Stellenbosch
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forward together
sonke siya phambili
saam vorentoe

MOVING FORWARD WITH

RESEARCH FOR IMPACT

2024

ACKNOWLEDGEMENTS

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Prof Wim de Villiers | Photo by Stefan Els

FOREWORD

In a world that continues to face uncertainty and upheaval, Stellenbosch University (SU) remains committed to pushing the boundaries of research and innovation.

Amidst the challenges, we find solace and inspiration in the transformative power of knowledge.

One of the most remarkable examples of this power is the work of Prof Pumla Gobodo-Madikizela, the SARChI Chair in Violent Histories and Transgenerational Trauma and the founding director of the Centre for the Study of the Afterlife of Violence and the Reparative Quest (AVReQ).

In 2024, Gobodo-Madikizela was awarded the prestigious Templeton Prize — an accolade often likened to the Nobel Prize — for her groundbreaking research on forgiveness and post-trauma repair. This global recognition honours not just her work but also the impact that research can have on healing and societal change.

Gobodo-Madikizela's remarkable contributions go beyond research, given her pledge to donate an extraordinary R8 million to SU. Her endowment will support AVReQ and provide scholarships, ensuring that future generations of students and postdoctoral fellows can focus on their studies and research.

As I reflect on my final stretch as SU's Rector and Vice-Chancellor, I am immensely proud of how far we've come.

Our research capabilities have grown tremendously over the last ten years, thanks to the tireless commitment of our staff. This success was not achieved by chance but through hard work, collaboration, and a shared vision of attaining excellence. SU has become an institution that attracts some of the world's brightest minds, and it is this community of innovative thinkers that drives our research forward.

According to the latest Department of Higher Education and Training figures, SU remains among South Africa's top five research-intensive universities, in terms of both research publications per capita and in terms of total research output. In 2023 alone, we saw the submission of 3 113 research articles — clear evidence of our expanding international research collaborations.

We now boast 505 National Research Foundation-rated researchers, including 22 A-rated scholars, the highest number we have ever had. Our commitment to advancing knowledge is further highlighted by the establishment of 50 fully funded research chairs, doubling the number from 2015.

Another significant achievement this year has been the growth of our postdoctoral research community. As at November 2024, we have 358 postdoctoral fellows, and aim to grow this number further by 2025. This postdoctoral community, along with our increasing international partnerships, is strengthening our position as a global hub for impactful research.

Our collective efforts continue to contribute to the greater good through research that not only enhances academic knowledge but also addresses critical societal, economic, and environmental challenges. As I prepare to step down, I know that SU's research legacy is in excellent hands, and its trajectory is set for sure success.

I hope you find the articles in this publication as inspiring as I do, as they highlight the strides we are making in conducting research for impact — research that advances society, drives innovation, and creates lasting change.

Prof Wim de Villiers

SU Rector and Vice-Chancellor, November 2024

RESEARCH FOR IMPACT

Knowledge and discovery are the cornerstones of human progress. It empowers us to better understand the world around us, solve complex problems, and innovate.

The pursuit of knowledge fuels curiosity and creativity, leading to breakthroughs in science, technology, and the arts. Discovery reveals new horizons and challenges our beliefs, pushing us to think differently and adapt.

Prof Sibusiso Moyo | Photo by Stefan Els

Albert Einstein beautifully captured the essence of knowledge and discovery: “The important thing is not to stop questioning; curiosity has its own reason for existing.”

Higher education, particularly at the postgraduate level, holds the transformative potential to address inequalities and contribute to a more equitable society. In this way, research and innovation can help shape a prosperous and just future for South Africa.

Universities are vital in tackling global challenges and enhancing lives. They drive innovation by transforming ideas into knowledge and inventions that benefit society. Through education, research, and collaboration, universities foster creativity and provide an environment that encourages exploration and new ideas that can have a significant societal impact.

Research is a transformative activity with the power to change the world. To stay relevant and competitive, universities must adopt innovative strategies and focus on their areas of expertise.

At SU, our academics, research fellows, and postgraduate students are breaking new ground in building healthy, strong, and sustainable communities through means of their future-oriented, innovative ideas.

SU’s new research and innovation strategy (the draft blueprint) is well aligned with its Vision 2040, and with its aspirations to be Africa’s leading research-intensive university, globally recognised as excellent, inclusive, and innovative in its advancement of knowledge in service of society.

In the blueprint for this new strategy, we focus on four dimensions: strategies 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.

Research-related activities and outputs are critical to expanding SU’s international reputation as an excellent research-intensive university and, through grants, contribute significantly to the University’s annual income. More importantly, new knowledge generated at SU is transferred to a broader national and also global audience, thereby promoting the application of research results and the development of high-level human capacity. This renders researchers some of the most important assets of any university. Our researchers continue to receive prestigious national and international accolades for their exceptional contributions to knowledge and discovery.

Graduates with advanced degrees bring to the job market the necessary specialised knowledge and critical thinking skills to tackle complex issues and drive innovation. By investing in research, South Africa can improve its global standing, attract international collaborations, and become a leader in scientific advancements.

This year, SU has made significant strides in its engagement with various stakeholders. For instance, we have collaborated with the African Research University Alliance (ARUA) and The Guild of European Research-Intensive Universities. As a result, SU is now co-leading four clusters of research excellence (CoREs).

These clusters focus on addressing global and African challenges through methods from the fields of artificial intelligence, data science, theoretical and computational thinking, genomics for health in Africa, nature-based solutions for climate change adaptation and mitigation, and renewable energy. SU is participating in other Africa-Europe CoREs that are aligned with the African Union and European Union Innovation Agenda.

SU is also participating in collaborative PhD programmes with ARUA and The Guild partners. If fully funded and adherent to a critical pipeline, this network will train at least 1 000 PhD students annually and 10 000 over a decade.

The University is engaged in efforts to establish a credible, responsible assessment measure for its research outputs. This entails looking at all kinds of metrics and indicators to assess the impact of our work. However, metrics alone do not tell the whole story of the impact of our research and the value of our scholarly endeavours.

We are learning about knowledge exchange paths and impact outcomes at different stages of the research process. We do this by exploring the narratives behind the research, which enriches our understanding of its impact and the processes that underpin it.

> Our research leaders are creating enabling environments for research team members and emerging researchers to express themselves and to thrive, while upholding all the SU values and displaying research integrity.

A stellar example is Prof Pumla Gobodo-Madikizela, the SARChI Chair in Violent Histories and Transgenerational Trauma and the founding director of the Centre for the Study of the Afterlife of Violence and the Reparative Quest (AVReQ). Gobodo-Madikizela was awarded the prestigious 2024 Templeton Prize for her groundbreaking work on forgiveness and healing after trauma. She is an example of a researcher who pursues excellence while showing great humility. We are grateful for her donation towards supporting emerging scholars on the SUNRISE programme for the promotion of future professors, and to AVReQ for postgraduate student funding and postdoctoral fellow support.

An enabling environment can only be created if all the contributing parties share the same vision and passion for the organisation.

> Leading from the frontline, I have seen fruitful collaboration within the University's faculties, schools, departments, centres, and support divisions.

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 infant mental health, advances in agri-informatics, the study of neurodegenerative diseases on a cellular level, or the use of big data in making smarter policy decisions, the work being done at SU is clearly having ground-level impact.

The articles show our researchers' dynamic and purpose-driven approach, highlight the social relevance of their work, the interdisciplinary collaboration it takes, 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.

We invite you to explore the stories about our progressive research environment, where knowledge fuels sustainable progress and shared achievement. 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.

May the following pages inspire, provoke thought, and instill a profound appreciation for the transformative power of our research. And, of course, may they feed your curiosity.

Prof Sibusiso Moyo
Deputy Vice-Chancellor: Research, Innovation, and Postgraduate Studies

Research for impact, in numbers (2024)

DISTINGUISHED RESEARCHERS

50 research chairs, of which **20** are South African Research Chairs Initiative (SARChI) chairs, funded by the Department of Science and Innovation through the National Research Foundation (NRF)

505 NRF-rated researchers, of which **22** are A-rated*

358 postdoctoral research fellows, of which **41** are consolidocs**

POSTGRADUATE STUDENTS

320 doctoral degrees awarded in 2023

4 920 master's students registered (as at June 2024)

1 555 PhD students registered (as at June 2024)

NETWORKS AND PARTNERSHIPS

365 bilateral partner institutions in **67** countries, across **6** continents

36 bilateral agreements with **23** other African universities

INNOVATION

107 Patent Cooperation Treaty applications submitted since 2014 (more than by any other entity in SA)

32 spin-out companies launched

RANKINGS

3RD SU ranks 3rd in SA and 283rd worldwide on the Quacquarelli 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

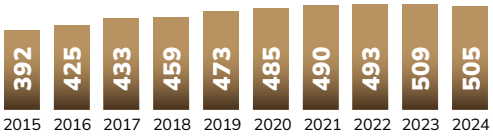
RESEARCH CONTRACTS

1 650 research contracts processed in 2023, compared to 956 in 2018 (a 72% increase in 5 years)

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

NRF-RATED RESEARCHERS

Totals (2015 to 2024)



A-rated (2015 to 2024)

RESEARCH OUTPUTS

3 113 number of articles in accredited journals (2023 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

Updated November 2024

Tackling global challenges

STRATEGIC RESEARCH AREAS AT SU

Health and human security

Promoting well-being for all

We prioritise research on communicable and non-communicable diseases, disability, biomedical engineering, sports medicine, and social determinants of health.

Sustainable development goals

1 2 3 4 6 8 9 10 11

Agenda 2063 goals

1 2 3 4 5 6 7 10

Associated SU entities

- SARChI Chair in Innovative Rehabilitation
- SARChI Chair in Mycobactomics
- SARChI Chair in Food, Environments, Nutrition and Health
- SARChI Chair in Paediatric Tuberculosis
- SARChI Chair in TB Biomarkers
- SARChI Chair in Mechanistic Modelling of Health and Epidemiology
- SARChI Chair in Integrative Skeletal Muscle Physiology, Biology and Biotechnology
- Sarah Turoff Endowed Chair in Schizophrenia Research
- Rand Water Chair in Public Health
- Africa-Europe Clusters of Research Excellence in Genomics for Health in Africa
- Centre of Excellence for Biomedical TB Research
- Centre for Epidemic Response and Innovation
- South African Centre for Epidemiological Modelling and Analysis
- Centre for Food Safety
- Desmond Tutu TB Centre
- Africa Cancer Institute
- Institute of Sport and Exercise Medicine

Human creativity and social innovation

Driving positive change through innovation

We foster creativity and develop innovative solutions to societal challenges like housing, education, and inequality.

Sustainable development goals

3 4 5 6 7 8 9 10 11 12 13 14 16 17

Agenda 2063 goals

1 2 3 4 10 11 12 13 18 19 20

Associated SU entities

- SARChI Chair in Science Communication
- Anton Mostert Chair of Intellectual Property
- Ton and Anet Vosloo Research Chair in Afrikaans Language Practice
- UNESCO Chair in Complex Systems and Transformative African Futures
- UNESCO Chair in Intercultural Competences
- DSI-NRF Centre of Excellence in Scientometrics and Science, Technology and Innovation Policy
- Africa Open Institute for Music, Research and Innovation
- Centre for Science and Technology Mass Communication
- Centre for Regional and Urban Innovation and Statistical Exploration
- Chair in Science Futures
- Standard Bank Centre for Agribusiness Development and Leadership
- Stellenbosch Institute for Advanced Study
- African Wildlife Economy Institute
- Stellenbosch University Centre for Pedagogy
- Confucius Institute at SU

Social justice and development

Building an equitable society

Our research addresses gender, racial, and cultural inequalities, while promoting human rights and dignity.

