4.0 simulates reality

Researchers in the SVRG are also exploring a human digital twin solution — a virtual representation of the real-time state and behaviour of a unique individual — for seafarers on the *SA Agulhas II*.

PhD student Nicole Taylor has introduced Mariner 4.0, a seafaring "passenger" or "crew member" with technologically augmented skills. This work explores human-related challenges on seafaring vessels and the expected value of human digital twin solutions for the maritime industry.

Bekker says Mariner 4.0 aims to represent human factors in digital systems and bridge the cyber-physical interfaces likely encountered by a seafarer in a digitalised ship environment. Taylor's research on this human digital twin facilitates the monitoring of motion sickness in passengers. Bekker says this information can be fused with subjective responses submitted through an Android handset and displayed on a screen.

In a recent paper, PhD student Martinique Engelbrecht also proposed a threshold for the onset of discomfort induced by vibrations transmitted to the human body through wave slamming. This threshold constituted the point at which 50% of the respondents indicated a level of discomfort that disturbed their sleep and work.

Bekker says this work could contribute to comfort thresholds for cruise ships where a positive passenger experience directly affects business success.

Sound passenger transit

Bekker and a team of collaborators are now setting up a passenger train digital twin for the Gibela Rail Transport Consortium. The consortium is manufacturing 600 state-of-the-art X'trapolis Mega commuter trains in Gauteng. To help ensure that the fleet is managed optimally during its lifetime, Bekker will be applying what she learnt about digital twins on the *SA Agulhas II* to this new project. She is developing a digital "watchman" in the form of a sensor array on the track that can automate some inspection tasks on trains.

The project includes research on new sensors and measurement strategies, signal processing, and data fusion.

IT'S NOT JUST ABOUT THE GUNS

ANÉL LEWIS

When Renamo leader Ossufo Momade handed over an AK47 rifle to Mozambican president Filipe Nyusi in June this year, it was a symbolic gesture confirming the end of the disarmament, demobilisation, and reintegration (DDR) process in Mozambique. The international community breathed a collective sigh of relief. Renamo is now formally recognised as a political party, and 48 years of conflict in this region have hopefully come to an end. But are disarmament programmes, many of them led by the United Nations (UN), doing enough to ensure post-conflict peace in the long run?

The international community has invested heavily in disarmament programmes. Yet, according to the School of Culture of Peace, there were upwards of 33 armed conflicts around the world in 2022, many of them in regions where disarmament and demobilisation have already taken place. Africa was host to nearly half of these conflicts.

The question as to why certain disarmament programmes work while others don't is the focus of DISARM, a 3,5-year-long project on the effect of disarmament on conflict recurrence. Funded by the Norwegian Research Council, the project is a pivotal collaboration between Stellenbosch University (SU) and the Peace Research Institute Oslo (PRIO). The institute researches the conditions necessary for peaceful relations between states, groups, and people.

The leader of this project on the SU side, Dr Guy Lamb from the Department of Political Science, has spent more than 25 years researching conflict, arms control, peace building, and violence reduction in Africa. But, he says, the DISARM project is the first systematic global study to look specifically at what causes conflict recurrence after disarmament has taken place. "Disarmament is often approached in a technical way and is seen as a priority by the United Nations."

The North Atlantic Treaty Organization (NATO) defines disarmament as "the act of eliminating or abolishing weapons either unilaterally or reciprocally". With this in mind, Lamb says the focus tends to be on how best to remove weapons from combatants, and how to subsequently destroy them. But there is no work being done on whether the process is effective and whether it has a lasting impact on peacekeeping.

To better understand the conditions under which disarmament can successfully prevent conflict recurrence, the DISARM team has applied a mixed-method research design in collecting data on disarmament provisions in all intra-state peace agreements worldwide between 1975 and 2020. The data makes it possible to quantitatively examine the relationship between disarmament and conflict recurrence by literally counting the incidences where violence reignited.

"Currently, little is known about how various disarmament programmes differ or overlap in design and impact," says Lamb. The team is therefore taking the research a step further by applying a qualitative lens to four case studies: Namibia, Mozambique, Indonesia, and the Philippines. "In this way, one can begin to understand how important disarmament is vis-à-vis rebuilding the state and peacekeeping," says Lamb. Work is already underway in Namibia and Mozambique, with plans to start fieldwork in the other regions towards the end of the year.

The Namibian 'success story'

The absence of a significant recurrence of conflict in Namibia after close to three decades of war is often hailed as a disarmament success story. While there have been flare-ups — Caprivi secessionist violence in the late 1990s and reports of ongoing violent crime — the situation in the country has remained comparatively controlled after three decades of war ended in 1989, noted SU researcher Haylene Bossau in a presentation at the British International Studies Association (BISA) 2023 Conference.

Lamb attributes this phenomenon to the multi-faceted dynamics that played a part in Namibia's reasonably successful transition to democracy. Various disarmament processes and government support of ex-combatants helped to reduce conflict. "South Africa's withdrawal from Namibia to focus on its own democratic transition also certainly helped," says Lamb.

Mozambique's fragile peace

Mozambique, however, offers an example of how disarmament efforts that ticked all the boxes for a peaceful transition can still be followed by conflict. "There was complete disarmament, demobilisation, and reintegration (DDR), and still weapons resurfaced," says Lamb.

In her analysis of the conflict situation in Mozambique over the past 50 years, also presented at the BISA 2023 Conference, SU PhD candidate Monique Bennett questioned why the country's warring parties, Frelimo and Renamo, returned to armed conflict even after the UN proclaimed the DDR process a success when the civil war ended in 1992.

Persistent mistrust between the parties posed a challenge to the long-term success of DDR, explains Bennett. She said the mandate was ambiguous, and the UN — faced with timing and resource allocation issues — could only find temporary solutions to the problems. She added that Renamo still had the same access to weapons as it had during the civil war that lasted from 1977 to 1992, and wartime networks also prevailed. The resultant tension between Renamo and Frelimo spilled over into banditry and criminal activity.

Well-intended attempts at DDR can have negative outcomes when coupled with unresolved grievances, Bennett emphasises. "If not done with adequate, careful design or implementation, as in the case of Mozambique, disarmament can create a 'fragile peace'."

Women and war

An often neclected aspect of disarmament — namely the impact it has on women combatants — is another topic under consideration by DISARM. Of the 33 armed conflicts that took place in 2022, 23 occurred in countries with a low level of gender equality. Yet, gender is a filter not often applied to discussions around disarmament and reintegration, explains Lamb.

"We need to understand how women view weapons and what the implications of disarmament will mean for them. Do peacekeeping programmes take the needs of women into account?"

Whereas previous studies have looked at women as victims, more needs to be done to investigate the role of women combatants in peacebuilding, he says.

In a conference paper titled "Still lacking representation: Women and minors in DDR provisions (1975–2021)", presented at Folke Bernadotte Academy in February 2023, Júlia Palik notes: "Women and minors participate in conflict directly as combatants or commanders, and in several different indirect roles. Despite the UN Security Council Resolution 1325 (2000) and the UN's Integrated DDR Standards' (2006) explicit calls to include women and minors in DDR programmes, both groups remain grossly underrepresented in these processes." Palik, a senior researcher at PRIO and leader of the DISARM project, adds that, in a study of 126 peace agreements with at least one DDR component each, only 2 made reference to women, 11 mentioned minors, and only 9 referred to both groups. Furthermore, these mentions of women and minors were "essentialist, vague", with both groups portrayed as victims.

What about nuclear disarmament?

Apart from those in the DISARM study, the Russia-Ukraine conflict is another clear example of cracks in efforts at disarmament and peacebuilding, especially in relation to nuclear weapons. The military invasion of Ukraine by Russia in February 2022 has caused mass turmoil and upheaval, leading to not only armed conflict but also a larger humanitarian crisis with a significant impact on the global community.

Earlier this year, Izimi Nakamitsu, Under-Secretary-General and High Representative for Disarmament Affairs, reported in a UN Security Council meeting that the risk of nuclear weapons being used in war is currently the greatest since the height of the Cold War. Her comments followed Moscow's announcement that it would station non-strategic nuclear weapons in Belarus.

Nakamitsu stated, with reference to the war in Ukraine, that "the absence of dialogue and the erosion of the disarmament and arms control architecture, combined with dangerous rhetoric and veiled threats, are key drivers of this potentially existential risk". On the other side, the Russian Federation argued that there has been a "severe erosion" of global security, with efforts by "victors of the Cold War" to "systematically dismantle key arms control agreements and confidence-building structures". Also during this meeting, a representative of Brazil said that nuclear disarmament seemed to have "gone into reverse" since the 2020 Treaty on the Non-Proliferation of Nuclear Weapons (NPT) Review Conference.

On the 78th anniversary of the atomic bombing of Nagasaki (Japan) in August this year, UN Secretary-General António Guterres declared the elimination of nuclear weapons the UN's "highest disarmament priority". He also outlined his policy brief on A New Agenda for Peace, which deals with ways to ensure stability in an evolving world. The New Agenda mentions that arms control frameworks have eroded in many regions and calls for a reassessment of disarmament mechanisms and policies.

The true power of weapons

One of the focal points of the DISARM project is the symbolism of weapons. "Disarmament cannot merely be a technical exercise," says Lamb. Programmes need to take into account the myriad of factors at play. Different genders, for example, have different associations with weapons. For men, a gun may be a symbol of masculinity and dominance. For women combatants, having a weapon is a means of asserting their power and establishing an equal footing with their male peers. Disarmament efforts that fail to take this aspect into account could have a profound effect on the women involved, says Lamb.

The symbolism of weapons can even carry through to the national flag. This is the case in Mozambique, the only country in the world whose flag depicts a modern weapon. The AK47 is said to represent vigilance, but for opposition parties, this remnant of the Frelimo flag symbolises violence and civil war.

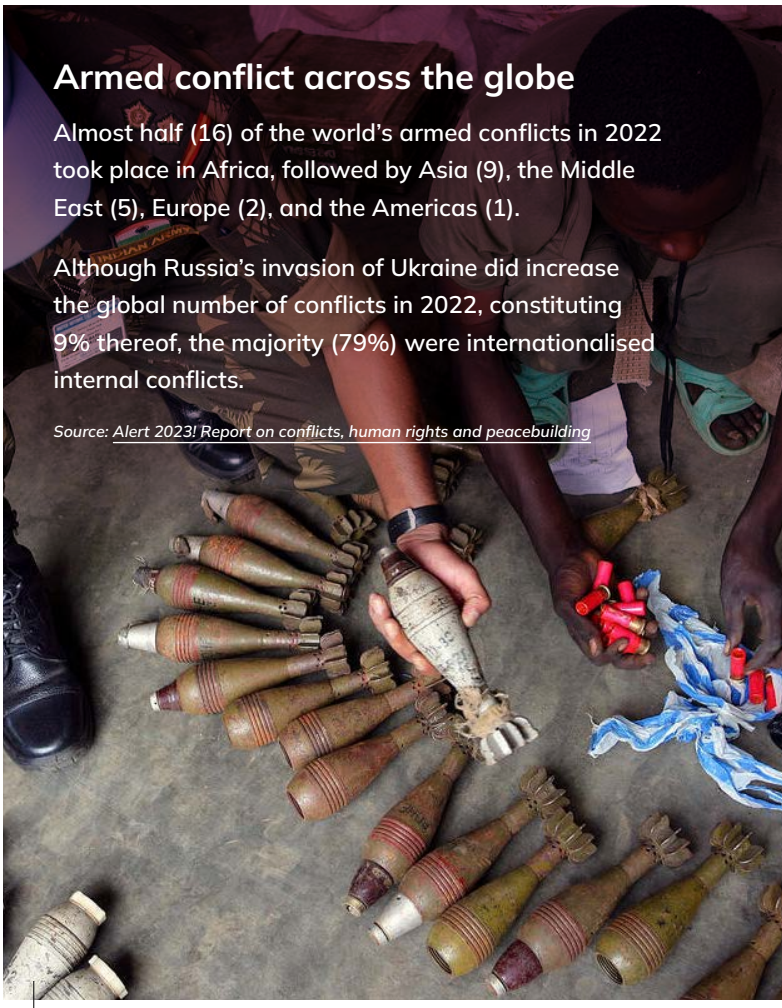
DDR programmes are deemed to have failed when implementation is incomplete, resulting in weapons not being handed in, or combatants and commanders remaining in contact after conflict has supposedly ceased, notes Lamb. Often, the governments involved are unable to prevent arms trafficking, despite the agreements that are in place. Understanding the impact of the availability of weapons on efforts to secure a peaceful resolution will benefit many contexts, he argues.

Armed conflict across the globe

Almost half (16) of the world's armed conflicts in 2022 took place in Africa, followed by Asia (9), the Middle East (5), Europe (2), and the Americas (1).

Although Russia's invasion of Ukraine did increase the global number of conflicts in 2022, constituting 9% thereof, the majority (79%) were internationalised internal conflicts.

Source: Alert 2023! Report on conflicts, human rights and peacebuilding



A peacekeeper from the Indian battalion of the United Nations Organization Mission in the Democratic Republic of the Congo (MONUC) takes stock of weapons and ammunition collected during the demobilisation process in Matembo, North Kivu | Photo courtesy of UN Photo/Martine Perret

Weapons are big business

World military expenditure rose by 3,7% in real terms (adjusted for inflation) in 2022. At a record high of US$2,24 trillion, this amounts to 2,2% of the total global economic output.

Total world military spending accounted for 2,2% of global gross domestic product in 2022.

The world is manufacturing enough bullets each year to kill nearly twice the number of people on the planet.