Sustainable development goals

1 2 3 4 5 7 8 10 11 15 16 17

Agenda 2063 goals

1 2 3 5 7 11 12 13 17 18 19 20

Associated SU entities

- SARChI Chair in the Sociology of Land, Environment and Sustainable Development
- SARChI Chair in Gender Politics
- SARChI Chair in Violent Histories and Transgenerational Trauma
- SA-Africa-UK Trilateral SARChI in Mainstreaming Gender for Energy Security in Urban Poor Environments
- Law Trust Chair in Social Justice
- HF Oppenheimer Chair in Human Rights Law
- Gys Steyn Chair in Financial Regulation Law
- Centre for the Study of the Afterlife of Violence and the Reparative Quest
- Centre for Research on Democracy
- Bureau for Economic Research
- Centre on Conflict and Collaboration
- Unit for Religion and Development Research
- Centre for Applied Ethics
- Centre for International and Comparative Politics
- Africa Centre for HIV/Aids Management
- Anti-Corruption Centre for Education and Research of SU
- Centre for Social Justice
- Security Institute for Governance and Leadership in Africa
- Centre for Military Studies

Sustainable development goals

Source: Research Information and Strategic Initiatives Office, Division for Research Development (DRD). September 2024.

SU's researchers aim to produce knowledge and have a real societal impact through our five strategic research areas. Identified to assist in achieving the University's strategic goal of research for impact, these areas support the United Nations' Sustainable Development Goals and the African Union's Agenda 2063 through interconnected and interdisciplinary collaboration.

Systems and technologies for the future

Leading technological advancements

Our research focuses on developing new and improved systems and technologies across various sectors, including economics, business, information technology, and infrastructure.

Sustainable development goals

1 2 3 4 6 7 8 9 11 12 13 15 16 17

Agenda 2063 goals

1 4 5 10 12 13 18 20

Associated SU entities

- SARChI Chair in Sugarcane Biorefining
- SARChI Chair in Antenna Systems for the SKA
- SARChI Chair in Power Systems Simulation
- SANRAL Chair in Pavement Engineering
- Chair of Computational Thinking for AI
- Capitec Chair of Applied AI
- MacroComm Smart Utility Solutions Chair
- Research Chair in the Internet of Things
- National Institute for Theoretical and Computational Sciences
- AUDA-NEPAD Centre of Excellence in Science, Technology and Innovation
- Gibela Engineering Research Chair
- Africa-Europe CoRE in Addressing in Global and African Challenges through Methods from Artificial Intelligence, Data Science and Theoretical and Computational Thinking
- School for Data Science and Computational Thinking
- Centre for Geographical Analysis
- Institute for Futures Research
- Centre for Complex Systems in Transition
- Institute for Wine Biotechnology
- Institute for Biomedical Engineering
- Research Alliance for Disaster and Risk Reduction
- Centre for Bioinformatics and Computational Biology
- Stellenbosch Phototonics Institute

The natural environment

Understanding and protecting our planet

Our research focuses on water, energy, food security, urban sustainability, biodiversity conservation, and mitigating environmental risks.

Sustainable development goals

1 2 3 4 5 6 7 9 10 11 12 14 15 17

Agenda 2063 goals

1 2 3 4 5 6 7 10 11 17 18 19 20

Associated SU entities

- SARChI Chair in Social-Ecological Systems and Resilience
- SARChI Chair in Integrated Wine Sciences
- SARChI Chair in Mathematical and Theoretical Physical Biosciences
- SARChI in Green Hydrogen Integration and Transition
- Research Chair in Management of Invasions in Protected Areas
- Chair in Plant Health
- Postharvest Physiology Research Chair in Deciduous Fruit
- Hans Merensky Chair in Advanced Modelling of Eucalyptus Wood Formation
- AIMS-Carnegie Junior Research Chair in Data Science
- Sasol Chair in Analytical Polymer Science
- African Rainbow Minerals ARM Geometallurgy Research Chair
- Africa-Europe CoRE in Nature-based Solutions for Climate Change Adaptation and Mitigation
- Africa-Europe CoRE in Renewable Energy
- Stellenbosch University Water Institute
- Centre for Renewable and Sustainable Energy
- Centre of Excellence for Invasion Biology
- School for Climate Studies

Abbreviations

SARChI: South African Research Chair Initiative
AUDA-NEPAD: African Union Development Agency-NEPAD
SANRAL: South African National Roads Agency Limited
SKA: Square Kilometre Array

Agenda 2063 goals

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

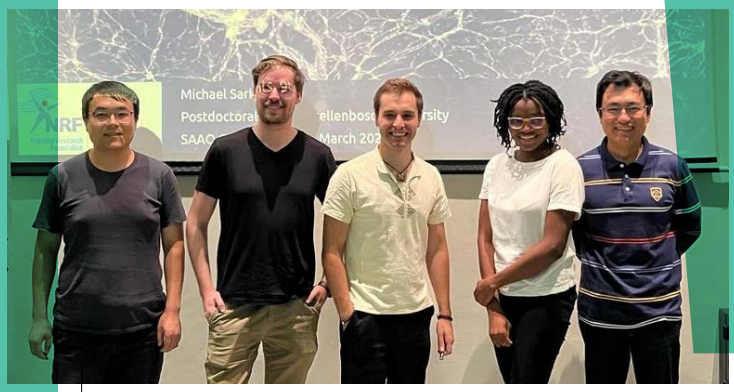
IN SEARCH OF THE INVISIBLE

ENGELA DUVENAGE

 Illustration by Ronel van Heerden

In a single minute, a video stored on astrophysicist Prof Yin-Zhe Ma's phone captures how, over the course of billions of years, our universe evolved out of darkness into potentially millions of galaxies, stars, and pulsars.

"It's absolutely beautiful," he sighs with pleasure as the 60 seconds of digitally simulated evolution end.



Members of the SU Astronomy and Astrophysics Research Group at an open night of the South African Astronomical Observatory in Cape Town, in March 2024. (From the left, postdoctoral researcher Dr Guo-Jian Wang, PhD student Phillip Badenhorst, postdoctoral researcher Dr Michael Sarkis, MSc student Victoria Nakafingo, and research group leader Prof Yin-Zhe Ma.) | Photo by Abigail Thambiran

As lead of the Astronomy and Astrophysics Research Group in the Department of Physics at Stellenbosch University (SU), Ma knows better than most that this on-screen portrayal captures but a fragment of the full universe — that is to say, only the visible part.

Gravity originating from this visible matter is simply not enough to have led to the formation of our galaxy or stars, he says. "We therefore know that there must be 'more'."

Other physicists agree, but no one has yet seen this 'more' or been able to pin it down. Finding it is considered one of the holy grails of science.

"What you learn in physics is generally restricted to the 4.8% of visible matter. Another 25% is dark matter, of which we know the gravitational nature. The majority of the universe, however — dark energy — remains unknown. We don't know its nature. It could function completely differently to the way we know. It's even more mysterious than dark matter. That 70% is the biggest thing in the universe that we can work on," Ma muses.

The quest to find dark energy

Ma is on a mission to connect fundamental physics with astronomical observations in order to understand the basic laws of the universe, as well as its expansion and the birth of the first galaxies (the so-called Cosmic Dawn and Epoch of Reionisation, respectively). Naturally, he also hopes to unravel the very nature of dark matter and dark energy, and to find ways to detect these phenomena and better understand their role in the expansion of the universe.

The term 'dark energy' was coined in 1998. In 2012, the journal *Science* claimed it was likely one of three things: "It could simply be a property of empty space itself. Einstein's theory of gravity, known as general relativity, allows for just such a 'cosmological constant' that would be a property of the vacuum and would stretch space. Or, in a radically different alternative, dark energy could be a new type of force field that occupies space, much as air fills a balloon. That second alternative is known as 'quintessence'. Finally, dark energy could be an illusion, a sign that scientists' understanding of gravity as encapsulated in general relativity isn't quite right."

Ma's quest is clearly not an easy one. "We may or may not find dark energy. It's very challenging," he admits. "Even if we don't, we hope to find unique constraints that exclude some regions, so that we may know it's not there and that we should search elsewhere. In other words, we hope to exclude some windows of opportunity — that would also contribute to science."

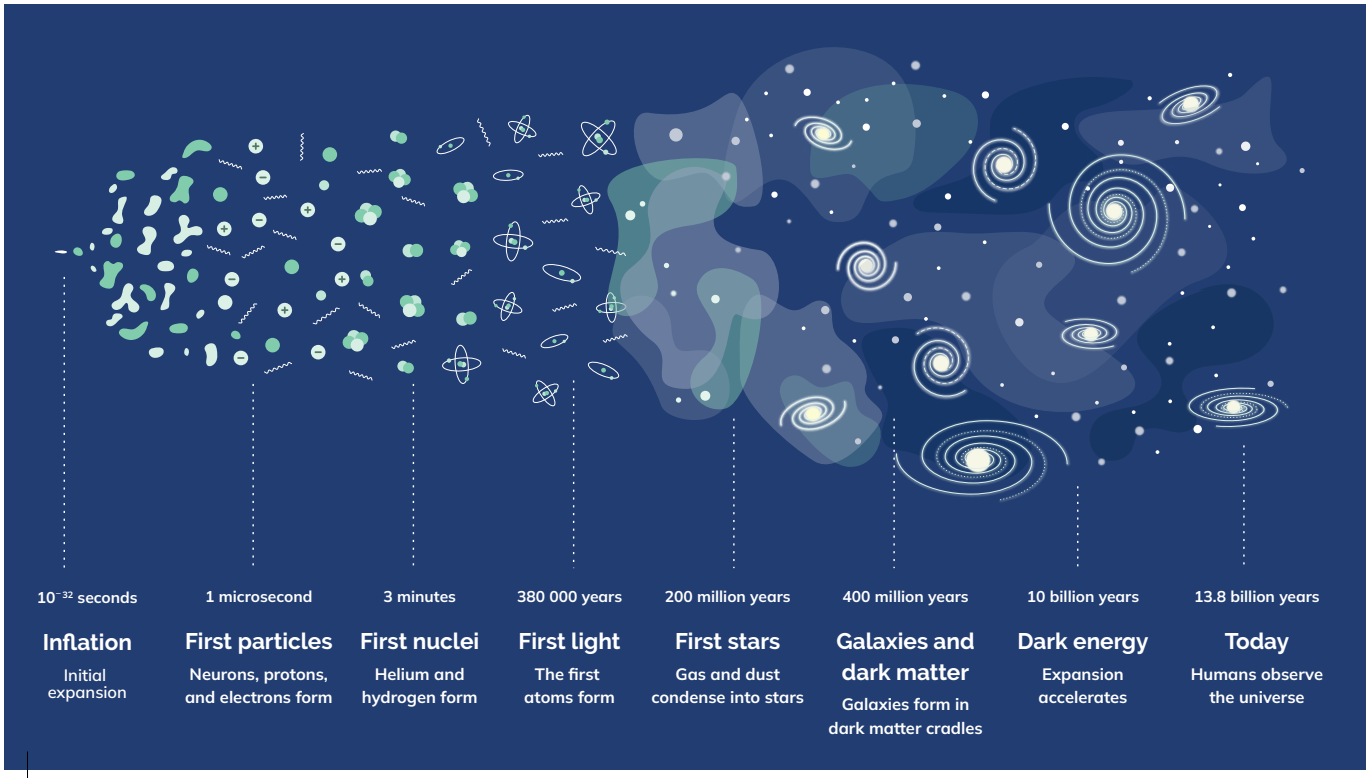
Signs of dark matter

Towards a similar end, PhD student Phillip Badenhorst is analysing data on two dwarf spheroidal galaxies, Reticulum II and Tucana II, captured in 2022 by the MeerKAT radio astronomy array in the Karoo in the Northern Cape. Respectively, the two galaxies lie some 98 000 and 82 000 light years from Earth.

"While relatively smaller than our Milky Way, Reticulum II and Tucana II still contain millions of stars. They are also reasonably close, considering the vast scale we are working on," Badenhorst explains.

Currently, he is examining data on the two galaxies in the hope of discovering signs of axions, hypothetical particles that many believe can play an important role in the search for dark matter in the cosmos.

"Axion-like particles constitute an extremely light and elusive type of dark matter," explains Dr Michael Sarkis, a postdoctoral researcher in the Astronomy and Astrophysics Research Group. "This type of dark matter will only be revealed through the most precise observations of astrophysical objects — something which the MeerKAT telescope (and eventually the Square Kilometre Array, or SKA) is well suited for," he says.



The history of the universe | Illustration by Ronel van Heerden (original diagram by Nasa)

As part of his PhD in physics at the University of the Witwatersrand, Sarkis developed a technique for modelling radio signals expected to be 'seen' emanating from dark matter. That proved to be a job easier said than done. "My collaborators and I used these models to search for dark matter in images of galaxy clusters taken with MeerKAT. We didn't find any indication of these emissions, but drew some conclusions about what the nature of dark matter could be," he says.

Sarkis' postdoctoral research is following along similar lines. This time round, he is using observations of the Milky Way provided by the MeerKAT-related Thousand Pulsar Array as part of the MeerTime project. These observations are of a group of more than a hundred highly compact, magnetised stars called 'pulsars'.

"Although we cannot see dark matter or dark energy directly, we indirectly study them by using visible matter. This constrains possible models of invisible matter," Ma explains.

Carving out a research niche

In 2023, his endeavour to set up the Astronomy and Astrophysics Research Group already broke new ground for SU. It is the first entity at the institution to focus specifically on the science rather than the engineering behind MeerKAT. SU engineers and alumni have, since the early 2000s, been involved in the design of the MeerKAT dishes, and in ensuring that electricity supply to the site, 90 km from Carnarvon in the Northern Cape, does not interfere with radio signals being collected from outer space.

Ma believes their group's practical use of terabytes worth of data gathered by MeerKAT and other radio astronomy telescopes will provide noteworthy links between existing research nodes in engineering and physics at SU, as well as between the University's recently established research programmes in theoretic and quantum physics and its School of Data Science and Computational Thinking.

"Science is always interconnected," Ma reiterates. Ma's group also has access to data from other of the world's best telescopes, such as those of the Hydrogen Epoch of Reionisation Array (HERA) in South Africa, the Dark Energy Spectroscopic Instrument in the USA, and the South Pole Telescope.

The group's research is deliberately focused on the Epoch of Reionisation, extragalactic astronomy, the early universe, and ways to indirectly detect dark matter, neutron stars, and black holes. Ma wants to carve out a specific niche for SU's researchers rather than duplicate sterling work already done, over many years, by established research groups at, for instance, the nearby University of Cape Town and the University of the Western Cape.

Devoted to finding the yet unfound

Ma's research on the origin and evolution of large-scale structures in the universe is continuing intensively. Earlier in 2024, he co-authored a paper detailing the deployment and commissioning of the second phase of HERA. This array is being built on the same site as MeerKAT, as a designated SKA pathfinder instrument.

Some of his other recent scientific contributions are contained in papers he co-authored in *The Astrophysics Journal* and in *Astronomy and Astrophysics*.

Ma was also the lead author of a recent paper on the study of cosmic voids, published in the *Monthly Notices of the Royal Astronomical Society*. Cosmic voids, known as the largest under-dense regions of the universe and for filling most of its volume, contain abundant cosmological information for probing dark energy, cosmic structure growth, and galaxy formation, Ma and his co-authors note.

Another of the endeavours that Ma is involved in is the Joint Astronomy Chair between SU and the University of Groningen in the Netherlands, the latter ranking among the world's 70 best universities in the fields of astrophysics and astronomy. Set up in June 2024, the Chair offers 10 co-supervised PhD students the opportunity to study at both universities and to receive funding while abroad. The process of recruiting students to conduct cutting-edge astrophysics research on the Epoch of Reionisation, structure formation, and dark matter is underway.

Searching for what can't be seen

Less than 5% of the universe is visible. What is the rest then made up of?

The visible universe — including our solar system's planets, the sun, other stars, and galaxies — is made of protons, neutrons, and electrons bundled together into atoms. While this ordinary (or 'baryonic') matter is everywhere in our daily lives, it constitutes but a fraction of the entire universe.

The rest appears to be composed of a mysterious, invisible substance called 'dark matter' (25%) and a force that repels gravity, known as 'dark energy' (70%).

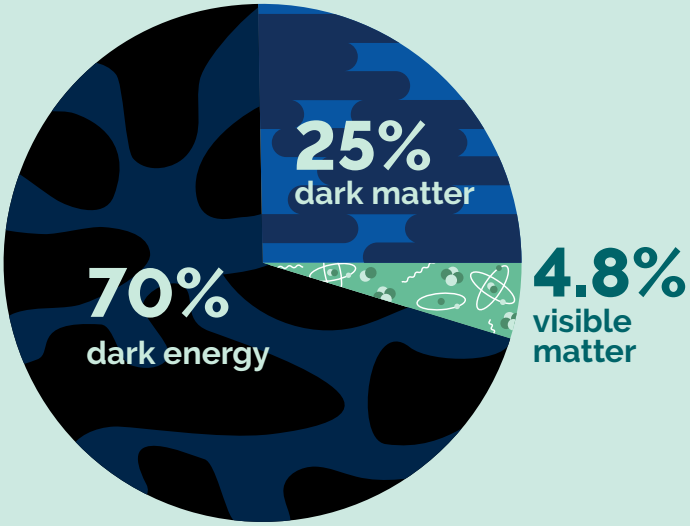
Finding the dark in space

Scientists have yet to observe dark matter directly. It doesn't interact with baryonic matter and is entirely invisible to light and other electromagnetic radiation, making it impossible to detect with current instruments. Scientists are confident, however, that it does exist because of the gravitational effects it appears to have on galaxies and galaxy clusters.

It is theorised that dark matter may consist of exotic particles that don't interact with normal matter or light but still exert a gravitational pull. Some scientists also suggest that the effects of dark matter could be explained by fundamentally modifying our theories of gravity, proposing the existence of multiple forms of gravity.

An expanding universe

Dark energy is even more mysterious than dark matter. Physicists previously assumed that gravity would slow the expansion of the universe, but measurements showed the opposite. This finding was likened to throwing a set of keys up into the air and expecting them to fall back down, only to see them fly straight up toward the ceiling.



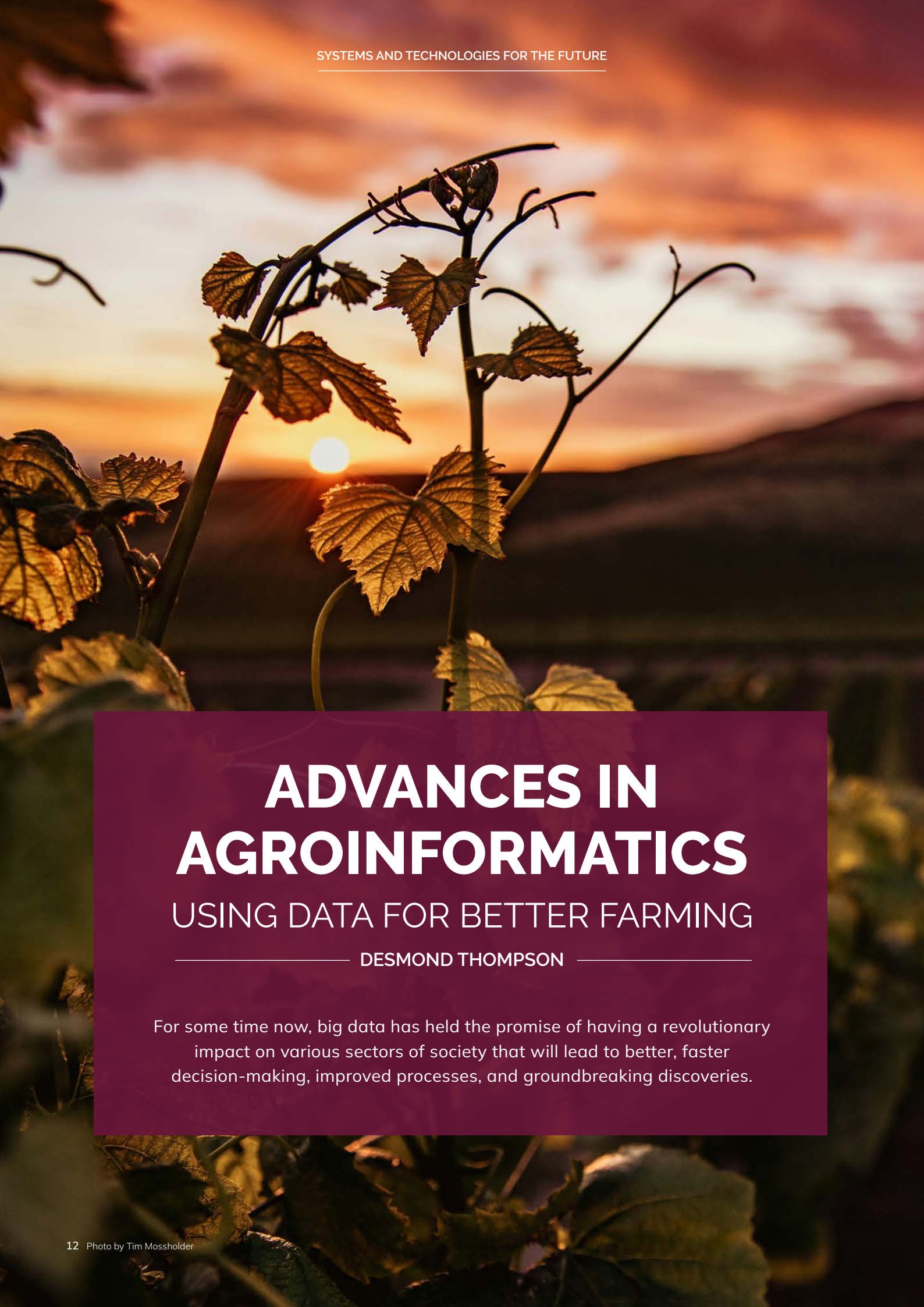
Scientists now believe that the accelerated expansion of the universe is caused by a repelling force created by tiny energy changes in 'empty' space. This force appears to become stronger as the universe gets bigger. Scientists have named this mysterious force 'dark energy'.