The five biggest military spenders in 2022 were the United States, China, Russia, India, and Saudi Arabia, which were collectively responsible for 63% of world military spending.

The way forward

The outcomes of DISARM's fieldwork, as well as the quantitative analysis of peace agreements in the period under review, will contribute to a novel set of policy recommendations that will have concrete applications in regions affected by conflict, says Lamb, even on a local level.

In the Western Cape, for example, where the availability of illegal guns has escalated gang violence in certain areas, the findings of the DISARM project will be highly relevant. Alarmingly, Western Cape Police Oversight and Community Safety MEC Reagen Allen revealed that 699 unlawful firearms were confiscated in only the first quarter of 2023, yet none were destroyed.

"This project will provide critical input to stakeholders in disarmament by providing empirically sound and gender-sensitive policy recommendations on disarmament design," Lamb concludes.

OXALIS

A GENUS IN A HURRY

WIIDA FOURIE-BASSON

Photo by Francois Roets

The Western Cape is renowned for being host to the most diverse geophyte flora in the world, including roughly 2 100 species from 20 families. The factors driving this remarkable diversity, however, are still poorly understood. Among these flowering bulbs are species of the Southern African *Oxalis* genus. They may seem like some of the most fragile, puny little plants out there, but in terms of adaptation, they are punching way above their weight.

Prof Léanne Dreyer | Photo by Stefan Els

As a matter of fact, the many strategies that the humble wood sorrel has developed over the past 20 to 35 million years to survive the extreme environments and droughts of Southern Africa still leave botanists dumbfounded. One such botanist is Prof Léanne Dreyer, a leading expert on Southern African *Oxalis* in the Department of Botany and Zoology at Stellenbosch University (SU). She has been studying this genus since the late 1980s, when she worked as a postgraduate student in the herbarium of the South African National Biodiversity Institute (SANBI) in Pretoria.

"One of my duties as scientific officer was plant identification, and it just so happened that *Oxalis* landed on my desk. The pile of unidentified specimens was way higher than that of the known species, and it also quickly became clear that the taxonomy of the known species needed urgent revision," she says.

The last such revision of the genus was done in 1944 by Terence Macleane Salter (1881–1969), an English-born South African amateur botanist and collector with strong ties to the Bolus Herbarium in Cape Town.

Leaving a legacy

In her corner office in the Natural Sciences Building at SU, Dreyer has her latest pet project on display: photographic plates documenting the germination of several rare species of *Oxalis* on a daily basis. She obtains the seeds from the *Oxalis* research collection in the SU Botanical Garden — the largest collection of Southern African *Oxalis* in the world, compiled over the past 25 years.

As soon as the seedlings have sprouted, Dreyer pots and returns them to the botanical garden. Dreyer is literally surrounded by more than 30 years of research on this genus. On the floor to her left lies a pile of micrographs of pollen grains from 210 *Oxalis* species, dating back to her PhD thesis, completed in 1986. On the right, under the large window, a collection of microscopic-sized seeds is laid out in petri dishes for the germination project.

Behind Dreyer lie piles of pressed *Oxalis* specimens, ready to be mounted and filed as part of her ever-growing herbarium collection. Moreover, behind a large bookshelf is a table with microscopes and plant material scattered over its surface. This is where the seedlings are meticulously studied and compared.

Another project Dreyer recently embarked on is the writing of an *Oxalis* field guide in collaboration with one of her first doctoral students, Dr Kenneth Oberlander. The curator of the SU Botanical Garden, Dr Donovan Kirkwood, is providing photographic input.

"We are finally putting everything we know about *Oxalis* into a field guide that the general public will be able to use and understand," she says. "It will include a general introduction to the biology of the genus, followed by short descriptions, including the diagnostic traits and distribution areas, of more than 200 species. A detailed photographic plate will accompany each species description."

An evolutionary predisposition for clinging to life

When learning about *Oxalis*' extraordinary feats of germination, one cannot help but admire the little plant's zest for life.

The first mind-boggling fact about *Oxalis* is that the Southern African species changed their growth form. Dreyer explains: "In the ancestral centre of *Oxalis* diversity in South-Central America, most species are either annual or form woody above-ground plant bodies. A few have subterranean tubers, and one species forms bulb-like structures out of the bases of their leafstalks. All Southern African *Oxalis* species, however, form true bulbs — a trait unique to all native species.

"This is the weirdest thing to have happened. We think *Oxalis* was pre-adapted to be drought tolerant and to survive in extreme environments.

"When it arrived in the Western Cape with its Mediterranean climate, it was already able to withstand long, hot summers and then made the best of the predictable onset of the winter rainfall season."

But going underground to survive the heat during the Western Cape's dry summer months is only the first trick in this tough little plant's arsenal of survival strategies.

Almost two-thirds of Southern African *Oxalis* species produce seeds that are recalcitrant, meaning they cannot tolerate desiccation (full moisture loss) and must germinate immediately after being shed. But even more unique in the case of many of these species is the incidence of reverse germination, a process in which the seed leaves and the first foliar leaf unfurl within the first 24 to 48 hours after shedding, without any elongation or support from an embryonic root (called a "radicle").

Biologically speaking, this kind of behaviour is unprecedented, says Dreyer. In the process of trying to understand this extraordinary feat of germination, Dreyer and one of her postgraduate students, Michelle Jooste, found evidence of an assemblage of endophytic bacteria in the vegetative and reproductive organs of these *Oxalis* species. (Plants generally use this type of bacteria to boost growth under normal and challenging conditions.)

"During germination, the bacteria inhabit the mucilage secreted at the base of recalcitrant *Oxalis* seedlings. The mucilage is a thick, gluey substance formed through the breakdown of a collar of cells at the base of the stem portion below the seed leaves. As the cells disintegrate, they release both sugars and hydrophilic substances around the base of the seedling. These hydrophilic substances attract water, thus building the mucilage, while the sugars provide a source of nutrition to the endophytic bacteria released into the mucilage," Dreyer explains.

These bacteria are hosted within the plant body, quite possibly in specialised structural cavities, where they feed on oxalate — an organic acid produced by plants as a byproduct of photosynthesis. Nine of the most abundant species of endophytic bacteria identified in *Oxalis* seeds and seedlings thus far belong to the genus *Bacillus*.

Dreyer explains the significance of this discovery: "*Bacillus* species are capable of fixing atmospheric nitrogen (and providing it to the seedling to grow), which helps explain how these seedlings can grow without roots. In turn, the bacteria thrive on oxalates as their only and often preferred source of carbon."

Luckily, *Oxalis* is so rich in oxalates that the genus name is derived from their abundant presence.

"We think this unusual relationship must have evolved over millions of years, helping *Oxalis* make the most of a very predictable winter rainfall season by giving it just enough time to spurt sufficient growth above ground to also form a bulb underground during the first year of seedling growth. Indeed, a Russian roulette of germination strategies!," Dreyer laughs.

In subsequent years, annual above-ground growth will emerge from the bulbs, flower, set seeds, nutritionally feed the bulb, and then go dormant at the onset of spring and summer.

Unique sexual reproduction system prevents inbreeding

Oxalis is one of only six genera in the world that display a unique sexual reproduction system called "tristyly", meaning a typical *Oxalis* species has three types of flowers (known as "floral morphs") named after the length of the style — short, medium, or long. The stamens (pollen-producing reproductive organs) of each morph are carried at separate levels, such that each flower has reproductive structures at distinct levels. The different morphs are more or less evenly distributed across populations. Seed formation will only take place once pollination has occurred between styles of the same height.

According to Dreyer, this is a strategy employed to prevent inbreeding in a population. But in a population already under stress caused by habitat loss and a changing climate, the equal ratio of morph types normally present in a population could be disturbed. If one or more morphs are lost from a population, the population will experience reduced or no seed set, which, if pushed to the extreme, could lead to the extinction of the species.

From seedling to bulb

According to Dreyer, researchers are only now starting to unravel the extremely rapid mode of bulb formation in *Oxalis*.

All plants have apical meristems — regions at or near stem and root tips where active cell division and growth take place. It is this capability of cells in these regions that enables plants to constantly keep growing. In the case of stemless *Oxalis* species, the apical meristem is situated just above ground level, and surrounded by the petioles (stalks) of the leaves. In recalcitrant species, the apical meristems are "contracted into" the mature radicle, mainly through the action of the central portion of the root known as the "stele".

At the end of the growing season, the stele starts coiling, the corkscrew-like action pulling the apical meristem deep into the root. This downward descent of the apical meristem is thought to be further helped along by an elongation of the petioles. The

Fast facts

Better known as "sorrel" in English or "suring" in Afrikaans, *Oxalis* is native to South America and Southern Africa, with about 800 different species in the genus.

The Southern African *Oxalis* species are all geophytes with true underground bulbs, while their South American counterparts are often shrubs and even trees. The genus was first described by Swedish botanist Carl Linnaeus in 1753.

apical meristem then transforms into the first bulb, which stays dormant below ground during summer.

"This is how *Oxalis* succeeds in forming a bulb directly after growing from seed in the first season," Dreyer explains. At the onset of the next growing season, a rhizome (in this case, a vertical underground plant stem) will emerge from the bulb and build the above-ground *Oxalis* plant body during the following wet winter months.

According to Dreyer, some of these bulbs are buried as deep as 60 cm underground. This makes them notoriously hard to find, even for baboons.

Locating rare species

Because it is so difficult to find these rare and elusive species, Dreyer relies on farmers and amateur botanists to alert her when an area receives good rainfall. At the end of June 2023, she and her team visited Nieuwoudtville, where the Cape fynbos biome meets the Succulent Karoo, after the region experienced one of the best rainy seasons in decades.

The team aimed to fill species gaps and preserve as much genetic diversity as possible in the *Oxalis* research collection at the SU Botanical Garden. Dreyer also revisited some of the locations where Salter identified certain rare species in the 1940s, most of which have not been observed since.

Over the years, her research group has documented a record number of more than 20 new species. Almost half of them were discovered in the Richtersveld following good rains in 2006 and 2007. Sometimes these little beauties hide in plain sight. In 2021, postgraduate student Frikkie Becker stumbled across a rare species, *Oxalis minuta*, popping up on the lawn in front of the GG Cillié Building on SU's main campus.

This species was known to occur in both the Jan Marais and Duthie Reserves in Stellenbosch, but in extremely small, dwindling populations. With the help of Kirkwood, this valuable newfound population was moved into cultivation to form part of the *Oxalis* living collection.

Subject(s) to change

Human activities, especially the fragmentation and destruction of natural habitats, are putting the survival of *Oxalis* at risk. When climate change is added to the mix, the picture becomes even bleaker. An increase in temperature of 0,5 to 1,0 °C and a 25% decrease in annual rainfall are predicted for the Cape Floral Region over the next 50 years. This will likely have a dramatic impact on especially the rare *Oxalis* species.

Oxalis hygrophila, for example, is known from a single locality on a moist, natural seepage band in the Pakhuis Pass in the northern Cederberg. It was identified for the first time in 1944. "When we visited the site in 2001, flowers were present in November. During 2005 and 2006, we visited on several occasions from October to November, but no plants were found, and there was no evidence of water seepage down this slope," Dreyer says.

Moreover, many of the rare *Oxalis* species have very specific habitat requirements, which confine them to small, isolated populations within specific localities. Given their dependence on suitable habitats to increase their population size, they are extremely threatened by future habitat loss.

Oxalis fragilis, for example, currently exists in only one known natural population in a highly fragmented landscape. Before its rediscovery in 2018, the species was last seen in 1936, despite repeated searches for it over the preceding 20 years. It was believed to have gone extinct in the wild.

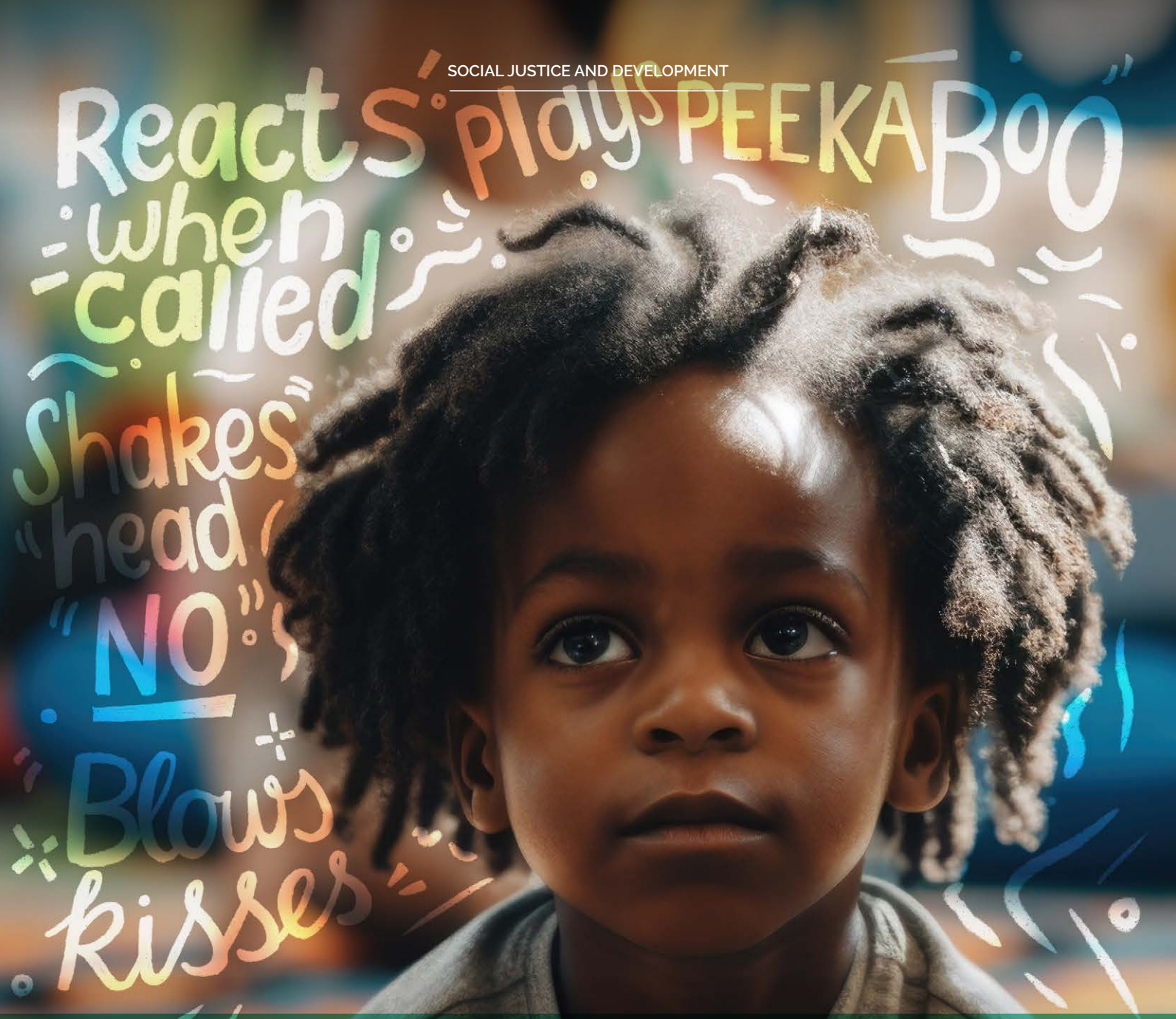
"We were shocked to learn that the site where this population was rediscovered had been approved for dam construction. The population that was likely isolated for more than 80 years is now conserved as part of the SU Botanical Garden's living collection," says Deyer.

Looking forward

Dreyer's lifetime of research is thriving in the form of the *Oxalis* research collection in the SU Botanical Garden, and work on the *Oxalis* field guide has reached a point where the co-authors are ready to approach a publisher.

Dreyer describes herself as an intuitive scientist, intrigued by the many forms of this little plant's seeds, flowers, and bulbs. "In trying to understand *Oxalis*, one cannot rely on statistics and data alone," she says. "I often first have an intuitive understanding of what may be happening, and then only do we set up experiments in the laboratory to test these ideas. Sometimes I'm right. Most of the time, though, I'm completely gobsmacked by our discoveries.

"When I die, they will write on my tombstone: She studied *Oxalis* — a genus in a hurry!," she quips with a hearty laugh.



MORE THAN JUST WORDS

DEVELOPING TOOLS TO MEASURE EARLY LANGUAGE DEVELOPMENT

ANÉL LEWIS

How do we know what they know, and don't? Without a comprehensive set of tools to determine what gestures and, later, words and grammatical structures children typically learn in the first 30 months of life, there is no reliable way to gauge any individual child's language development.

Prof Heather Brookes | Photo by Stefan Els

South Africa has 12 official languages — Afrikaans, siNdebele, Sepedi, Sesotho, Setswana, South African English, siSwati, Xitsonga, Tshivenda, isiXhosa, isiZulu, and South African Sign Language (SASL). Each requires their own culturally appropriate linguistic tools for assessing language development. "There are very few tools available in our languages, and those that are available, are for older children," says Prof Heather Brookes of the Department of General Linguistics at Stellenbosch University (SU).

The solution is not as easy as it may seem: "Translating English instruments to use in other languages is problematic, given the lexical and grammatical differences between languages."

The lack of reliable assessment tools means that speech-language therapists often do not have any objective, empirical measures of a child's language ability. Early assessments of language proficiency may prove critical to improving children's success at school, and ultimately their life chances.

Gathering the right tools

Children with language delays run the risk of developing learning disabilities, anxiety, and even behavioural problems, says Brookes. However, there is no one-size-fits-all pattern when it comes to language development. It happens differently in different languages. For speech therapists to accurately identify delays in language development, they need to know the norms of child language acquisition in the specific language being acquired. Until recently, however, this type of information was unavailable in South Africa.

Internationally, tools like the MacArthur-Bates Communicative Development Inventories (MB-CDIs) are used to collect information on the words children learn in different languages and contexts. A CDI is a tool for measuring language development in infants aged 8 to 18 months and toddlers aged 18 to 30 months. Set up as questionnaires or report forms, they are given by speech practitioners to parents or caregivers to note a child's use of gestures, words, and sentences. Originally designed for American English, MB-CDIs have since been developed into nearly 100 languages around the world, including two in Kenya and two in Mozambique.

SU researchers working in this field note that South Africa's languages are spoken in cultural contexts that differ significantly from the context for which the original MB-CDIs were developed. Creating a locally relevant set of tools requires more than just the translation of existing English tools.

Until now, there has been a lack of valid, reliable tools to measure language development and to diagnose delays in African languages. "We don't have the norms of language development for any language in South Africa, not even South African English," says Prof Frenette Southwood of the Child Language Development Node (CLDN) of the South African Centre for Digital Language Resources (SADiLaR).

Intent on filling this diagnostic vacuum, the CLDN, hosted by the Department of General Linguistics at SU, is working on a flagship project to develop locally relevant CDIs for all of South Africa's official languages, including SASL.

The SA-CDI project

The South African Communicative Development Inventories (SA-CDI) project, currently in its third phase, will provide the first comprehensive overview of early-stage language development in this country.

The ongoing study has thus far involved 2 800 children in developing valid instruments for identifying language development norms for children aged 6 to 30 months, in 11 of the country's 12 official languages.

Around the country, field workers have been collecting information from parents and caregivers about their children or charges' first gestures, words, and sentences. Parents' knowledge of their children's language use is usually fairly accurate, says Brookes.

Overall, the parent report forms are good indicators of communicative development norms. They are especially useful in contexts where children are not accustomed to clinical testing. The data, collected in a culturally appropriate manner using information provided by parents and caregivers, can be used to formulate norms that form the basis of linguistic and cognitive assessments for speech pathologists and therapists to use in their practices.

By the end of 2023, the multi-site team will have validated CDIs for eight languages. In the process of validation, the team looks for correlations between children's scores, ages, and other variables such as family socioeconomic status. The CDIs for the remaining three languages will be validated in 2024, at which point the team will begin norming with an estimated 22 000 children, at 2 000 speakers per language.

Work will soon start on a CDI for SASL, which became South Africa's twelfth official language in July 2023. The end result will be easy, inexpensive checklists that can be used by professionals to assess children's language development.

> Without a set of valid, reliable tools based on typical developmental norms, there's a risk of under- or overdiagnosis of language acquisition delay. "At least going forward, if a parent comes to a speech-language therapist, they can say, 'Let's do the CDI and see what the child knows'," says Brookes.

She notes that CDIs have many benefits, "but in particular, administration does not require a qualified psychologist or speech-language therapist, making them ideal for settings with poor access to professionals". They are also cost-effective to administer at scale, which is beneficial in low-resource settings.

Language variation

Many different factors affect early language development, says Brookes. Socioeconomic factors (including the parents' level of education) and a myriad of possible contextual factors such as rural versus city life and monolingual versus multilingual communities all play a role.

In a recent book chapter titled "Child Language Assessment Across Different Multilingual Contexts", Southwood notes that, in many cases, assessment tools are only available in well-studied languages, often those with a "higher social status" or the language of schooling. "For preschool children, being assessed only in the majority language may render misleading results if the language is not spoken in the child's home and the child has little or no exposure to it." She cautions that multilingualism needs to be "disentangled from language impairment" as the characteristics may appear similar in young children — children who are exposed to more than one language may appear to lag behind their monolingual peers, similar to a child with a language impediment, if only one of their languages is assessed.

Southwood adds that there is no uniform definition of what constitutes a multilingual child because multilingualism takes so many forms. For example, it can be a result of a child acquiring two languages from birth, or acquiring a second language from slightly later and only to the point of understanding, not speaking it. "All languages could be acquired in the child's home context or some of them in the community only."

Feedback from the field

Mikateko Ndhambi is a speech-language pathology and audiology lecturer at Sefako Makgatho Health Sciences University in Pretoria North. She is part of the CLDN network and a University of Cape Town PhD candidate in Xitsonga child language acquisition. She explains that the adapted SA-CDIs will allow practitioners to access language developmental norms.

"Understanding developmental norms is beneficial for tracking individual development and identifying broader trends and challenges in language acquisition," she says. "It allows for the early detection of language development delays, which, when addressed promptly, can significantly improve a child's literacy and overall educational outcomes."

One of the results of the adaptation of the CDIs to a South African context is the realisation that speech practitioners need to be culturally and linguistically sensitive when choosing items for inclusion in a CDI, she says. "This highlights the importance of curriculum developers being sensitive when choosing items to facilitate pre-literacy skills in different contexts. As practitioners, there is a need to be actively involved in curriculum development."

Ndhambi says that community involvement in the adaptation and validation of the SA-CDIs has raised local awareness about language acquisition and the importance of early identification of language delays. "Early intervention based on accurate assessments ensures that children receive the support they need to develop strong language skills, which are foundational for literacy."

Multilingualism is the norm in a heterogeneous country like South Africa, Southwood says. There is no single country-wide dominant language. Of the 12 official languages, isiZulu has the largest percentage of home language speakers at 25%. English, despite being the lingua franca, is only spoken as a first language by 8% of the population, notes Southwood. And yet, despite most children not having sufficient exposure to English to be proficient in it when they start school, it is the preferred language of education.

This disconnect between the home language and the language used at school and for learning is exacerbated by the fact that almost half of South Africa's young children are not at preschool or in professional childcare, and therefore most of their exposure to language occurs at home. Unfortunately, in many cases children are not exposed to activities at home that adequately support language development, irrespective of the language that is spoken, with Southwood pointing out that only about half of children under the age of six are read to or told stories by family members at home.

"Given the variation in the number of languages and the combination of languages, the age of first exposure and the quality and cumulative quantity of exposure to each language, the amount of community support for each language, the language-related expectation in the school system, and the cultural and other contexts in which children acquire their languages, the over-generalisation of research findings and assessment results should be avoided," notes Southwood.

With this in mind, the team at SU has begun piloting a CDI for bilingual children.

Moving forward, collaboratively

The SA-CDI team is currently working on an online CDI app in collaboration with SU's Department of Computer Science. The app will use pictures, text-to-speech, and a variety of multimodal strategies that will make it easier for parents with different education levels to respond to questions about their children's language development. "This is already being tested with our own target audiences," says Brookes.

> "We want children to be properly socialised and academically prepared — and they need language for that," adds Southwood.

A good early language development trajectory positively influences later language and school success. Studying a language also contributes to a region's cultural heritage, and by making sure the CDIs are linguistically and culturally appropriate, the SA-CDI project recognises South Africa's language diversity.

Prof Frenette Southwood | Photo by Stefan Els

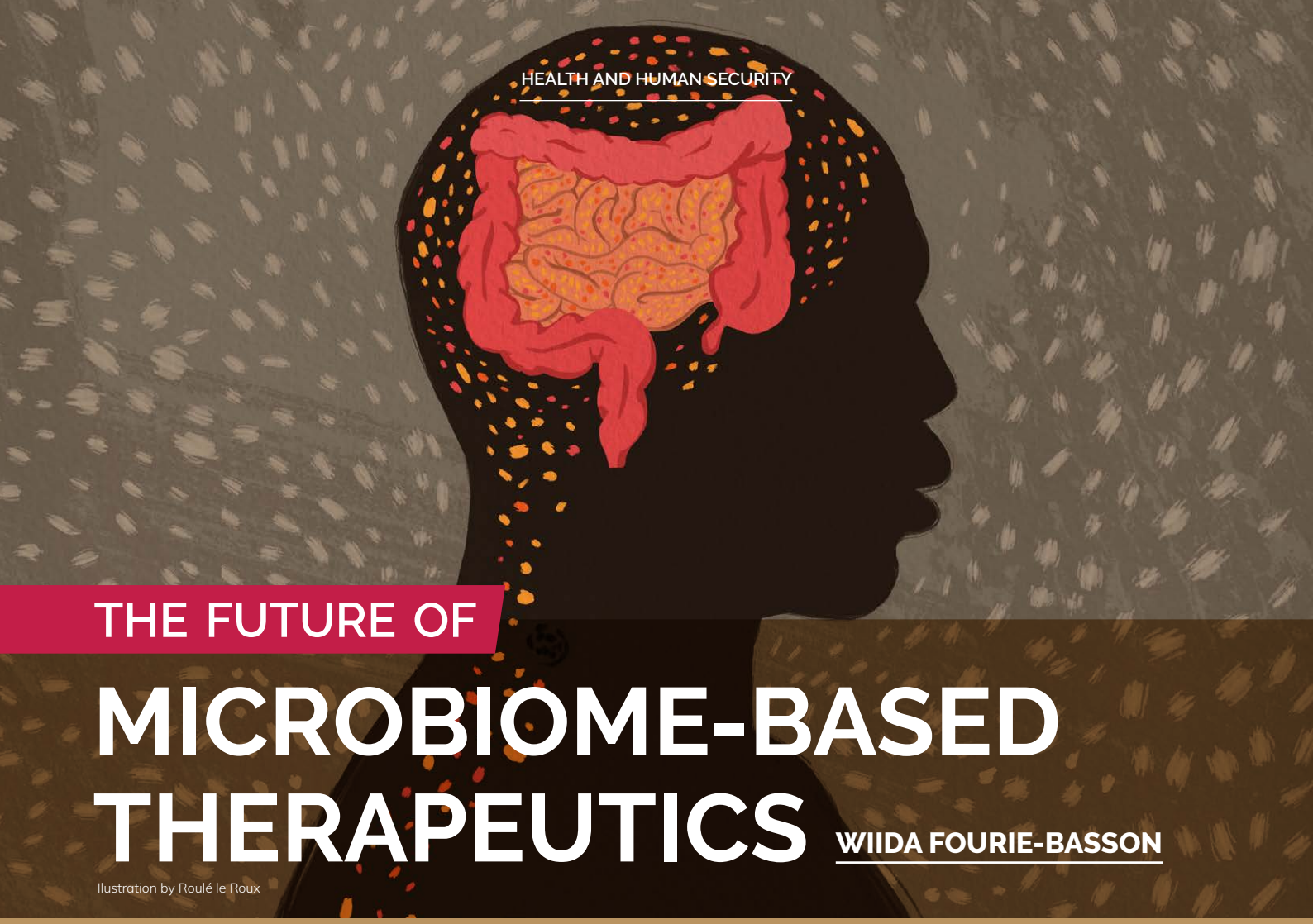
The CDIs will ultimately constitute valid, reliable tools to diagnose language delays in all official languages, making it easier for speech practitioners to detect any deficiencies before there is a knock-on effect on reading and comprehension, says Southwood.