The nature of dark energy lacks a viable explanation, unlike dark matter. One theory posits that dark energy could be a previously undiscovered fifth fundamental force known as quintessence, which fills the universe like a fluid.

Universe's 'gravitational scaffold'

The nature of dark matter remains a mystery to scientists. Even though it occupies about a quarter of the universe, it does not interact with light, making it difficult to detect.

Scientists theorise that dark matter exists in a vast, web-like structure that winds through the universe — a gravitational scaffold that attracts most of the cosmos' normal matter. Research efforts to uncover the identity of dark matter are ongoing.



ADVANCES IN AGROINFORMATICS

USING DATA FOR BETTER FARMING

DESMOND THOMPSON

For some time now, big data has held the promise of having a revolutionary impact on various sectors of society that will lead to better, faster decision-making, improved processes, and groundbreaking discoveries.

 Photo by Tim Mossholder

In agriculture specifically, better data management, analysis, and application can boost animal and crop improvement, biosecurity and disease control, postharvest technology, agroprocessing, value chain analysis and development, as well as food sustainability and security. It can also help counter and build resilience against climate change.

Data for food security

A closer look at just one of these aspects — food security — clearly illustrates why data is considered a game changer.

In compiling the *Food Waste Index Report 2024*, researchers found that the world squanders over a billion meals a day, amounting to almost a fifth of all food available to consumers. Inger Andersen, executive director of the United Nations Environment Programme, describes this situation as a "global tragedy" because, despite this wastage, nearly 800 000 people go hungry daily and a third of humanity faces food insecurity.

The agricultural sector has an important role to play in addressing this problem. Dr Jan Greyling, a senior lecturer in the Department of Agricultural Economics at Stellenbosch University (SU), says: "It's a massive task to feed a global population of eight billion people three times a day, and that responsibility falls to agriculture."

Greyling believes that big data analysis can improve food availability, access, and utilisation, among other things. However, this potential is not yet being fully realised, he says.

> "Big data can change the world, but it's gushing at us like water from a firehose, and we're not actually making sense of it. We need to look at it differently. We must move from numbers to actionable insights."

A revolutionary impact

The use of digital technologies — including smartphones, tablets, sensors, drones, and satellites — has become common in the agricultural sector, providing a range of farming solutions, from the remote measurement of soil conditions to real-time livestock and crop monitoring.

"There's lots of technology in agriculture and forestry — such as autosteering tractors connected to satellites and lately to the internet, machines going through orchards and counting fruit, drones spraying crops and taking high-resolution images," Greyling says. "But these technologies are all things we can physically see and touch. What's not so visible is the constant stream of data that they produce. We're not fully exploiting that yet."

The statistics on big data are truly staggering. According to trends monitor Exploding Topics, around 329 million terabytes of data are created every day. Considering that an estimated 90% of the world's data was generated in the last two years alone, data generation is expected to continue increasing at an exponential rate as the Internet of Things (IoT) and new developments in artificial intelligence (AI) expand humanity's digital footprint.

In the case of agriculture, big data analysis has the potential to revolutionise the sector. In this regard, Greyling has a specific challenge for the research community: "We need to view data in itself as an asset — something valuable to invest in and not just something to be written up in a thesis or journal article and then to be dumped in an obscure repository where it is ostensibly available to others. Only once we start combining existing stores of big data in new ways and start analysing it properly, agroinformatics will really change the world."

A big data initiative

Prof Danie Brink, dean of AgriSciences at SU, has placed agroinformatics at the heart of the Faculty's research and innovation strategy. As such, one of its new projects focuses on changing the way in which big data is integrated into agriculture and forestry research. It's called the 'Stellenbosch Agroinformatics Initiative' (SAI) and is aimed at enabling data-intensive interdisciplinary research and innovation partnerships that span departments, faculties, universities, companies, and continents.

Greyling, head of the SAI, says: "Effective data management and sharing, as well as collaboration across disciplines are crucial components of research that can make a meaningful impact on society and the agricultural sector."

The SAI brings researchers from different academic fields together to establish communities of practice around five core data-intensive research techniques: image processing, LiDAR (light detection and ranging), the IoT, special analysis, and genomics.

"The challenge is to bring domain experts from different fields together, combining their expertise to solve the major challenges facing the agri-food and natural resources sectors," says Greyling.

Agtech in practice

According to Suné van Zyl, who used the Western Cape Department of Agriculture as a case study in her master's thesis on using big data in the public interest, the use of technology in agriculture is known as 'agtech' or 'Agriculture 4.0'.

"Vast information sets generated by remote sensing technologies such as drones, satellites, soil monitors, and infrared sensors can produce a multitude of insights into weather and land conditions," she says. "This sort of information can inform and guide farmers in monitoring the productivity of their land, anticipating disasters

such as droughts, and choosing crops that best suit the specific conditions of their land."

In this way, farming informed by big data "can increase productivity, reduce waste, and assist farmers in monitoring the conditions of their resources. Furthermore, such [data-driven] insights can assist the sector in pre-empting land degradation and desertification, and ultimately enhance the sector's resilience against climate change and related disasters".

Image processing

In the SAI's image processing community of practice, Prof Lizel Mostert of the Faculty's Department of Plant Pathology is using AI to help with the identification of plant disease symptoms.

"Grapevine leafroll is an economically devastating disease for grapevine producers in South Africa," she says. "To ensure clean propagation material, it is essential to identify diseased vines. But that's easier said than done as it can be quite hard to distinguish infected leaves from ones that have been mechanically damaged or are suffering from a phosphorus deficiency."

This fact has led to a study aimed at developing an AI-based system that uses deep learning techniques to identify leafroll-infected vines via photos taken with a smartphone.

This research is being conducted in collaboration with SU's School for Data Science and Computational Thinking, its Department of Industrial Engineering, and the South African Grape and Wine Research Institute (SAGWRI).

Smart farming for the future

Non-invasive technologies such as that used for grapevine leafroll identification also feature prominently in another of the Faculty's communities of practice, that focuses on the IoT. The latter consists of sensor-embedded devices that share data with each other and with analytic systems via the internet or other communication networks.

The IoT is transforming agriculture into a more efficient, data-driven practice, often referred to as 'precision agriculture' or 'smart farming'.

Prof Carlos Poblete-Echeverría coordinates SAGWRI's research group on digital agriculture, which is based on the principles of smart farming. "We are looking at a group of new technologies — sensors, platforms, algorithms and the like — that can be used to provide useful information for optimising management practices in viticulture and the broader field of agriculture," he says.

Data acquisition is the first step in digital viticulture, he reckons. Of the many non-invasive technologies available for use in sensors, the most familiar is digital photography based on visible light. "There are plenty of applications for simple cameras, especially when you attach them to a drone or vehicle. You can also use time-lapse photography. Normal cameras are a great low-cost technology."

Other digital imaging technologies such as spectroscopy, multi- and hyperspectral imaging, and infrared thermography rely on non-visible light. Besides light-based sensors, there are also sensors that detect electrical resistance and conductance for use in soil analysis.

'Robots are coming'

For sensors to collect data from a whole vineyard, they must be mounted on observational platforms such as satellites, human crewed or remote controlled aircraft, ground-based vehicles, or robots.

According to Poblete-Echeverría, drones represent a radical shift for aerial sensors.

> "We are almost at a moment where remotely piloted aerial vehicles are fully automatic, and we can have excellent resolution with the images we obtain."

Ground-based sensors, on the other hand, can be mounted on tractors or quad bikes and linked to global positioning systems to obtain accurate spatial data. "Robots are coming — it's certain that they will soon be used to perform specific tasks and capture information," says Poblete-Echeverría.

Already, SU's Department of Viticulture and Oenology has collaborated with South Africa's Council for Scientific and Industrial Research to implement a prototype robotic platform specifically designed for vineyards. Called 'the Dassie', the robot trundles up and down the work rows, carrying a suit of sensors to collect data about each vine it passes. This information is fed to a computer programme to evaluate aspects such as canopy growth or the

Prof Carlos Poblete-Echeverría, left, with two of his students, using a drone and 'the Dassie' – a robotic platform designed for vineyards. Photo supplied

temperature and humidity around leaves and grape bunches. In such ways, AI is increasingly being used to comprehend the data extracted from sensors based on observational platforms. Computers are essentially being trained to simulate human reasoning in order to draw conclusions from data.

Poblete-Echeverría is confident about the value of new technologies such as those described above, but cautions that AI "is not magic. We need to follow certain steps to produce correct models, and models should be trained and tested properly before being released to the market".

'Two agricultures'

Wandile Sihlobo, chief economist of the Agricultural Business Chamber of South Africa and a senior fellow in SU's Department of Agricultural Economics, points out that the country's agriculture sector has "grown tremendously" over the past 30 years.

Sihlobo highlights new production technologies and better farming skills as two of the main reasons for the country's increased production levels. However, he argues that "the gains we've seen in agricultural production [...] have not been equitably distributed across the agricultural industry".

In his recent book, *A Country of Two Agricultures*, he writes: "On the one hand, we have a subsistence, primarily non-commercial and black farming segment; on the other, we have predominantly commercial and white farmers."

> These two agricultural segments are linked to the notion of a 'digital divide', which is evident in today's information society. Factors contributing to the divide include access to devices such as smartphones and computers, internet availability and affordability, and digital literacy.

To have an impact on South Africa's non-commercial farming segment, agtech applications should ideally be free of charge, require little data to access, and be easily accessible via the cell phones of subsistence farmers and community gardeners who might not have unlimited access to computers or the internet.

Sihlobo insists that we must never become complacent with the current dualism in agricultural production, and that the "task before us is [that of determining] how to keep growing the sector in a more inclusive and transformative manner". One way to do this is by modernising agriculture through science, technology, and innovation.

Hyperspectral imaging

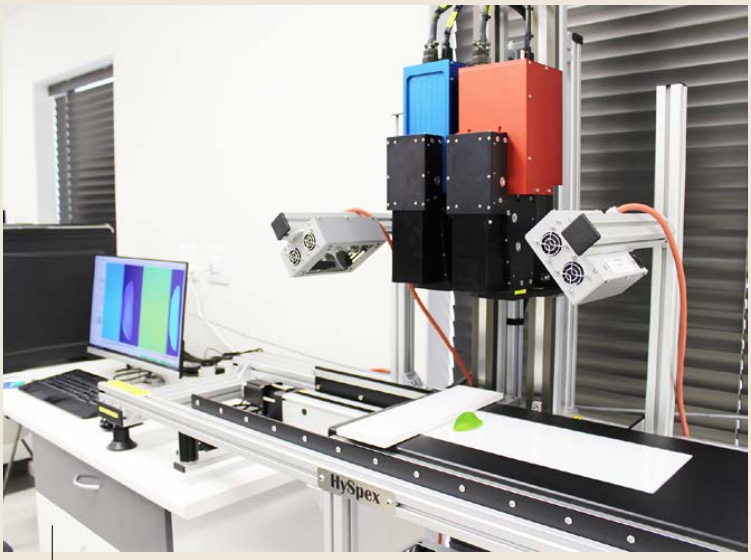
While field analysis on the go is useful, more extensive investigation is sometimes necessary. It is then that a tool such as the HySpex hyperspectral imaging system comes in handy. Housed in the Faculty's Department of Food Science, this system is used in plant pathology studies, as well as food chemistry and microbiology research. Its care has been entrusted to Dr Paul Williams, a data scientist and spectroscopy expert in the department.