> Moreover, with the CDIs resulting in linguistic norms being available in all of South Africa's official languages, it will be possible for scientists across the country to assess children's early language development, and create new assessment tools, interventions, and age-appropriate materials for different learning environments. This will significantly impact literacy and, ultimately, the lives of children in South Africa, she emphasises.

The development of CDIs for language assessment in Africa is a mammoth task that requires a collaborative effort. The SA-CDI project comprises a network of scientists working on language development in different disciplines and departments at the following universities across South Africa: the North-West University, University of Cape Town, Sefako Makgatho Health Sciences University, University of KwaZulu-Natal, University of Limpopo, University of Mpumalanga, University of the Western Cape, and University of Pretoria.

The CLDN is furthermore committed to expanding this work across Southern Africa, and workshops have already been held with researchers in early child language development from elsewhere on the continent.

All the data generated as a result of the SA-CDI project will be hosted by SADiLaR so that it is freely available for future research, concludes Southwood.



THE FUTURE OF MICROBIOME-BASED THERAPEUTICS

WIIDA FOURIE-BASSON

Illustration by Roulé le Roux

A new study on the relationship between our gut microbiome and the brain provides a stepping stone for future research into microbiome-related therapeutics to prevent or treat mental health disorders.

Bacteria have been around for the past 1,6 billion years and coevolved with humans to perform a range of beneficial functions in our bodies: They help digest our food, regulate our immune system, protect against other disease-causing bacteria, and produce vitamins. But the more we discover about the human gut microbiome, the more questions arise about the influence that trillions of these microorganisms may also have on our mental condition, mood, and overall psychiatric well-being.

The known genes of the microorganisms in the human microbiome outnumber human genes by a hundred to one, and most of them have not even been identified yet. So, while we may be aware of the intricate symbiosis between ourselves and the microorganisms helping us to thrive (or not), there is still much left to unravel.

A gut feeling for research

For the past 35 years, Prof Leon Dicks has dedicated his research in the Department of Microbiology at Stellenbosch University to the study of lactic acid bacteria, a group of bacteria that are beneficial to humans. He has focused specifically on their probiotic properties and ability to produce antimicrobial peptides under certain conditions. This research has led to the development of, amongst other patents, the probiotic EntiroTM, produced and marketed by Cipla Medpro.

Despite these advances, Dicks strongly believes that we are yet to realise the full potential of the human microbiome. “I am two years from retirement, but the field of microbiology is only now coming into full bloom. We are standing on the cusp of major new discoveries in the field of microbiology in general, and specifically in the emerging field of a microbial-based approach to the treatment and management of psychiatric disorders and serious diseases such as cancer,” he explains.

In January 2022, Dicks embarked on a second doctoral dissertation to better understand the connection between the gut and the brain. The result, for which he was awarded a DSc degree in March 2023, is a powerful synthesis of the current

knowledge in this emerging field, and our understanding thereof. Dicks has made this research accessible by consolidating several very complex ideas regarding the gut microbiome and the gut-brain axis into a coherent story.

Our second brain

In discussing the research for his dissertation, Dicks firstly highlights the importance of our "second brain" — a community of almost 5 000 microbial species living in the human gut, of which 90% are bacteria. This "brain within the gut" sends out signals to our central nervous system and reacts on signals received from the brain.

> "We know a lot of the microbes in the human gut, but there are many more that we have not yet identified. We also know that they are talking to each other by means of chemical signals, a process we call 'quorum sensing'. These bacteria are having conversations with each other, and it may sound like a *lekker kuier* [a pleasant social event], but it's actually a biochemical process that has an effect on our psyche," he explains.

Most of the time, this intricate control system of chemical signalling and immune response keeps the gut microbiome in a balanced state. A healthy gastrointestinal tract is characterised by such a balanced gut microbiome with a core population of beneficial microbiota. When things go wrong, however, changes in the microbial population will ultimately affect communication with the central nervous system, and vice versa.

But exactly how does this two-way communication process take place? The highway of communication is the vagus nerve, which runs from your brain to your large intestine and the enteric nervous system. Importantly, fibres of the vagus nerve are not in direct contact with the gut or intestinal microbiota. Instead, signals reach the gut microbiota via 100 to 500 million neurons from the enteric nervous system. These neurons form a network of nerve fibres in the muscular layers of the digestive tract.

According to Dicks, it is evident that the intestinal barrier is controlled by fine-tuned communication between gut microbes and the host immune system. Understanding this communication, however, is another matter completely. The complexity of these interactions raises questions around our current level of understanding, and explains why it has been so difficult, up to now, to develop specific therapeutic targets, Dicks writes in the conclusion to his dissertation.

Linking neurotransmitters and bacteria

Take the case of serotonin as an example, he says. Serotonin is one of the key neurotransmitters in the brain, regulating our appetite, gut motility, mood, cognition, and sleep patterns. As much as 80% of this important neurotransmitter is produced in the gastrointestinal tract by, for example, *E. coli*, *Hafnia*, *Bacteriodes*, *Streptococcus*, *Bifidobacterium*, *Lactococcus*, *Lactobacillus*, and *Morganella*.

"Serotonin production by gut microbiota may have a greater effect on the central nervous system than originally anticipated," he writes in one of his published dissertation papers. A study on germ-free mice, for example, has shown that neuronal dysfunction could be reversed by the recolonisation of specific gut microbiota, especially those that produce short-chain fatty acids.

These acids, which stimulate endothelial cells to produce serotonin, are largely produced in the colon by *Bifidobacterium*, *Lactobacillus*, *Lachnospiraceae*, *Blautia*, *Coprococcus*, *Roseburia*, and *Faecalibacterium*.

In humans, changes in serotonin levels are also associated with irritable bowel syndrome and, in patients with ulcerative colitis and Crohn's disease, drastic increases in serotonin-immunoreactive cells in the colon. Furthermore, a lack of communication between gut microbiota and the enteric nervous system has been directly linked to dysbiosis (an imbalance in your gut microbiota) and other gastrointestinal disorders.

A recent report suggests that certain neurotransmitters may even serve as growth substrates for intestinal bacteria. In other words, without these neurotransmitters, some bacteria would be incapable of surviving in the human gut. This observation raises questions about a possible symbiotic relationship between bacteria and neurotransmitters.

Looking into the future

Dicks is convinced that, in the not-so-distant future, the gut microbiome will be integral to the development of novel therapeutics, probiotics, and psychobiotics aimed at treating gastrointestinal disorders, improving cognitive functions, and preventing or treating mental disorders such as depression and schizophrenia, as well as conditions on the autism spectrum. While we know that gut microbiota have an immense impact on the gut-brain axis and on overall mental health, Dicks warns that our understanding of exactly how gut microorganisms affect cognitive behaviour, mood, and neuropsychiatric disorders remains limited.

Perhaps it is not time for retirement just yet — there is simply still too much to learn: "The Creator keeps us busy!," he quips with a glint in the eye.

THE SCIENCE OF FIRE

JORISNA BONTHUYS

Photo by Justin Sullivan

According to statistics, up to 115 people die annually due to fires in Cape Town's informal settlements. The city is known as the "fire capital" of South Africa due to its high number of fire-related incidents, recorded with its effective data collection systems. Other cities could potentially have higher death rates but often have incomplete fire incident data.

Access to communal water supply is essential for fighting fires in informal settlements | Photo by Justin Sullivan

Fires leave countless people homeless in the metropolitan area every year. Annually, 4 500 dwellings are damaged or destroyed, shattering many communities. And this destruction is not limited to Cape Town. The August 2023 fire incident in Johannesburg, in which at least 77 people died and hundreds were left homeless, clearly illustrates the sweeping extent of fire risk across the country. Apart from the lives lost, the more than 40 000 fires reported in South Africa annually translate to roughly R4 billion in financial losses.

"As a society, we need to understand how fires spread if we are to prevent them from becoming total disasters," says Prof Richard Walls, who heads up the fire engineering team, FireSUN, at Stellenbosch University (SU). "Urban fires can be incredibly dangerous, particularly in informal settlements."

Established in SU's Department of Civil Engineering, FireSUn is training the next generation of fire safety experts. In 2019, SU launched its master's and PhD degree programmes in fire safety engineering — the first academic offerings of their kind on the African continent. In 2024, an online master's degree is being launched to train engineers across South Africa and the developing world.

A place to dwell

Across the country, an estimated 7,6 million people live in primary dwellings and the so-called "backyard dwellings" behind them in informal settlements. These settlements are dense, unplanned, and ramshackle, typically housing low-income communities. Most of the homes are make-shift enclosures ("shacks") cobbled together from corrugated-iron and plastic sheets, as well as wooden materials. And their numbers are growing.

"Whether we like it or not, we live in flammable cities with high densities and many flammable buildings," Walls says. "The consequences of urban fires are often devastating — but preventable."

All sorts of things can start fires in informal settlements, from open flames and dodgy electrical setups to a variety of other causes. Climate change has also made fire-prone weather conditions twice as likely in Cape Town today than in the late 1970s. A recent attribution study showed that the extreme, destructive wildfire of April 2021 on the slopes of Devil's Peak has become around 90% more likely in a warmer world.

In holistic fire management, Walls says, both understanding fire behaviour (the physics of why things burn) and fire safety engineering (design approaches that improve fire safety) are crucial.

Engineering for change

Before joining SU as a lecturer and researcher, Walls worked as a structural engineer designing industrial, petrochemical, and commercial buildings.

"I became involved with fire safety engineering by accident during my PhD studies at SU," he says. "At the time, my study leader [in civil engineering] suggested I focus on fire safety and steel structures. I soon realised there is a massive gap in this field and became interested in the teaching aspects of it."

But Walls' connection with communities affected by fire started much earlier. As an 18-year-old student, he volunteered at a soup kitchen in Braamfontein (Johannesburg) called Paballo Ya Batho, and at Children of Fire, a charity working with young fire survivors. These experiences made him aware of the hardship caused by the legacy of fires for both individuals and households. Today, he wants to bring fire-related risks and safety issues to the fore to help make our cities and informal settlements more fire resistant.

He works closely with fire services to develop solutions for local fire challenges, embraces innovative approaches to engineering education, and engages on the global stage to help find practical solutions to complex fire problems. Moreover, Walls was instrumental in developing the *Fire Safety Engineering Guideline*

for Informal Settlements, a project co-funded by Lloyd's Register Foundation, for the Western Cape Department of Human Settlements. These guidelines were formulated in a collaborative effort between FireSUN, the Research Alliance for Disaster and Risk Reduction (RADAR), the Milnerton Fire Brigade, and Kindling (a US-based non-profit fire safety organisation). This is the world's first set of technical guidelines on fire safety in informal settlements.

Spreading like wildfire

South Africa has one of the highest incidences of fire-related casualties in the world. Daily, at least 30 fires are recorded in informal settlements across the country, accounting for at least one person's death per day. Yet, little is known about such fires' triggers and impacts.

With this in mind, FireSUN has done experiments to determine how fires spread and how fast this happens in informal settlements. Over the years, Walls and his students have burned down more than 70 life-sized dwellings.

Some of this research was done in 2018 as a part of the world's largest informal settlement fire experiment to date. Twenty full-scale homes were set up, fitted with instruments, and burnt down to try to understand the spread of fires between dwellings in informal settlements. The results of this research, conducted with collaborators from the University of Edinburgh (Scotland) and the Breede Valley Fire Department, were published in the journal *Fire Technology*.

Even with a relatively mild wind speed of 15 to 25 km/h, common in Cape Town's metropolitan area and adjacent regions, the fire spread through the mock settlement within five minutes. The research team knew that the burning dwellings would act as tinderboxes, igniting nearby structures. Following the ignition of a shack, the engulfing of the entire dwelling in flames, or "flashover", happens extremely fast. The experiment revealed the sheer speed at which this happens: Temperatures reached more than 1 000 °C within a minute and downwind neighbouring structures ignited less than a minute after that.

According to Walls, fire behaviour in informal settlements differs significantly from that in formal-building fires. When a fire rips through an informal settlement, this is analogous to a wildfire with a continuous firefront moving through a natural area. While individual dwellings still follow the distinct phases of enclosure fires, they collapse faster than formal structures.