Hyperspectral imaging is a technique that combines digital imaging with spectroscopy to capture and analyse reflected light across hundreds of spectral bands, Williams explains.

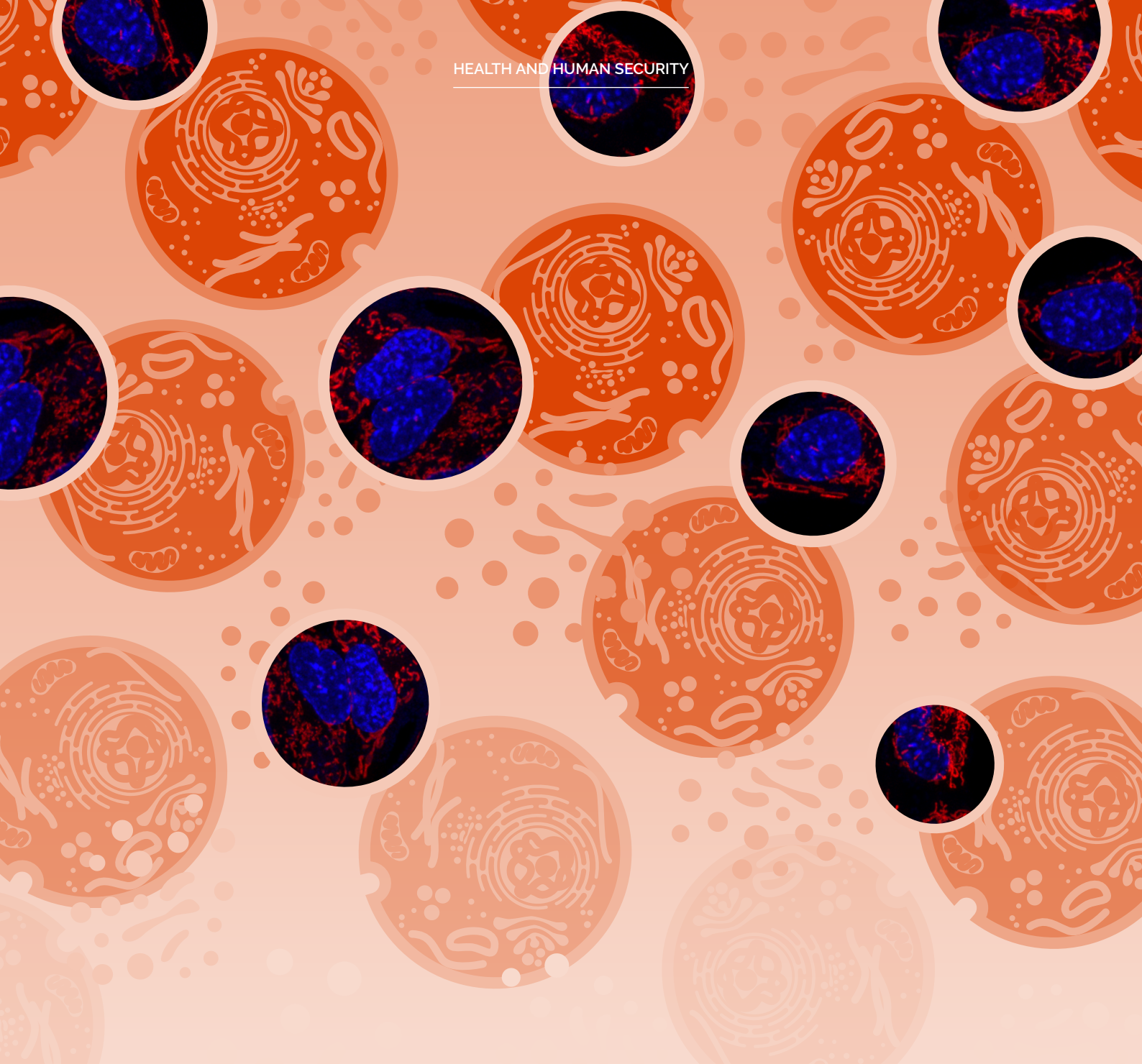
While our eyes typically perceive only the colours red, green, and blue, hyperspectral imaging captures a much broader range of the electromagnetic spectrum, thereby providing a very detailed picture of an object.

Hyperspectral snapshot cameras enable the real-time inspection of crops for the early detection of disease and water stress, and for the analysis of soil quality.

"Hyperspectral imaging is fast, accurate, and allows samples to be analysed non-destructively and non-invasively with minimum or no sample preparation," Williams explains.



SU's hyperspectral imaging system can be used to acquire spectra of samples in the visible near-infrared and shortwave infrared wavelengths. Photo supplied



WIIDA FOURIE-BASSON

NEURODEGENERATIVE DISEASES

ON A CELLULAR LEVEL, AND IN 3D

What if we could tell whether or not a cell is in distress? Or whether the mitochondria in a cell are ‘fit’ or ‘ill’?

 Illustration by Ronel van Heerden

In the context of neurodegenerative conditions, wouldn't knowing that a cell is in distress provide us with an early warning of diseases such as Alzheimer's and Parkinson's? After all, in the case of both these diseases, dysfunctional mitochondria are an early hallmark.

Prof Ben Loos | Photo by Stefan Els

Back in 2015, these were the questions that made two specialists — one in the field of cell physiology and the other an electronic engineer — start discussing challenges in the imaging field and how to better work with three dimensional (3D) images of cell processes.

Eight years and two postgraduate students later, Prof Ben Loos from the Department of Physiological Sciences and Prof Thomas Niesler from the Department of Electrical and Electronic Engineering at Stellenbosch University (SU) can say, with confidence, that they have developed a very finely calibrated method for understanding cellular health.

With this expert pair as study leaders, Dr Rensu Theart developed the mitochondrial event localiser (MEL) as part of his doctoral research on the virtual reality visualisation and analysis of microscopy data. Theart received his PhD in 2021 and is currently a lecturer in the Department of Electrical and Electronic Engineering, where he continues to collaborate with Loos, as well as with the next generation of postgraduate students.

Capturing the elusive

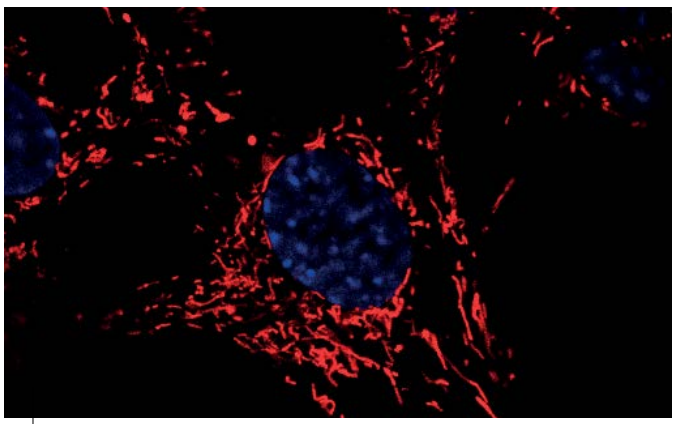
Loos studies the susceptibility of cells to cell death, and the molecular mechanisms that govern this cellular response. He is especially interested in a fundamental cellular stress response termed 'autophagy' (from the Greek word for 'self-eating'). Autophagy is a process by which cells degrade long-lived proteins and damaged organelles (subunits in cells that have a specific function). When dysfunctional, this process leads to early cell death (such as that observed in neurodegenerative diseases, including Alzheimer's and Parkinson's), but it can also assist in keeping the cell alive (as in the case of most cancers).

According to Loos, there are many tools and techniques to assess the morphological features of mitochondria, such as their number, size, and sphericity. "However, none of these methods adequately addresses the dynamic character of mitochondria. Mitochondria are constantly undergoing movement, with parts of any one mitochondrion joining with other mitochondria, or being pinched off from larger mitochondria. Many of these so-called 'fusion' and 'fission' events happen in an instant," he explains.

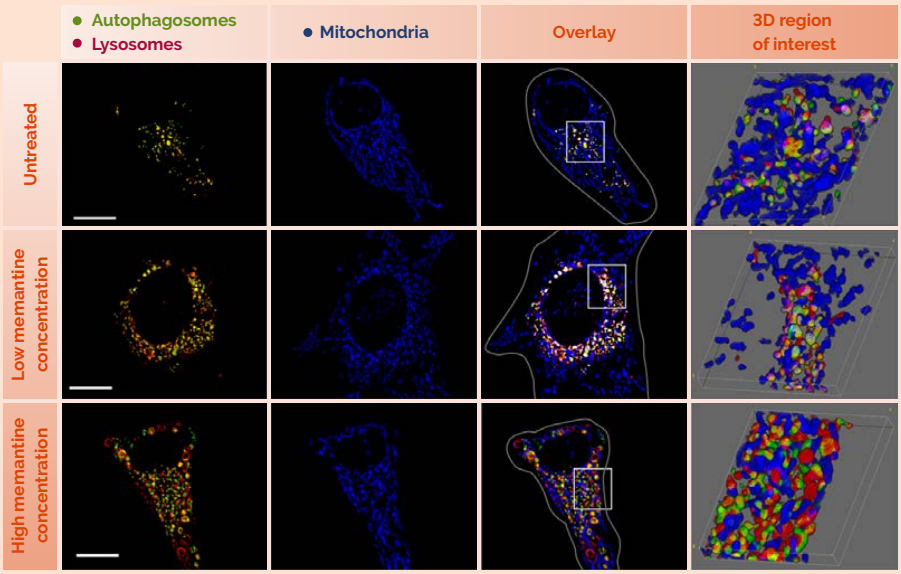
Not only is it now possible to quantify these two types of events, but one can also do it in the 3D space of the cell. For Theart, delving into the difficult topic of neurodegenerative diseases means that his work could one day contribute to treatment that will improve the lives of patients in a very direct way: "Some challenges in biology are difficult to resolve from a purely life sciences approach. The small bit that I can contribute in order to accelerate discoveries through cross-disciplinary research fuels me to continue the work, despite challenges."

Unravelling the mechanics of memantine

Theart recently collaborated with one of Loos' postgraduate students, Dr Sholto de Wet, to better understand, on a cellular level, the effects of the Alzheimer's drug memantine on autophagy and the mitochondrial network. Autophagy is likened to a type of recycling system by which cell components, mainly dysfunctional proteins and organelles, are recycled intracellularly. Memantine is one of the main drugs prescribed for patients with mild to severe Alzheimer's disease. Yet, despite an 8.5% worldwide increase in the use of the drug between 2008 and 2018, uncertainty remain regarding the most favourable treatment concentrations.



A microscopic image of neuronal cells in which the mitochondria have been stained red in order to observe their movement over a brief period of time. The nucleus of each cell has been stained blue to aid in distinguishing between individual cells. Image courtesy of Dr Sholto de Wet



The effect of two different concentrations of memantine on cells. Memantine is one of the main drugs prescribed for patients with mild to severe Alzheimer's disease. Those treated with low concentrations (50 uM) experienced more mitochondrial events (as shown by the presence of more pink and white dots inside the acidic lysosome, indicating that mitochondria are being 'eaten'). At higher concentrations (100 uM), this did not happen to the same extent. The researchers did notice, however, that the 'mouths' and 'stomachs' of the cells were enlarged.