Many factors influence the spread of fire, including the building materials used. At FireSUN, researchers consider how different construction materials behave when burning. For instance, Dr Antonio Cicione and others have investigated the effect of fire on cladding materials (specifically timber versus steel cladding, often used in informal settlements). An important finding of this study was that separation is critical: A gap of roughly three to five metres between dwellings is necessary to prevent the spread of fire between them. Cicione, an adjunct senior lecturer in structural fire engineering at SU, is also the founder of CFS Engineering Consultants and the fire safety engineering lead at Kindling.

Understanding large-scale disasters

Global estimates indicate that up to 300 000 people die annually because of fires. This means that fire kills up to five times more people than natural disasters do.

Over 95% of reported fire deaths and burn injuries occur in low- and middle-income countries in the Middle East, Asia, and Africa, said Dr Danielle Antonellis, an extraordinary staff member of FireSUN, in a recent webinar. She is also the founder and executive director of Kindling.

> Urban fires disproportionately impact people, property, and livelihoods in vulnerable communities, she said. In informal settlements, fire investigations are often not conducted, and close to 40% of all fire causes are labelled as "undetermined".

Often, a lack of evidence at the scene hinders fire investigations. With this fact in mind, postdoctoral researcher Dr Natalia Flores Quiroz developed a framework for the complex task of fire investigation in informal settlements, which was published in the *Fire Safety Journal*.

Fire risks are also acute in high-density refugee camps, including the Cox's Bazar camp in Bangladesh. In March 2023, an estimated 15 000 Rohingya refugees from Myanmar were left without shelter after a massive fire tore through Camp 11 of the larger camp, destroying 2 800 shelters, as well as several mosques and learning centres. The Cox's Bazar camp houses almost 1 million people overall, making it the world's largest and most populated refugee camp.

Flores Quiroz and Walls have been involved in international collaborations to understand fire risks in Camp 11 to better inform humanitarian efforts. After working closely with the Migrant Offshore Aid Station and fire engineers from the University of Maryland, they provided guidance to disaster agencies working in the camp, including the UN Refugee Agency.

Together, the researchers reconstructed the most recent disaster incident — from the fire, all the way through to the response and evacuation — based on firefighters' statements, media reports, and satellite imagery. Their findings were published in the journal *Fire Technology*. This is the first detailed documentation of such a large-scale refugee camp incident in the academic literature and is especially relevant at a time when global displacement is on the rise.

Forensic investigations

In recent years, fires such as that at the South African parliament in 2022 and at the Charlotte Maxeke Hospital in Johannesburg in 2021 have reportedly caused the South African government and parastatals direct losses of between R5 billion and R10 billion. Sections of the hospital, one of the biggest in the country, were closed for months, causing a huge disruption to the provision of healthcare services in Gauteng. FireSUN researchers subsequently examined the effect of fires on critical hospital infrastructure and have been involved in reconstructing the hospital.

The 2017 Knysna fire disaster also provided the research team with food for thought about the challenges of wildfires and the urban edge. Several points of ignition and severe climatic and meteorological conditions (including storm winds of more than 90 km/h) led to this event, considered South Africa's largest ever wildfire disaster in terms of structural and economic losses. "With close to 1 000 homes destroyed and billions of rands worth of damage, it is important that we understand this and similar incidents," Walls says. Fire brands (small flaming particles) jumped distances of up to 2,8 km.

Under the leadership of Flores Quiroz, SU researchers investigated the Knysna event in detail, including how the fire spread and the influence of vegetation and weather.

"It is necessary to understand large-scale fire incidents and have data on grounds of which evidence-based interventions can be developed. We cannot prevent these fires from happening altogether, but we can prepare for them and reduce potential impacts," Walls emphasises.

What is more flammable, peanuts or wood?

FireSUN's researchers are exploring several fire-related topics, such as the effect of fire on 3D-printed concrete and fire safety challenges related to "green" buildings. "In our unit, we've burned all sorts of weird and wonderful things," Walls says. These investigations range from testing how flammable train seats are to determining the fire risks involved in using eco-bricks and storing peanuts in warehouses.

Anene Oguaka focused his recent PhD dissertation on the fire behaviour of bulk African foodstuffs, with the purpose of advancing food safety. In 2023, based on this experimental research, he published a research article, co-authored by Walls and Flores Quiroz.

The researchers considered the fire hazard of food grains being stored in warehouses. Oven-dried cowpeas, lentils, millet, soybeans, flax seed (linseed), peanuts, and sunflower and sesame seeds were subjected to different heat fluxes. Their findings show some grains, including peanuts, to have a higher fire hazard than even wood pellets.

"This means there are fire risks in large storage units which, in turn, pose a risk to food security in our region," Walls explains.

Greening the future

One of the biggest barriers to sustainable construction is fire safety, Walls points out. Green intentions and fire safety do not necessarily align — rigorous testing of products and materials is necessary.

"Green buildings pose their own fire risk challenge," Walls says. "This is because many of the ecologically sustainable products on the market used to, for instance, insulate these buildings are made of biomass or waste, which is normally oil-based. In many of the novel sustainable [building] products, one of the main barriers to commercialisation is fire. Overseas, 18-storey timber structures are being built in a move away from using traditional building materials with a large carbon footprint. But are these buildings posing fire risks? If so, how can we design and build them in a way that reduces that risk?"

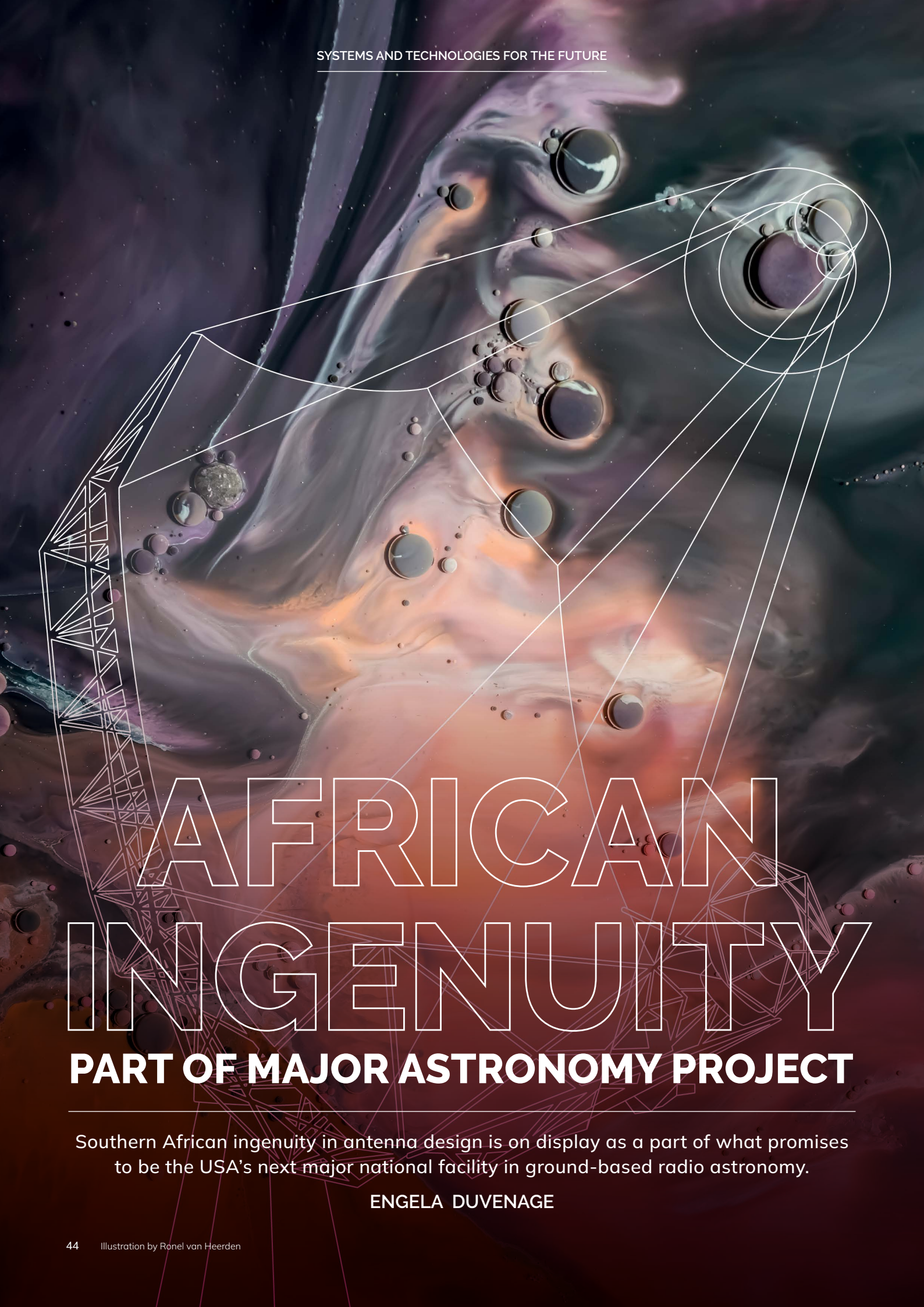
As the demand for exposed structural timber continues to grow, it's becoming increasingly important to understand how these structures will behave in the event of a fire. FireSUN is involved in developing biomass-based fire protection systems, including coatings on timber for fire protection. Going forward, FireSUN's researchers will consider the fire-resistance rating of different materials, including local plywood. The unit is also investigating the use of fire-resistant timber as a construction material in high-rise buildings.

Solutions, not gadgets needed

Engineering solutions can help sort out many fire-related issues in the urban landscape, Walls says. "From alarms to fire trucks — a lot can be done to improve our responses to fires in informal settlements. Too often, one-size-fits-all 'solutions' are offered to mayors and city officials. Some of these solutions are inappropriate and not as effective as promised. We need solutions, not gadgets," he emphasises. "The ideal situation would be to provide people with safer, code-compliant homes, but resources are limited. However, there is still a lot that authorities can do to reduce fire risks."

Walls believes fire and structural engineers can help make towns and cities more fire resistant and ultimately help provide a roadmap for making living spaces safer for local communities.

"Understanding fire behaviour is vital," he says. "Before you try out interventions [to improve fire safety], ask yourself if it has been tested in local communities and in a technical environment. We need to learn how to make buildings safer by seeing what can go wrong. How many more billions of rands must go up in smoke before we start engineering a better future?"



AFRICAN INGENUITY

PART OF MAJOR ASTRONOMY PROJECT

Southern African ingenuity in antenna design is on display as a part of what promises to be the USA's next major national facility in ground-based radio astronomy.

ENGELA DUVENAGE

 Illustration by Ronel van Heerden

If you plan to ever travel across the Plains of San Agustin in the American state of New Mexico, make a mental note to stop at a picnic spot along Route 60, some 35 kilometres from the hamlet of Magdalena, to do some astronomy tourism.

Thousands of years ago, this flatland was a great lake. By the late 2020s, the expanse will be dotted with 263 interferometric radio antennas as a part of the planned project around the building of the USA's Next Generation Very Large Array (ngVLA).

The 244 bigger 18-metre-wide shaped offset Gregorian reflector systems (the characteristic "dishes") among them will be more than beacons of discovery into the distant origins of the universe — they will also serve as markers of Southern African astronomical engineering in action.

Namibian Prof Robert Lehmensiek and South African Prof Dirk de Villiers are the duo behind the specific, highly exact shape and surface design of these reflector systems.

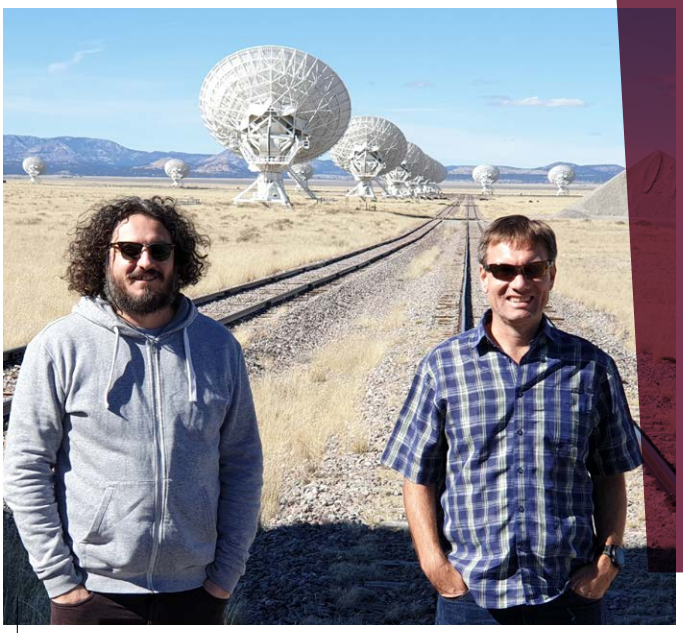
The duo's handiwork will help determine just how far into the yet-unexplored and often cloudy, dusty corners of the universe astronomers will be able to probe with the ngVLA, all in search of the faintest possible signs of distant galaxies and previously unknown celestial objects.

"The ngVLA will be the biggest radio telescope operating in the northern hemisphere, working as an observatory that allows for different types of experiments to be performed," explains De Villiers. Since 2018, he has been serving as the SARChI Research Chair in Antenna Systems for the Square Kilometre Array (SKA) in the Department of Electrical and Electronic Engineering at Stellenbosch University (SU).

"It's an honour to work on the ngVLA, knowing that it will perform better than any other radio astronomy telescope currently in operation over the same frequency bands," says Lehmensiek, formerly of EMSS Antennas in Stellenbosch and, since 2022, a research engineer at the National Radio Astronomy Observatory (NRAO) Central Development Laboratory (CDL) in Charlottesville, USA. He is still an extraordinary professor in SU's Department of Electrical and Electronic Engineering.

Both antenna specialists are SU alumni, Lehmensiek having received his doctoral degree in engineering in 2001 and De Villiers his in 2007. Both honed their skills in dish and antenna design as a part of the SKA radio telescope project at large, for which the first prototype dishes are already operational near Carnarvon in the Northern Cape Karoo. Over the past 15 years, they were involved in the design of SKA precursors such as KAT-7 and MeerKAT.

"Each of the 244 identical dishes will have six horn antennas, as the ngVLA will work over six frequency bands," says De Villiers. "In all, the ngVLA will operate at similar frequencies to the Jansky VLA it is set to replace (from 1,2 GHz to 116 GHz), with a gap between 50 GHz and 70 GHz where radio waves cannot propagate through our atmosphere due to absorption by oxygen molecules."



Prof Dirk de Villiers (left) and Prof Robert Lehmensiek (right) | Photo by Prof Robert Lehmensiek

It will, however, be 10 times more sensitive than the Jansky VLA and have significantly better spatial resolution. "This means it will be able to 'see' 10 times further and in 10 times more detail," Lehmensiek points out.

"Together, the combination of dish and horn antennas forms the 'eye' of the telescope — a very sensitive one that picks up on electromagnetic radio waves," he explains.

Global recognition

Modern antenna designs such as that of the ngVLA rely heavily on numerical simulation and the optimisation of physical structures to ensure that each individual element in the series of dishes in an array functions optimally, all to best register electromagnetic signals from outer space. The goal is to provide astronomers with a clear "view" of the radio waves emitted by celestial objects across the universe.

"The resultant optics, feeds, and overall sensitivities achieved are close to the theoretical optimum," Lehmensiek and De Villiers wrote about the design in their 2021 paper titled "An Optimal 18 m Shaped Offset Gregorian Reflector for the ngVLA Radio Telescope". In 2022, the pair received the Harold A. Wheeler Applications Prize Paper Award from the Institute of Electrical and Electronics Engineers for this paper.

De Villiers and Lehmensiek are the first researchers from Africa to receive this international award celebrating leadership in practical antenna design.

The prototype

The ngVLA prototype is currently being cut — panel by panel — by a network of suppliers in Europe, brought together by MTEX antenna technology, a German mechanical engineering company specialising in the manufacture of large reflector antennas. Each section of the design will be shipped to the USA before on-site construction can, hopefully, start by late 2023.

The German engineering company designed the mechanics behind the antennas, the support strut or "pedestal" on which each dish will be mounted, the foundations, and other related frameworks. All these components must be extremely stable to withstand the possible influences of wind, gravity, and temperature extremes.

"The dishes work at 116 GHz, which corresponds to a wavelength of only about 2,5 millimetres. To remain focused, they must move as little as possible during scanning," explains De Villiers, who is evaluating this part of the design process with Lehmensiek.

Over the past 15 years, De Villiers and Lehmensiek have worked together on the design of SKA precursors such as MeerKAT (shown here) and KAT-7. | Photo by Prof Dirk de Villiers

As sensitive as possible

The colleagues believe they have squeezed every last bit of possible sensitivity from their dish design. This allows the total performance of the ngVLA array to be several percentage points better than that of any other similar piece of pricy infrastructure currently in use.

> "In theory, this means that if you plan to build 100 dishes, and each one is 1% more sensitive than what we had before, the telescope will be as sensitive as 101 dishes. In other words, you'd only need to build 100 dishes to get the sensitivity of 101. This will save millions of dollars," De Villiers explains.

The duo's designs are all about achieving maximum receiving sensitivity, and about getting every micron of the surface shape of each dish just right, De Villiers reiterates. But it's also about matching the reflector optics to the antenna feed horns. This is done to maximally reduce factors such as plate scale, cross-polarisation, scan loss, and the sidelobes of an antenna's far-field radiation pattern, while still maximising the sensitivity.

"High-performance dishes are only possible when the antennas receiving the energy reflected from the dishes are themselves near optimal. Therefore, we first designed the so-called 'feed antennas' to have maximally symmetric radiation patterns over their operating bandwidths," De Villiers notes.

In the design of these antennas, they also ensured that they do not pick up radiation coming from the sides and from behind the feeds.

"The feed antennas optimally absorb all the energy from space so carefully focused by the dishes," says De Villiers. "The antenna at the focus of each dish is sensitive to signals coming from all around, though less so to signals coming from the dishes. The dishes are focused to reflect energy mostly coming from the cold sky into the receiver."

The reflective surface of a 1x4-metre sub-reflector extension shields each antenna's sensitive receiver from picking up "scrambled", unwanted ground noise caused by the earth's warmer temperature. It is fixed to the bottom of the smaller of the two mirrors (the so-called "sub-reflector") in the system.

> "This makes the dishes much more sensitive to the very faint signals of research interest coming from space," says De Villiers.

The duo first introduced this "shield" in their designs of the MeerKAT dishes, to much acclaim from other designers.

REACH-ing
BEYOND THE STARS

Stellenbosch University (SU) and Cambridge University are leading the Radio Experiment for the Analysis of the Cosmic Hydrogen (REACH) project. This project is to be put into operation in 2023 in the Northern Cape's Karoo Radio Astronomy Reserve, which is already home to the Hydrogen Epoch of Reionization Array (HERA), the MeerKAT, and the first antennas of the Square Kilometre Array (SKA)1-Mid experiments.

The project aims to help determine how the first luminous objects in the sky formed, and in what manner they subsequently shaped the universe.

A team effort

The two principal investigators in this project are Prof Dirk de Villiers, SARChI Research Chair in Antenna Systems for the SKA in the Department of Electrical and Electronic Engineering at SU, and Prof Eloy de Lera Acedo of the Cavendish Astrophysics Group at Cambridge University in the United Kingdom.

The design work behind the 2,5-metre-tall REACH unit was initially done by De Villiers and a former postdoctoral associate, Dr Brandt Klopper. With input from the two principal investigators, the design was then finalised by Dr John Cumner as part of his PhD studies at Cambridge University.

The entire antenna was built by SU technicians and was proudly displayed for a few weeks on the roof of the SU Engineering Building.

A design like no other

To the untrained eye, the design of the REACH Phase 1 field system might resemble that of a side table standing on top of a large fence. It is, however, an independent solar-powered radiometer with a hexagonal dipole antenna. The antenna is placed atop a large 20x20-metre elevated ground mesh, and the antenna plates are supported by a wooden structure. The ground mesh acts as a reflector behind the antenna to direct incoming cosmic signals towards it, and to shield the system from the effects of the ground.

"Solid metal plates are used as the ground plane in the vicinity of the antenna to ensure excellent reflectivity, but also to shield the sensitive receiver box from the harsh Karoo sun. The receiver is placed as close as possible to the antenna terminals to minimise losses, and must be kept at a near-constant temperature to ensure proper calibration of the electronics," De Villiers explains.

Preventing interference

He describes the prevention of interference with existing equipment as a rigorous part of commissioning REACH: "All electronic devices must comply with regulations around how much radiation they are allowed to emit.

"These regulations are, of course, much stricter for devices operating within the radio-quiet reserve where the SKA and other radio telescopes are hosted, to ensure that the different instruments do not interfere with one another. All electronics must therefore be carefully shielded to suppress all the spurious radiation."

To this end, the South African Radio Astronomy Observatory (SARAO) performed rigorous compliance testing before it issued an electromagnetic interference (EMI) compliance certificate for the REACH antenna.

Dr Saurabh Pegwall, a postdoctoral researcher in SU's Department of Electrical and Electronic Engineering, is now tasked with ensuring that all technical aspects are in place to secure the proverbial "lift-off" of the system. Pegwall will also be in charge of the installation, testing, and qualification of the equipment, which will hopefully commence in 2023 still.

Later stages in the project could see scaled-up versions of the phase 1 antenna, or even complementary antenna systems sensitive to other polarisations of the sky radiation.

The science behind REACH

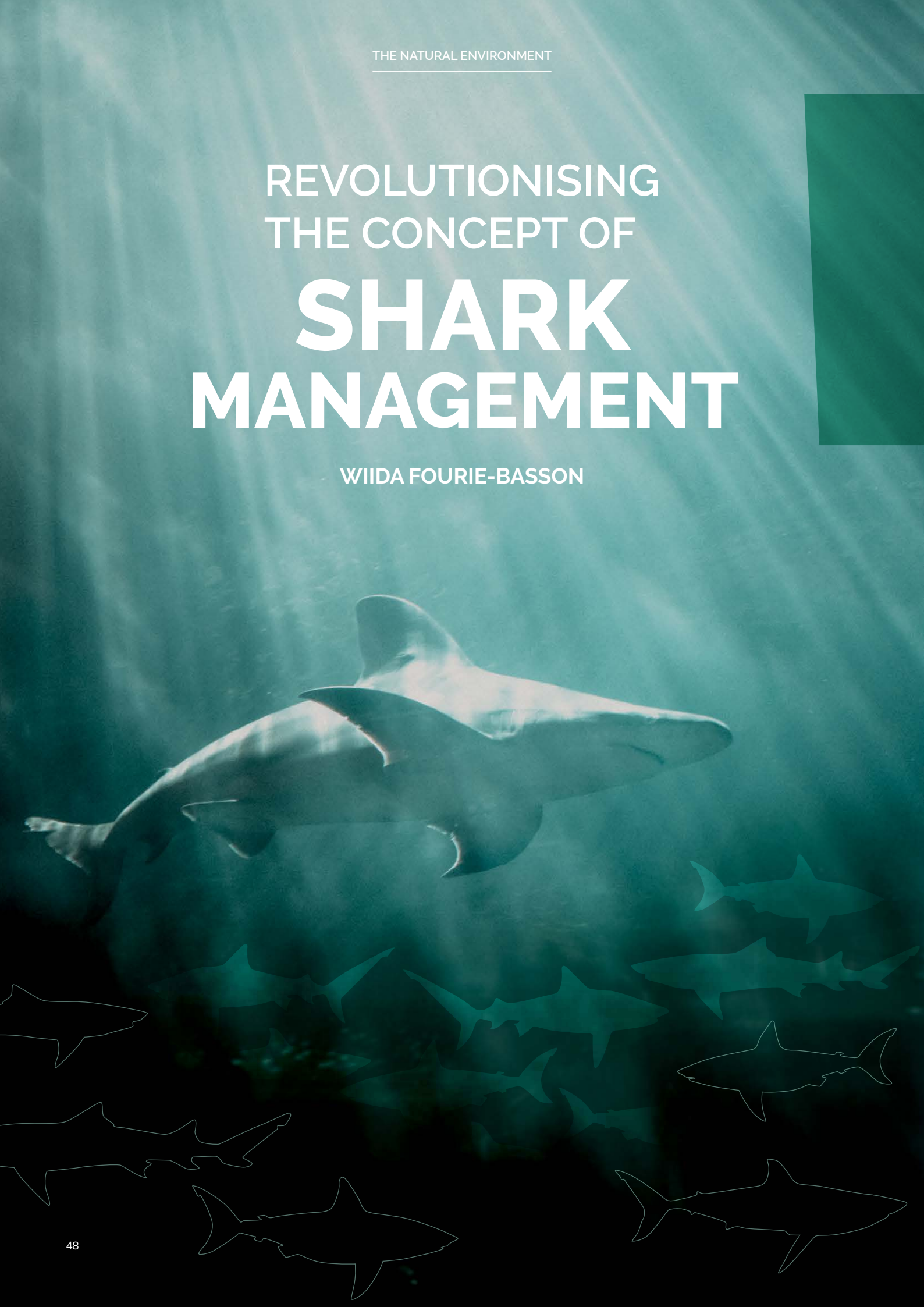
REACH is one of many interconnected projects currently underway to give astronomers greater insight into the development of the early universe. Its antenna will function between the low frequencies of 50 and 130 MHz in an effort to detect and analyse redshifted radio emission and absorption from the so-called "21-centimetre line". (The hyperfine transition of neutral hydrogen has a rest-frame wavelength of 21 centimetres.)

By making observations at low radio frequencies, researchers are able to directly study hydrogen in the gas clouds that provided the raw material for the formation of the first luminous cosmic structures during the earliest epochs of the universe.

According to the REACH webpage, these first luminous objects helped shape the universe some 0,35 to 1 billion years ago, between its initial evolution (commonly referred to as the "Big Bang") and the development and appearance of stars and other celestial objects.

REVOLUTIONISING THE CONCEPT OF SHARK MANAGEMENT

WIIDA FOURIE-BASSON



Shark-specific barrier technology developed by marine biologists from Stellenbosch University (SU) and their collaborators has been installed in the Bahamas by one of the top cruise line operators in the world, Royal Caribbean International. In 2011, the Bahamas proclaimed the first shark sanctuary in the Atlantic Ocean and, in 2018, a Marine Action Partnership for Sustainable Fisheries.

Dr Sara Andreotti | Photo by Elsa Hoffmann

The installation of the 30-metre-long SharkSafe Barrier™ along a bay on one of the islands will further strengthen marine conservation efforts in the Bahamas. The SharkSafe Barrier™ combines biomimicry of a thick kelp forest and magnetic fields to keep humans at bay from sharks without harming them or any other large marine species. Biomimicry is a practice that learns from and mimics the strategies found in nature in order to solve challenges in the human world.

The nature-inspired SharkSafe Barrier™ technology, 15 years in development, is currently the only eco-friendly alternative to shark nets. The latter "walls of death", in use since 1950, are not shark specific and kill thousands of harmless sharks, whales, dolphins, sea turtles, and large bony fish every year. According to new data published by the government of New South Wales, almost 90% of marine animals caught in shark nets along this Australian state's coast over the past year were non-targeted species.