Image courtesy of Dr Sholto de Wet

In his doctoral research, De Wet investigated the concentration-dependent effect of memantine in a neuronal cell model. Intriguingly, he found that low (notably, not high) concentrations of memantine led to the induction of mitophagy, a type of autophagy that targets dysfunctional mitochondria through selective degradation — a process that has been shown to enhance cell survival and longevity.

"This [faster mitophagy] ensures the presence of new and properly functioning mitochondria that contribute towards the cell's energetic state. When higher concentrations of memantine were used, it was noted that autophagy, a pathway responsible for the degradation of proteins, was increased," De Wet explains.

Further research is now needed to apply these findings to more complex model systems, including the brain.

Understanding interconnected intracellular processes

Until recently, scientists studying neurodegenerative diseases mostly focused on the insoluble aggregates of misfolded proteins deposited in regions of the brain that are typically affected in the later stages of such diseases. Now, however, the exact process by which these proteins are degraded inside the cell, as well as the role of mitochondria therein, is gaining increasing interest, De Wet says.

Researchers are now starting to understand that there is an interdependent relationship between three important cell processes (autophagy flux, mitochondrial network function, and lysosomal acidification). De Wet compares these processes to the functioning of a recycling plant: The speed at which a recycling truck is loaded with recyclables and delivered to the recycling plant (the lysosome) is akin to the rate of protein degradation (autophagy flux); the electricity that the plant needs to properly process these recyclables is similar to the energy provided to cells through means of the functioning of the mitochondrial network; and the breakdown of the recyclables is much like the acidification of proteins in the lysosome.

Previously, these processes were studied either separately or only in relation to one other, rather than as three interdependent systems. This new way of thinking allows a much better understanding of the molecular defect that drives neurodegenerative diseases.

De Wet and Loos argue that it is not the insoluble protein aggregates that are the root cause of neurotoxicity but rather the fact that they arise in the first place due to the dysfunctioning of the protein degradation pathway.

Dr Sholto de Wet | Photo by Wiida Fourie-Basson

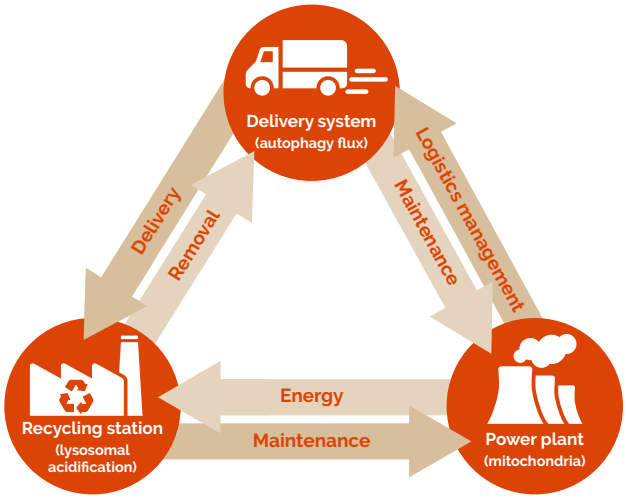
In a co-authored article, De Wet, Theart, and Loos show that the moment the interdependent relationship between the aforementioned three processes is disrupted, the system is thrown out of balance and the problematic proteins aren't degraded. In the case of neurodegenerative diseases, the proteins will continue to be overproduced and interact with different parts of the cell, including the mitochondria, finally leading to cell death if their levels aren't suppressed.

This means that the cell can be protected by targeting any of the three sides of the triangle, for example by enhancing mitophagy. "This is important, seeing as many problematic proteins associated with neurodegenerative diseases have been shown to damage the cell by interrupting mitochondrial activity. Memantine may, therefore, offer an avenue by which the mitochondria that are being interfered with can be removed from the system, possibly along with the problematic proteins," De Wet explains.

"In the context of neurodegenerative diseases, it is known that lysosomes, the recycling stations, don't work properly. This leads to the building up of material that contributes to the progression of the disease.

"In my thesis, we demonstrated that memantine leads to the reacidification of lysosomes following damage to the mitochondria," he adds. "This may have been an indirect effect of mitophagy, but to our knowledge this isn't something that has previously been shown and, as such, deserves attention."

For Loos, their research points to an important mechanism in the working of memantine that has not been described previously: "If exploited in a well-targeted manner, understanding this mechanism may contribute to a new way of thinking about and approaching the treatment of neurodegenerative diseases."



The interdependent relationship between three important processes in a cell — autophagy flux, the mitochondrial network function, and lysosomal acidification — can be compared to the functioning of a recycling plant. | Image courtesy of Dr Sholto de Wet

Health, disability, and neurological conditions

- Neurological conditions are the leading cause of ill health and disability worldwide. The overall incidence of disability, illness, and premature death (measured by disability-adjusted life years) caused by neurological conditions has increased by 18% since 1990.
- According to a recent study, more than 3 billion people worldwide were living with a neurological condition in 2021, with over 80% of neurology-related deaths and health loss occurring in low- and middle-income countries.
- The number of people living with or dying from disorders of the nervous system has risen dramatically over the past three decades, with 43% of the world's population — 3.4 billion people — having been affected in 2021. Researchers say the rise is due to the global population's growth, higher life expectancy, and increased exposure to environmental, metabolic, and lifestyle risk factors such as pollution, obesity, and diet.
- The biggest contributors to neurological health loss globally were strokes, neonatal encephalopathy (brain injury), migraines, Alzheimer's disease and other dementias, and diabetic neuropathy (nerve damage).
- The regions with the highest burden of nervous system disorders in 2021 were central and western sub-Saharan Africa.
- Access to treatment for neurological conditions varies widely: High-income countries have up to 70 times more neurological professionals per 100 000 people than low- and middle-income countries do.

Sources: *The Lancet Neurology*, the World Health Organization, and Eurekalert.org

PTSD

THE BODY REMEMBERS

ENGELA DUVENAGE

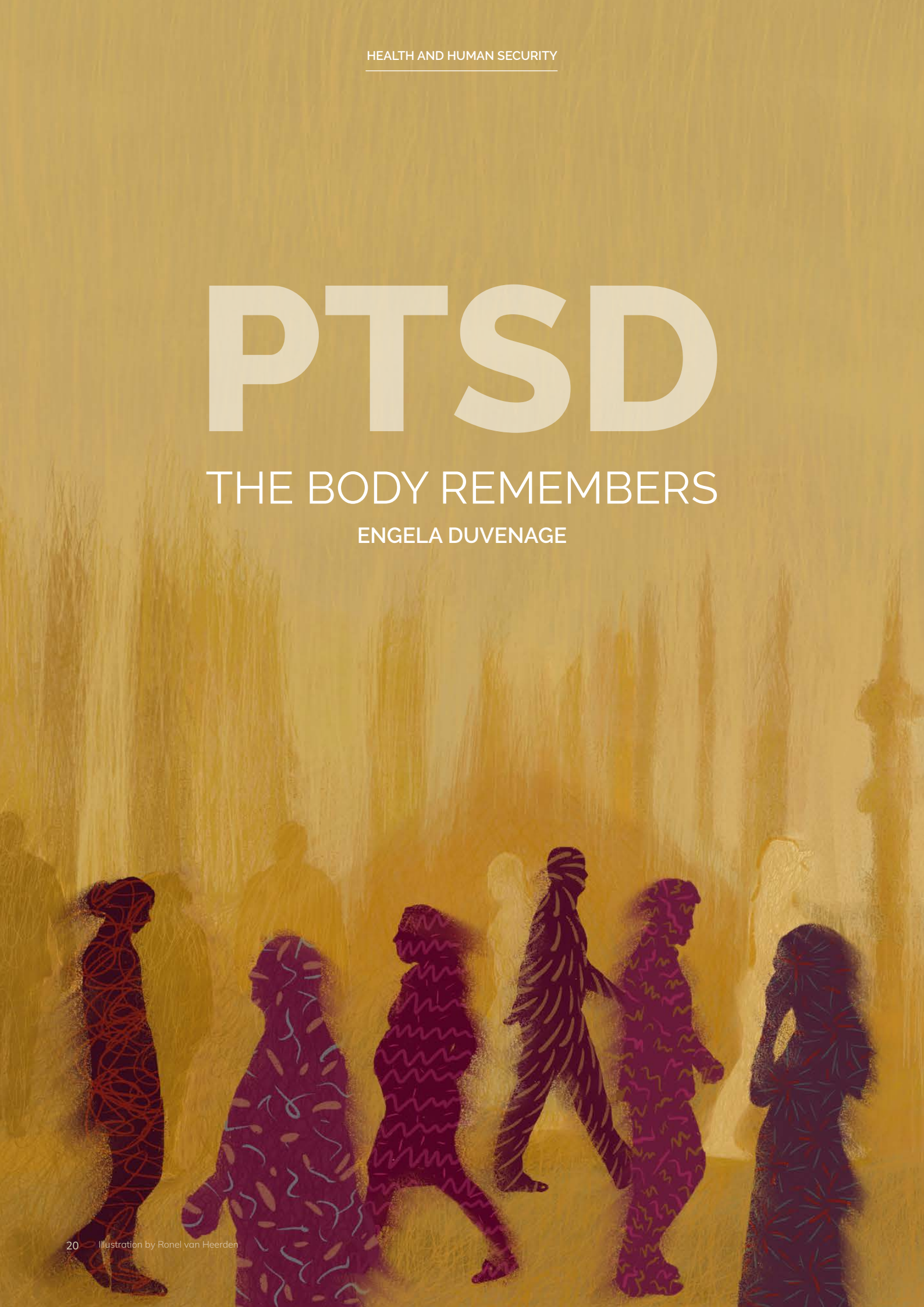


 Illustration by Ronel van Heerden

The lasting effect of a traumatic ordeal not only plays mind games with people who subsequently develop post-traumatic stress disorder (PTSD) — a trauma-induced, often debilitating mental disorder that counts prolonged flashbacks, nightmares, and severe panic attacks among its many symptoms.

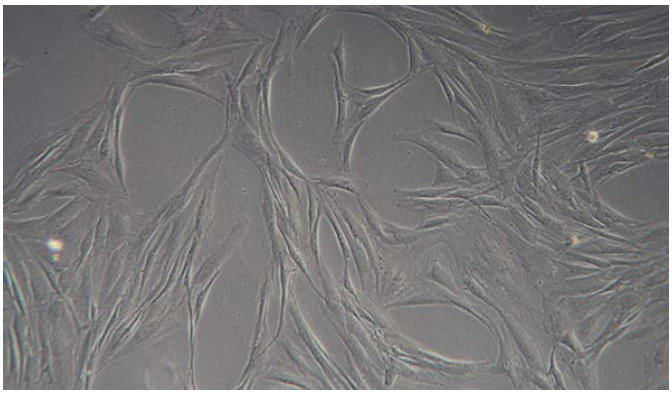
Prof Mari van de Vyver | Photo by Stefan Els

It also leaves physical 'fingerprints' in the body that can be so permanent that it predisposes the individual to chronic metabolic diseases such as diabetes and heart conditions.

This is one of the main findings of a recent study, published in *Biochimie*, by researchers from Stellenbosch University's (SU's) Division of General Internal Medicine, Division of Clinical Pharmacology, and Department of Psychiatry.

Under the microscope, the researchers compared the inner workings of basal dermal fibroblasts, gathered from the skin of 20 people with PTSD resulting from childhood trauma, to those of another 20 people who also experienced such trauma but did not develop the condition.