Dr Sara Andreotti, extraordinary lecturer in marine biology at SU and a founding director of SharkSafe Barrier™, says the kelp-like forest created by their barrier technology has been designed to remain in the water for at least 20 years with minimal maintenance required. Eventually, it changes into a reef-like haven for local sea life.

The barrier has been tried and tested extensively in South African coastal waters — from those crashing on the rough, rocky shores of Gansbaai to the sandy beaches of Glencairn — as well as in the tropical waters of Réunion island and the Bahamas. However, the SharkSafe Barrier™ in the Bahamas constitutes the first commercial installation of this technology. Andreotti is now working with coastal municipalities in South Africa to develop alternative funding mechanisms for installations locally, as well as with municipal authorities in Australia and New Caledonia.

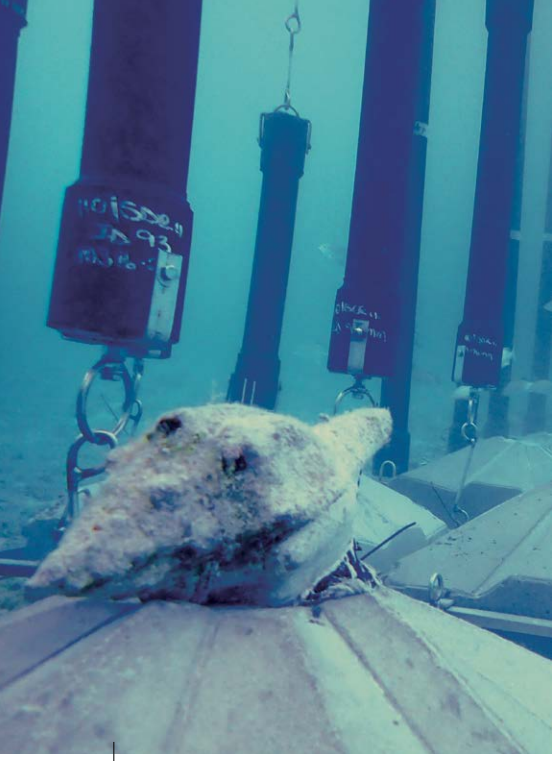
Rooted in research

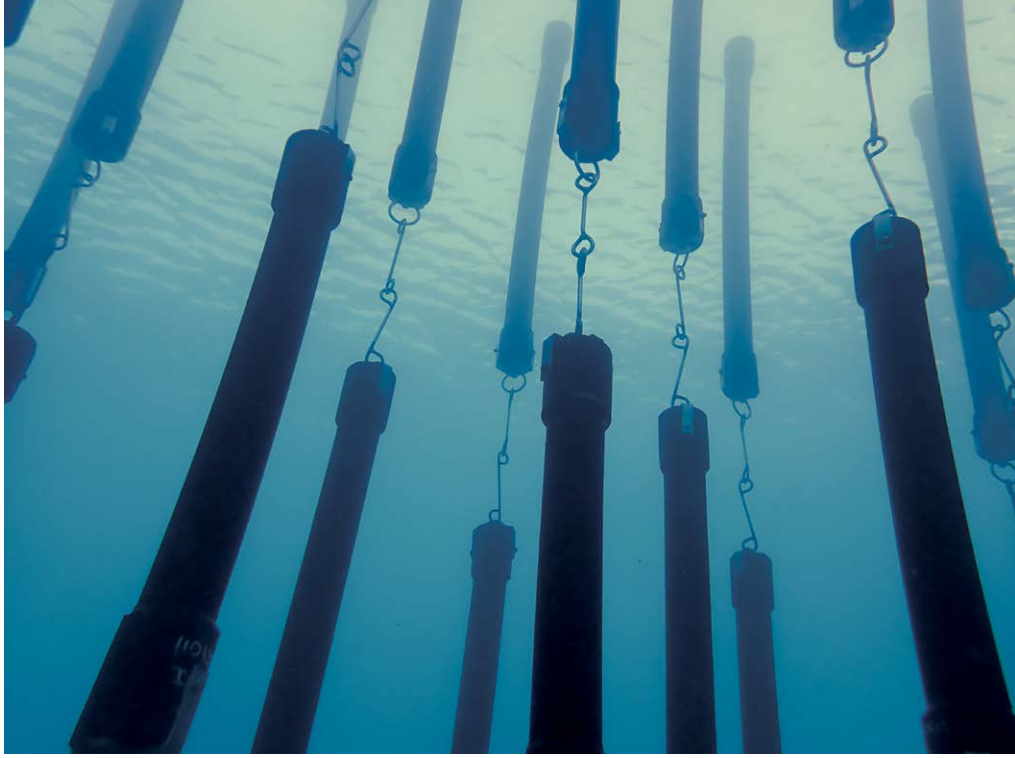
The roots for the development of the SharkSafe Barrier™ can be traced back to Andreotti's doctoral research on the population numbers and genetic diversity of South Africa's great white shark (*Carcharodon carcharias*). Between 2009 and 2011, she conducted the largest yet field research study on this species with the help of the shark conservationist Mark Rutzen. They lived at sea for up to two months at a time to count and collect biopsies from these sharks for genetic analysis.

Andreotti worked with an applied mathematician, Prof Ben Herbst, and a software engineer, Dr Pieter Holtzhausen, at SU to develop a custom-made software package that can standardise data collection among great white sharks. The result, IDentifin, enables scientists to compare new photographs of dorsal fins to the existing database of over 5 000 images. In this way, they circumvent the problem of double-counting — identifying the same shark more than once as different individuals.

At the time, the results from Andreotti's doctoral research painted a bleak picture. Not only did the great white shark population along the South African coastline display the lowest genetic diversity of all such shark populations worldwide, there were also only between 353 and 522 individuals left. According to Andreotti, this was 52% lower than what was estimated in previous mark-recapture studies.

"If the situation stays the same," she warned during an international media conference in 2016, "South Africa's great white sharks are heading for possible extinction".





A conch exploring the new SharkSafe Barrier™ installation in the Bahamas. This eco-friendly installation biomimics the visual effect of a kelp forest, and generates a strong magnetic field through means of ceramic magnets. This forms a double barrier (both visual and magnetic) that keeps sharks at bay. | Photos courtesy of SharkSafe Barrier™

Among the possible reasons identified for the sharp decline in great white shark numbers was the impact of shark nets and baited hooks implemented on the eastern seaboard of South Africa. Between 1978 and 2008, for example, about 1 063 great white sharks were killed due to shark protection measures alone. Other contributing factors were poaching, habitat encroachment, pollution, and depletion of their food sources.

In the face of these alarming results, Andreotti, Rutzen and Prof Conrad Matthee from SU's Department of Botany and Zoology realised they needed to find an alternative to shark nets — something that would make beaches safer for bathers and sharks alike.

Inspired by nature

"The thinking behind the development of the SharkSafe Barrier™ was based on a combination of practical experience with sharks and our understanding of their biology and behaviour," Andreotti explains. Firstly, Rutzen observed how fish and other marine animals such as seals use kelp forests to hide from predatory sharks. This is when the idea of biomimicking a natural kelp forest originated.

The team's knowledge of marine animal behaviour was combined with existing research on the use of magnetic fields to deter sharks. Most shark species are sensitive to strong, permanent magnetic fields because of the presence of electromagnetic receptors on the tips of their heads. These small, gel-filled pores — called "Ampullae of Lorenzini" — are connected directly to sharks' brains and allow them to register faint bioelectrical impulses dispersed in the water by their prey.

Instead of attracting the attention of a shark, the biologists reasoned, a strong magnetic field would overstimulate the Ampullae of Lorenzini and have the opposite effect. In other words, by inserting strong magnets into the kelp-like pipes of the barrier, it would further strengthen the ability of the design to repel sharks.

The concept was registered as a patent in 2012 through SU's technology transfer company Innovus. In 2014, the SharkSafe Barrier™ company was commercialised. That was when the real work started.

For the past decade, Andreotti has been working with marine engineer Laurie Barwell and other individuals and organisations to not only develop a business model that will attract investors but, first and foremost, to perfect the technology behind the barrier through rigorous testing in South Africa's turbulent oceans.

Today, the SharkSafe Barrier™ consists of high-density polyethylene pipes manufactured locally by KND Fabrications in Maitland, Cape Town. During installation in the ocean, the buoyant pipes are anchored on a grid-like structure one metre apart from one another, with large ceramic magnets staggered in the ocean-facing row. The grid is then weighted by limpet-shaped 200-kilogram cement blocks and secured by rock anchors and sand.

In 2020, the SharkSafe Barrier™ company really took off when the barrier design was labelled a Solar Impulse Efficient Solution and selected as a finalist in the Smart Eco-Responsible Tourism category of the Tech4Island Awards. In the same year, the inventors of the SharkSafe Barrier™ technology also received the prestigious NSTF-Lewis Foundation Green Economy Award at the NSTF-South32 Awards function. In 2021, the company was recognised by the World Economic Forum's digital platform UpLink as one of its top ocean innovators.

Revolutionising the concept of shark management

For Andreotti, the first commercial installation of the SharkSafe Barrier™ is the breakthrough that the team has been working towards for the past 15 years.

> "We now have the technology to allow the rightful inhabitants of the oceans to survive and thrive, and for sea-loving humans to enjoy their time in the water safely," she says.

This is a win-win situation, especially for areas that rely on ocean recreation as a main source of revenue, such as beach towns in South Africa, Brazil, New Caledonia, and Réunion. In the past, negative encounters with sharks have had adverse effects on local economies.

In April this year, Conservation International's CI Ventures invested US$250 000 (roughly R4,7 million) in SharkSafe Barrier™. According to Gracie White, lead of Global Ocean Investments for CI Ventures, lethal control measures for managing sharks are outdated. "It's time to modernise, for both marine biodiversity and human well-being," she said in a recent statement.

Hopefully, it's not too late for South Africa's great white sharks. According to Andreotti, these sharks have been counted using manual photographic identification in only three studies, the last of which was conducted about a decade ago. "In two of the three studies, it was estimated that there were fewer than 500 sharks left. A more recent study indicated that even the very conservative levels of human-related removal of great white sharks may be sufficient to drive abundance decline, and new mitigation measures may be required to ensure population recovery.

"In contrast, studies based on unconfirmed sightings always risk overestimating the status of the local populations," she warns.

"We cannot continue to waste time by debating whether the removal of a few individuals by orcas in our local waters could have impacted this population significantly more than decades of human-related, targeted removal with shark nets and drumlines, and the adverse side-effects of bycatch and overfishing of their food resources.

"My fear is that these animals will simply go extinct on our watch.

"It is time", she says, "for a revolution".

Great whites are the most iconic of all sharks. They are large and imposing but surprisingly elusive, in part owing to their ambush predation techniques. They take advantage of low-light situations (at dawn or dusk) to ambush unsuspecting prey, sometimes by breaching. | Photo by Dr Sara Andreotti

EDIBLE INSECTS

ALEC BASSON

Photo by Dr Bronwyn Egan

Most people would probably turn up their noses at a dish of grasshoppers, but locals in rural Limpopo love to tuck into bowlfuls of these insects, which are a key part of their diet and cultural tradition. Plus, they have different ways of preparing their favourite grasshopper dishes.

Typically, people from this area catch the insects by hand, pluck off their hind legs, and collect all the parts in buckets. After the grasshoppers have been rinsed, they are fried in a pan (usually over a fire), salted, and eaten as a snack. At times, they are also cooked with tomato and onions, and consumed as an evening meal with pap.

The locals here use unique identifiers to distinguish the edible grasshoppers in their area. Different species are given vernacular names (called “ethnospecies”) that may differ from one area to the next.

Candidates for mass-rearing

According to scientists from Stellenbosch University (SU), the University of Limpopo, and the University of Strasbourg (France), some of these edible grasshopper species harvested from the wild could be suitable candidates for mass-rearing. Their findings were recently published in the journal *Biodiversity and Conservation*.

The research team consisted of Michaela O’Hare, Dr Sylvain Hugel, Dr Bronwyn Egan, Christi Greyling, Megan Hendrickse, and Dr Barbara van Asch.

O'Hare is currently an MSc candidate in SU's Division of Molecular Biology and Human Genetics and a member of its Neuropsychiatric Genetics Research Group. During this research project, she was a postgraduate student in SU's Department of Genetics. Greyling is an MSc student, and Van Asch is a senior lecturer in the same department where she hosts a research group on insect biodiversity. Hugel is a researcher at the Institute of Cellular and Integrative Neuroscience in France and has worked extensively on edible insects in Africa. Egan is currently the curator of the Larry Leach Herbarium but has been researching edible insects in Limpopo for over a decade.

"Being an already well-known food resource, commercial exploitation of grasshoppers could assist in addressing food insecurity, elevating traditional food cultures, and promoting economic development in South Africa," the researchers point out. The problem is, however, that edible grasshoppers are largely uncharacterised in South Africa, making it challenging to link nutritional properties and biological aspects with species names. This, in turn, hinders the progress of potential mass-rearing and commercialisation.

Insects as food

Globally, edible insects are becoming increasingly popular due to their potential to improve food security. Scientists are investigating ways to expand the use of insect protein in both animal feed and human diets.

> Edible insects require less land, water, and feed to farm than livestock, while emitting much lower levels of greenhouse gases. Moreover, edible insects are a rich source of protein and essential minerals, making them a sustainable and nutritious food option.

In Africa, there is very little commercial rearing of grasshoppers compared to Asia, where farming of edible insects has helped to alleviate poverty in many communities in recent years. Thailand, for example, had at least 20 000 registered insect farming enterprises in 2013, according to a study by the UN's Food and Agriculture Organization published that year and cited by O'Hare and her co-authors in their aforementioned paper.