Fibroblasts are reasonably robust cells that are widespread in all types of body tissue except the brain. These 'connector cells' secrete collagen proteins to support and maintain the structural framework of body tissue. They are activated whenever there is some sort of injury in the body, and are therefore vital to healing and cell regeneration. Basal dermal cells, found at the bottom of the epidermis, produce new skin cells to replace the older ones on the skin surface as they die and are sloughed off.



Fibroblasts, as seen under a light microscope. These robust 'connector cells' are found throughout the human body, except in the brain. | Image courtesy of Prof Mari van de Vyver and Dr Rohan Benecke

"In the resting phase, the fibroblasts of the two groups of people looked the same. However, when primed, the PTSD group's cells did not react when stimulated," says the lead author of the paper, Associate Professor Mari van de Vyver of SU's Department of Medicine. Van de Vyver is also a member of the Experimental Medicine Research Group in the University's Faculty of Medicine and Health Sciences.

> "We found that PTSD, a psychiatric disorder, causes functional blunting of patients' fibroblasts outside the brain. This means that the signalling capacity of these tissue cells are blunted. Patients' fibroblasts therefore seem to be desensitised to environmental stimuli and do not respond as they should," Van de Vyver explains.

The research team also noted that there was less movement of calcium in the cells of PTSD patients. This mineral helps build bones and muscles, and improves signalling between nerves. All body cells use calcium to regulate their activity in response to stimuli.

The researchers believe that the functional blunting of fibroblasts could, at least in part, be caused by this lack of calcium movement.

PTSD: Cause and effect

Changes in cellular calcium signalling or in homeostasis in the body could potentially disrupt normal physiological processes and drive the development of PTSD, says physiologist Prof Carine Smith, leader of the Experimental Medicine Research Group and member of the Department of Medicine.

Prof Carine Smith | Photo by Damien Schumann

The findings in the aforementioned study indicate that even if patients receive successful PTSD treatment, typically through trauma-focused cognitive behavioural therapy and the use of prescribed antidepressants, their bodies might still 'remember' the impact of their traumatic ordeal at a cellular level.

The authors note that the global rise in cases of somatic disease coinciding with mental disorders such as PTSD is, at least in part, exacerbated by a so-called "allostatic predisposition to stress on a cellular level". ('Allostatic' refers to the wear-and-tear impact of chronic stress on the body.) They also state that, as yet, relatively little is known about the effect that PTSD could have on body tissue, despite many other diseases being associated with it.

Prof Soraya Seedat | Photo by Stefan Els

According to an American study, patients suffering from PTSD have a 27% greater risk than others of also suffering from cardiovascular disease, while Scandinavian research shows them to have a 46% greater chance of developing autoimmune diseases.

"It is clear that when it comes to this disorder, it is important to study and treat more than just the brain. PTSD can influence the rest of the body too. We need to do more preclinical and longitudinal studies to confirm the impact of PTSD on body cells, and to establish the point at which the blunting of fibroblasts begins," notes Smith, the lead researcher involved in the *Biochimie* paper.

The samples and clinical data used were initially gathered as part of the South African Medical Research Council's flagship project on the common causes of neuropsychiatric disorders and modifiable risk factors for cardiovascular disease (the MRC SHARED ROOTS Flagship Project). A research grant for the project was awarded to Distinguished Professor Soraya Seedat of SU's Department of Psychiatry.

Under Smith's guidance, the Experimental Medicine Research Group is studying how and why the body's regulatory (nervous, endocrine, immune, and microbiome) systems become maladapted when a patient is exposed to too much stress and inflammation.

More specifically, Smith's group is investigating the role of regulatory system maladaptation in chronic inflammatory conditions such as rheumatoid arthritis, systemic lupus erythematosus, autism spectrum disorder, and PTSD. They use various research models — from cellular to zebrafish, rodent, and human models — to perform disease modelling aimed at therapeutic target identification, drug discovery, drug delivery, and efficacy testing.

Smith's passion for contributing to research sustainability in Africa led her to establish the SU Zebrafish Unit, which she now directs. More recently, she helped set up the Zebrafish African Network, through which she hopes to build increased capacity for zebrafish-based research on the continent. Smith is also the vice-chair of SU's Research Ethics Committee: Animal Care and Use.

The SU Zebrafish Unit, hosted within the Department of Medicine, has been involved in numerous recent projects, including ones on the anxiety-busting properties of green rooibos tea, the adverse effects of ivermectin use, and the influence of Sceletium (a succulent plant, *Mesembryanthemum tortuosum*, also known as 'kanna') on anxiety-like behaviour.

The 'invisibly wounded'

Working in the field of traumatic stress is like "working with the invisibly wounded who walk a resiliency-vulnerability tightrope in the early and late aftermath of exposure to horrific traumatic events". This is how Distinguished Professor Soraya Seedat, executive head of the SU Department of Psychiatry, describes efforts by clinicians and researchers to better understand the roots of and possible treatment options for PTSD.

Until 2022, for three cycles, Seedat was head of the South African Research Chair in PTSD. She is currently the director of the South African Medical Research Council's Unit on the Genomics of Brain Disorders.

Seedat describes PTSD as a mental disorder "unique in the psychiatric diagnostic nomenclature" because it specifically develops after exposure to an external traumatic event. "It is a multifactorial, neurobiologically and phenomenologically complex disorder characterised by pre-existing risk factors that predate exposure to a traumatic event," she adds.

The contemporary understanding of PTSD, Seedat says, is that it is essentially "a disorder of fear extinction". (Extinction learning is used as part of exposure therapy, which is commonly used to treat pathological fear. During extinction, individuals learn a new association with the given stimulus that inhibits the expression of the original fear memory.)

"Fear and anxiety in individuals who meet the criteria for the disorder do not extinguish over time, as reflected by persistent aberrations in pathophysiology, symptomatology, and behaviour.

"There is accumulating evidence that early therapeutic manipulation of extinction can interrupt fear and memory consolidation, thereby attenuating trauma memories and reducing the risk for the subsequent development of PTSD. Thus, the influence of traumatic stress on memory formation is a critical nexus in the genesis of PTSD in individuals exposed to traumatic events."

Although it affects people worldwide, PTSD is especially common in areas with a high prevalence of interpersonal trauma, war, and armed conflict, such as sub-Saharan Africa. Moreover, earlier research by Seedat has shown that, compared to men, women have double the risk of developing PTSD, as well as a greater symptom burden, a longer course of illness, and poorer quality-of-life outcomes.

"The preponderance of PTSD in women reflects a convergence of biological, psychological, social, and cultural factors, such as culturally influenced gender roles that may impact on PTSD symptom expression in women," she notes.

An ethical framework for treatment

There is a significant body of research on the preventive science of PTSD, and on the ethical quandaries of memory modulation. According to Seedat, the wider ethical issues around PTSD prevention must be addressed through the development of consensus bioethical frameworks.

To this end, she believes that research on the therapeutic prevention of PTSD should include the dimensions of self-determination, personal liberty, and informed consent for participants. It should be beneficial and non-maleficent, with cases being treated in a professional, confidential, and socially responsible manner by the practitioners involved.

In numbers

- Globally, around 70% of individuals experience at least one traumatic event in their lives, the majority of such events occurring early in life.
- While the vast majority of adults and youth exposed to a traumatic event will recover spontaneously, about a third will experience enduring PTSD symptoms over many years. In multi-national population surveys from the World Mental Health Surveys Initiative, the cross-national lifetime prevalence of PTSD among trauma-exposed adults was found to be 5.6%.
- In sub-Saharan Africa, the overall pooled prevalence of probable PTSD cases among adults has been estimated at 22%.
- There is an extremely high prevalence of PTSD among internally displaced people in sub-Saharan Africa, according to a recent Ethiopian study. The prevalence ranged from 12% in Central Sudan to 86% in Nigeria. Eight of 11 studies found a prevalence greater than 50%. These prevalence rates are much higher than those in similar studies conducted in other regions.

Sources: World Health Organization, Prof Soraya Seedat's thesis, and the Joint Data Centre for Forced Displacement

ENLARGING THE GAZE ON INFANT MENTAL HEALTH

UFRIEDA HO

Illustration by Roulé le Roux

Milk teeth peeping through and those first wobbly steps are typical milestones that parents and caregivers look out for in infants. But researchers say there's more to take note of and good reasons for it too, especially when it comes to mental health benefits.

Dr Berna Gerber and Dr Anusha Lachman | Photo by Stefan Els

The first 1 000 days of life — from conception to about two years of age — are critical in a child's development. During this time, the brain's 'wiring' develops at a staggeringly rapid rate: First, nerve cells (or neurons) migrate and grow to become the structures that form synapses; next, the synapses connect to form neural pathways and circuits.

Researchers have long known that this so-called 'golden period' offers an ideal window for increased support and intervention toward optimal foetus and infant development. Nutrition and stimulation have long been considered critical to supporting brain development for a stronger metabolism and immune system. But as researchers delve deeper into the complexity of neural pathway development, they've started homing in on mental health. Thus far, this research has yielded a wide range of practices that pregnant couples, parents, caregivers, and healthcare professionals should be aware of.

This call for early intervention is based on a growing body of research that shows that the architecture of certain mental health disorders seen in adults is cemented long before adulthood.

A starting block

Stellenbosch University (SU) recently launched the Early Intervention and Child Mental Health Public Square. The latter recognises the urgency of responding proactively and innovatively to this new information.

Dr Berna Gerber is a co-lead of this health sciences public square. "The square is about moving outside of one's own discipline into a shared space and also about addressing real-world problems and making a difference," she says.

The square aims for research to translate into impact, especially in the form of support for children and persons with disabilities (including those who have or are at risk of developing mental health issues). In addition, it hopes to raise the call for interventions that may help prevent certain mental health and developmental problems as an infant grows.

"Our public square is directed at the health and well-being of young children. It also considers what happens during pregnancy, and even before pregnancy, because so many things in one's life depend on factors like what was going on in your parents' lives before you were born — even before you were conceived," says Gerber.

Her work in the Division of Speech-Language and Hearing Therapy examines the connection between learning and communication in infants, and how this affects them as they grow. She also focuses on supporting mothers of preterm babies, and on early communication development in such infants.

She says: "We know that children who may be at risk of mental health difficulties may also be at risk of other developmental delays, including delays in growth, learning, and communication, and vice versa."

Much is still unknown, however, about the effect of infants' experiences and emotions on their development. To complicate the matter, although many find it obvious to think of infants as "feeling, thinking, experiencing, and sensitive" young humans, it simply isn't a universal concept, Gerber says. This means that the way that people interact with infants doesn't follow a single standardised approach.

Gerber illustrates this point with the fact that some parents believe a child should not be spoken to in so-called 'baby talk' or, in certain cultures, spoken to at all. Also, not so long ago, it was considered acceptable for corporal punishment to play a role in the disciplining of children. And, she says, until quite recently, infant pain was not a serious consideration in medical care or research.

"I think, though, that awareness is shifting; societies are evolving. But we really are just at the starting point when it comes to understanding how important it is to spotlight the needs of infants, including their mental health needs," she says.

The point, however, is simply to start, Gerber says. According to her own research, parents and caregivers should be encouraged to realise the benefits of being fully present when spending time with

a baby or small child: "We use programmes that teach caregivers to 'observe, wait, and listen' or 'watch, wait, and wonder' when they are interacting with a baby. Of course, we are competing against things like screen time and being in a perpetual rush, but nothing can make up for attention, reciprocity, or nurturing between a baby and its primary caregiver. Equally important is ensuring that caregivers are supported and that their most important needs are met."