Harnessing traditional knowledge

O'Hare and her collaborators worked closely with community members who helped collect specimens. This was done with a traditional method where leafy branches were used to disturb underbrush and agitate the insects, forcing them into the air. Once the grasshoppers landed again, they were stunned with the branches and collected by hand. (Typically, the insects' hind legs are removed to prevent them from escaping.)

In this study, a total of 36 genetic species were identified, and named in 35 ethnospecies in Sepedi, Xitsonga, Lobedu, and Tshivenda.

The vernacular insect names are highly correlated with the localities where they are collected and often vary between villages. These names also differ in tone or spelling or are completely distinct.

"Considering that traditional knowledge has suffered from increasing urbanisation and adoption of modern lifestyles, the expertise of the community members in identifying grasshoppers was impressive, and many of the ethnospecies matched with the genetic data," the authors point out.

DNA studies unlock new knowledge

After collection, the researchers extracted DNA from the grasshoppers' leg muscles and generated DNA barcodes for the different ethnospecies.

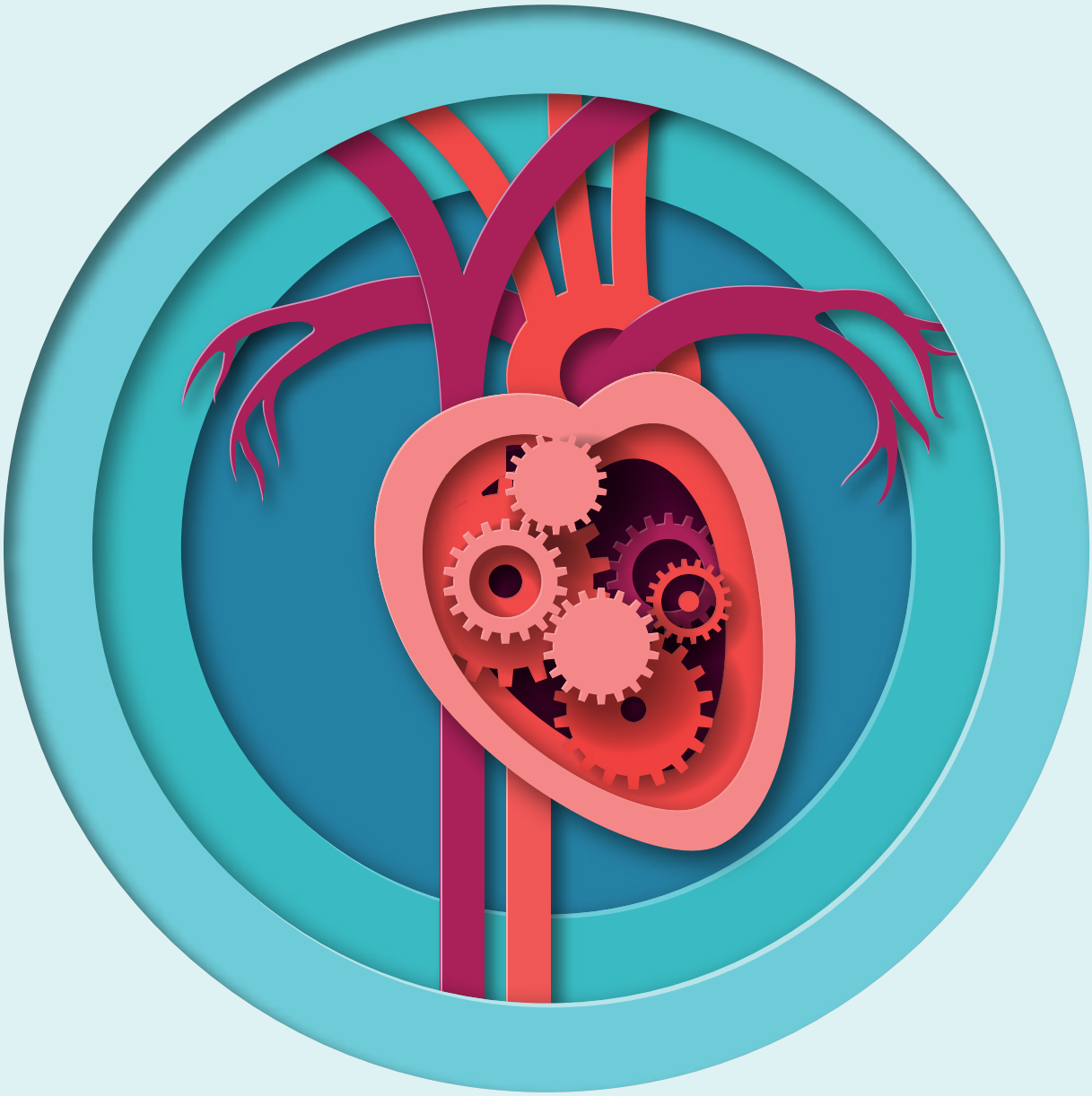
"Our DNA analyses showed the utilisation of 36 species that likely represent distinct species. Our study is the first to show that people in Limpopo eat about seven additional grasshopper species that have not been documented previously," the report states. "We found that the overall diversity of edible grasshoppers traditionally consumed in South Africa is higher than previously reported.

"The fact that 10 out of 35 (29%) of the ethnospecies found in our study were recorded more than 20 years ago reiterates the importance of present-day cultural resources and local knowledge for documenting biodiversity."

Filling the gaps

According to the researchers, this is the first study on edible insects that associates DNA-based data with a specific set of specimens available for future reference, along with their vernacular names.

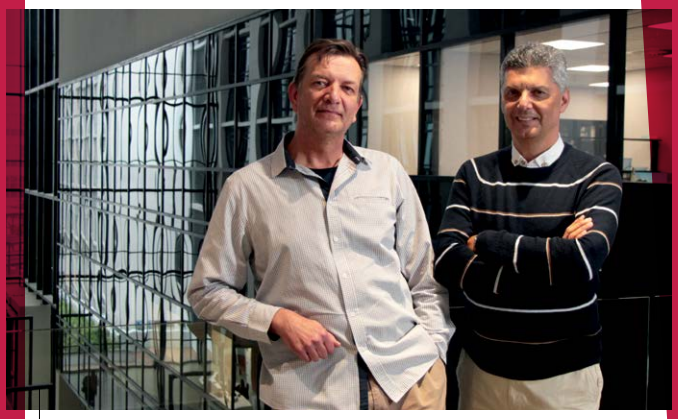
"Our study represents a step forward in documenting edible grasshoppers used by South Africans," the researchers add. "The use of different sources of information contributes to unravelling the fantastic abundance of edible insect cultural and biological diversity in Africa and worldwide. Genetic information, such as DNA barcodes, may assist in closing the species identification gap using sequences of specimens expertly identified as reference for querying unknown sequences," the team concludes.



RESEARCH TO CURB THE SCOURGE OF CARDIO-METABOLIC DISEASE

UFRIEDA HO

The burden of heart disease in South Africa is a ticking time bomb. Scientists know that it's exacerbated by HIV and stress, but understanding exactly how and why is imperative to pushing back the clock. Researchers are looking at the deep local context as a critical key to unlocking solutions.



Prof Hans Strijdom (left) and Prof Faadiel Essop (right) | Photo by Wilma Stassen

An intentional first step taken by the Centre for Cardio-metabolic Research in Africa (CARMA), established in 2020 in Stellenbosch University's Faculty of Medicine and Health Sciences, has been the reframing of its research activities to be locally focused and appropriate. Prof Faadiel Essop, the director of CARMA, says building more bridges between the research done at the centre and that done in a broad range of disciplines is necessary to modernise research in a way that makes it relevant to a wider audience.

True collaboration for greater public impact

"Research can be very focused on the individual — be it for personal achievement or personal promotion — and as a result, we researchers and scientists tend to duplicate our work, which is wasteful. We work in silos, and there are very few interdisciplinary links. CARMA wants to change this and also address the fact that we have very limited studies conducted in a developing-world context, which keeps a colonial legacy entrenched in our research approach."

At CARMA, Essop says, they hope to go beyond superficial partnerships to thereby establish a robust platform for collaboration and knowledge sharing both within the University and among academics from across the country and continent. The centre's aim is to build stronger, more enduring research capacity in Africa, as research emanating from here can attract new funding and grant opportunities. The latter widen the possible scope and output of research efforts and can ultimately inform more strategic, effective public health policies and life-saving interventions.

"The big-picture aim is to strive towards the eradication of the cardio-metabolic disease burden in Africa. Projections are that cardiovascular and related metabolic diseases, such as diabetes and obesity, will substantially increase on the continent."

These diseases have become some of the trappings of modern living, which is marked by sustained high stress levels.

Stressful living: A slow crawl to disease

This is where the focus of Essop's own research lies: the relationship between rising levels of chronic stress in South Africa and cardio-metabolic disease. This is a largely understudied research area and a very relevant one, seeing as South Africa is regarded as one of the most stressed nations globally.

Essop's work includes looking for mitochondrial protein markers that could offer clues to how cell structures and functions are being changed by stress.

Mitochondria function as our organs' energy makers, he says. "Mitochondria produce energy called 'ATP' [adenosine triphosphate]. This energy sustains the workings of a cell, whether it's a heart cell, a liver cell, or whatever other cell. But if there is some dysfunction, the mitochondria won't be able to produce sufficient energy, and the relevant cell shrinks and dies."

By examining the patterns of how mitochondrial protein markers show up in the cells, scientists are able to identify signs of dysfunction sooner. It can help guide patients to seek earlier screening and intervention and to be monitored to stave off serious illness and death.

But Essop admits that even early detection of cardio-metabolic disease and the supplying of patients with guidelines for lifestyle changes have their limits. This is because of circumstances, contexts, and realities, he says.

"If you're living in an area with high levels of violence or poverty, or in a household where you can't buy nutritious food, then the option of resetting your anxiety levels by going for a long walk isn't always available. This is what we [as researchers] need to be thinking about, instead of just giving advice that people can't relate to.

"Over time, this kind of chronic stress is normalised but continues to cause dysfunction and increases the chances of developing heart disease. We might hear that someone dropped dead of a heart attack, but really the disease didn't suddenly occur — it developed over time," Essop says.

The double burden of HIV and heart disease

Another key area of research at CARMA is the devastating burden of HIV in South Africa and its connection to heart disease. Over the past 10 years, the link between HIV, antiretroviral therapy (ART), and heart disease has been well established by researchers. South Africa — with its outsized HIV-infected population of an estimated 7,5 million people in 2021, according to UNAIDS — is set to see a correlating spike in heart disease over the coming years.

Prof Hans Strijdom, the deputy director of CARMA, says: "We now suspect that people with HIV, regardless of age, have a two-fold increased risk of developing heart disease. Unfortunately, we have had to rely on data from Europe and North America, so we have never known how applicable research from these countries apply to our situation in sub-Saharan Africa." he says.

In 2015, Strijdom and his team were able to secure funding from the European Union to research how HIV and ART might cause changes and dysfunction in the endothelium, the single-cell membrane forming the inner lining of blood vessels.

"Endothelial cells are pivotal [to the protection of the body] because they constitute the single barrier between harmful molecules and toxins in the blood, and the rest of the body. Blood is not just the body's transport system for oxygen and nutrients — it also carries free radicals, fatty acids, and toxins that we want excreted from our bodies.

"Our research evaluates the extent to which HIV and the treatment of HIV affect the layer of endothelial cells, causing it to loosen, develop gaps, and leak. When endothelial cells become dysfunctional or are harmed, those gaps in the cell layer allow harmful things to be siphoned off into the organs, where they cause inflammation and disease.

"The question is whether this might be the origin of HIV patients' increased susceptibility to heart disease and strokes," says Strijdom.

Retinal eye imaging techniques

As another tool for the early diagnosis of heart disease, Strijdom's research team is adopting retinal eye imaging techniques that are currently used in optometry. He explains: "A retinal imaging tool can quickly indicate the condition of someone's blood vessels. It can also help us assess that person's risk of getting heart disease. Most people will go for an eye test at some point. The optometrist can then take a photo of the retinal blood vessels and Whatsapp it to a specialist in another location who can do the assessment and send back a diagnosis."

For Strijdom, the beauty of the endothelium is that the early stages of dysfunction are reversible, which means early interventions can slow down the onset of heart disease, and possibly even reverse the damage. To him, this is where research can have true impact.

> "Sometimes we researchers get so bogged down in our labs, looking into petri dishes, that we forget that it's not about a molecule or something under the microscope. It's about doing research that can eventually make its way to a nurse or a doctor who can inform a patient about the steps they can take to prevent heart disease."

The research ethos that CARMA has adapted constitutes a gear shift. By viewing science and research through the lenses of inequality and socio-historical and political injustices, it is encouraging more reflective and critical thinking among students and staff.

The result, thus far, has been an unveiling of in situ solutions that light the path towards better health for more people.

Research for real-world impact

CARMA's research approach is rooted in public communication and community outreach. Strijdom is unequivocal in his summary of what needs to be communicated in HIV messaging: the importance of knowing your status, not defaulting on treatment, and managing your risk of developing heart disease.

"When we are treating someone with HIV, we must understand that we are not just treating HIV; we must keep in mind that patients are at risk of developing other diseases and comorbidities. We also know that the occurrence of heart disease and strokes will increase over time as our HIV population gets older and stays on treatment longer."

What the patient management protocol should reinforce, Strijdom argues, is the need for better screening. It's as basic as doing regular blood pressure and blood cholesterol tests for HIV patients, and listening to their heartbeat, he says.

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