Local data for local good

The public square approach emphasises the need to advance research and the collection of data deemed relevant to and reflective of South African contexts.

Prof Heather Brookes, a member of the public square, heads the Child Language Development Node of the South African Centre for Digital Language Resources (SADiLaR), housed at SU. Her current research shows just how necessary more nuanced research and data are if we want to understand the interaction between cognition, communication, and behaviour within the first days of life.

What we know, Brookes explains, is that there is an interplay between language development and cognitive development. As such, language development is a predictor of things such as behavioural development, success at school, and mental health challenges.

To this end, Brookes and a team of other scientists have adapted a developmental assessment tool to establish gesturing, communication, and early word formation norms for South Africa's 11 official spoken languages. The South African Communicative Development Inventories project gathers data on children between the ages of 8 and 30 months through questionnaires completed by parents and primary caregivers.

Prof Heather Brookes | Photo by Stefan Els

The large data set will be developed into a comprehensive inventory that promises to be a game changer for the field, says Brookes.

"Knowing what typical development in our languages looks like will mean early detection and intervention in tackling language delay that might otherwise result in learning and mental health challenges further down the line."

In the development of the inventories, the researchers are deliberately enrolling parents from both rural and urban households to report on their children's first gestures, words, and sentences. Brookes says this is necessary to ensure that the developmental tool takes into account South Africa's socioculturally and geographically diverse, multilingual society.

The project is six years in the making and is now aimed at collecting data from 28 000 households that represent all 11 spoken languages. Globally, it will be one of the largest surveys of child language development yet. As huge and seemingly insurmountable as the task may appear, it is essential — relying on western tests and norms in our African context poses inherent problems, Brookes says.

"Using a British measuring tool, for instance, could lead to South African children being underdiagnosed or overdiagnosed because of the tool not factoring in our linguistic and cultural differences," she explains.

One of the aims of the project is to create a free and anonymised online child language database and assessment checklist, in collaboration with SADiLaR.

Academic expertise gets back to basics

Prof Xanthe Hunt is a faculty member in SU's Department of Global Health. She is also the mental health lead at the Africa Health Research Institute, and a part of the Early Intervention and Child Mental Health Public Square. Her work focuses on ways to strengthen mental health frameworks and to ensure more appropriate interventions toward systemic changes that will prevent mental health care — especially that for adolescents — being pushed to the margins by an overburdened health care system.

For Hunt, the public square offers an opportunity for a collective of specialists to reflect more deeply on how to translate their individual expertise into maximum impact. She believes it begins with acknowledging the blind spots within academia.

The pursuit of academic specialisation can result in careers being "siloed", she argues. As such, she believes generalist scientists can play a critical role in bridging discrepant pieces of research.

Such a generalist approach will allow people to see a much bigger picture and tie together seemingly disparate strands of information, she says. Moreover, she is of the opinion that

Prof Xanthe Hunt | Photo by Samora Chapman

understanding different perspectives will reveal to researchers that mental health issues are not separate from, for instance, socioeconomic and environmental factors, or generational trauma. Growing up in communities that have fallen through the cracks and suffer high degrees of violence, crime, and drug misuse, for example, can significantly impact mental health. Even babies are affected by living in environments marked by persistent fear and anxiety, Hunt explains.

"We have to recognise that ecosystem change is necessary in the fields of child development and public health [research] and this does require generalists, or at least people with a broad enough perspective to foster interdisciplinarity."

She adds that inculcating a generalist approach means science and research can take up more seats at different tables. This is essential to growing awareness, strengthening advocacy, and affecting change among a range of actors from government officials, policymakers, civil society members, and community health workers to everyday moms and dads.

Understanding individual, community, and household needs, Hunt says, enables the implementation of interventions that are more relatable and therefore more impactful than they would otherwise have been. She argues that it's important for programmes and interventions to "meet people where they are and not make assumptions".

"We need to understand that someone who struggles with emotional regulation as an adult may not have had the opportunity for co-regulation in a responsive relationship with their caregiver when they were an infant," she adds. We must also realise that to interrupt intergenerational cycles of hurt and harm, we need to focus on the parent-child dyad."

Growing the knowledge network

Dr Anusha Lachman is a senior lecturer in psychiatry and head of the Clinical Unit of Child Psychiatry at Tygerberg Hospital. She has been involved in implementing a graduate programme focused on infant mental health through an interdisciplinary training infrastructure. The first cohort of master's students graduated in 2017 and included psychologists, nurses, dieticians, and doctors. To date, 13 students have graduated from the programme.

Over the years, as the programme grew, limited supervision capacity meant that not all the applicants could be accommodated. Lachman says the demand has been encouraging, but also shows how much more ground needs to be covered if infant mental health is to become a part of the mainstream healthcare framework, and if the growing demand is to be met.

Fortunately, she says, the challenge of limited capacity to reach more students presented an opportunity for creative problem-solving through different interventions. The first intervention enlisted the help of the MPhil graduates. "By using our students, we were able to run outreach workshops that served to upskill clinicians on the ground, and to support their education and training.

"Having insufficient capacity also forced us to think creatively around ways to make the information and the field in general more accessible to clinicians, allied health professionals, and educators. This resulted in the creation of our first online short course on infant mental health, which was launched in 2022 and has been offered twice since," Lachman says.

By offering the course on an online platform, which continues to grow in popularity, students from beyond South Africa's borders are now able to access the training. "This has been a huge step for us toward making infant mental health in Africa more accessible," Lachman says. The square may still be taking baby steps toward its ambitions, but each one of them is moving the initiative steadfastly forward.

Scientists collaborate in public squares

SU's Public Squares initiative is a new research development programme that was launched in 2024. In these exciting spaces, our researchers interact, brainstorm fresh ideas, develop novel focus areas, and become equipped with novel research methodologies, public engagement tools, budgeting expertise, and grant-writing skills to advance their careers and make a meaningful impact on society.

SU currently has 11 public squares, selected on grounds of their ability to address some of society's most pressing challenges. These squares capitalise on SU's unique research expertise and location, and on the University's potential to strengthen the United Nations' Sustainable Development Goals and the African Union's Agenda 2063.

Read more at https://www.sun.ac.za/english/research-innovation/Research-Development/Pages/public-squares.aspx.

THE (SUSTAINABLE) POWER OF THE PUBLIC PURSE

ANÉL LEWIS

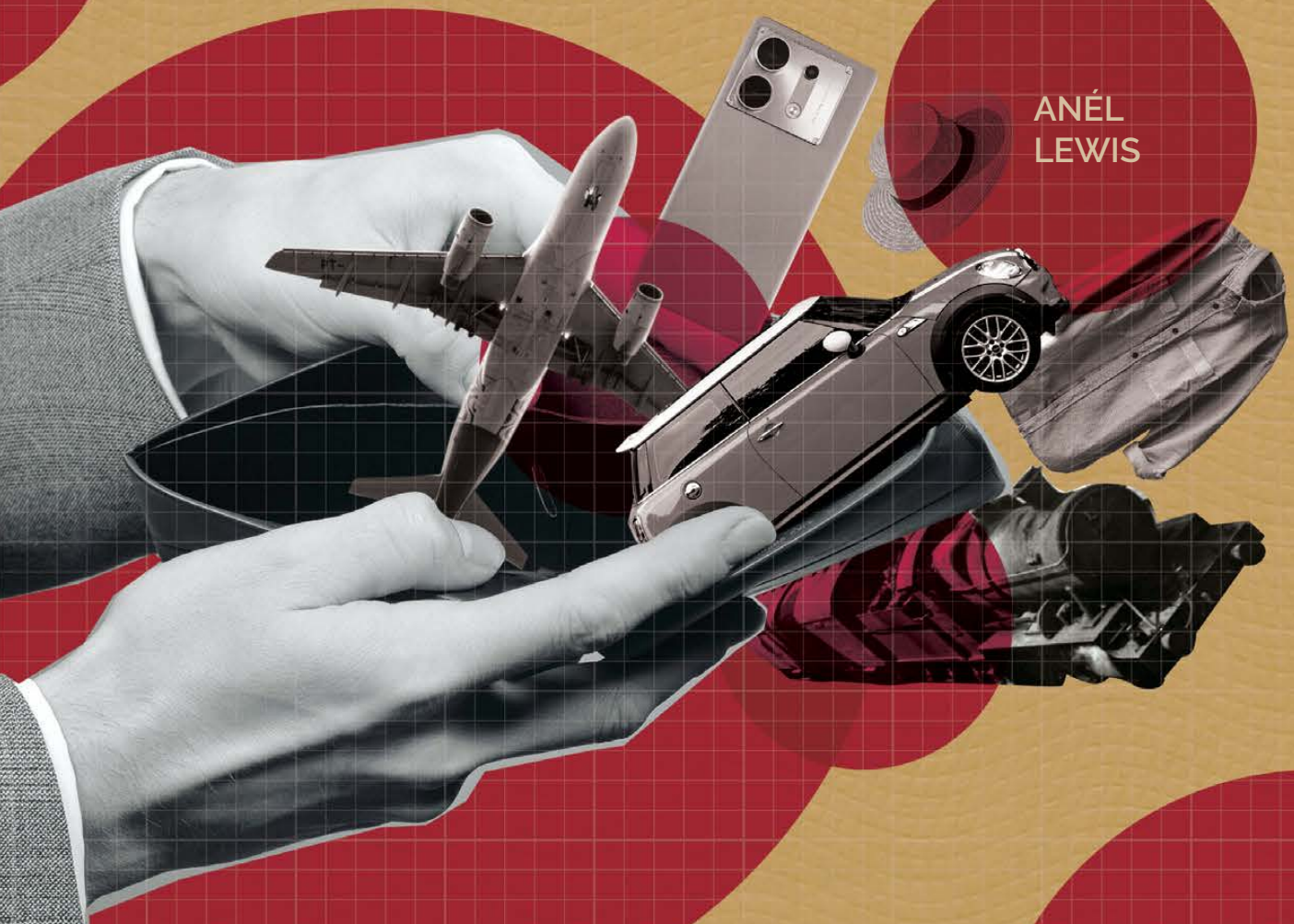


Illustration by Ronel van Heerden

Public procurement is big business. Globally, governments spend around USD13 trillion on the procurement of goods and services each year. In South Africa, this government expense amounts to almost R1 trillion annually — around 12% of the country's annual gross domestic product.

Prof Geo Quinot | Photo by Stefan Els

According to Prof Geo Quinot of Stellenbosch University's (SU) Department of Public Law, public procurement is the world's single largest commercial activity. He points out that the United States federal government is the world's biggest consumer by far, with clothing, food, paper, and electronics topping the procurement list of consumer items in terms of both volume and value.

Apart from its economic burden on the state, public procurement is also responsible, be it directly or indirectly, for a significant portion (15%) of global greenhouse gas emissions, according to research by the World Economic Forum.

It is an area of public administration that is highly regulated. "Unlike you and I who can buy whatever and however we want, the state does not have that freedom. It is bound by legal rules around who buys what and how," says Quinot.

As the director of the multi-institutional African Procurement Law Unit (housed at SU), he focuses much of his efforts on promoting research on public procurement regulation on the continent.

The state as driver of sustainability

When public procurement laws are clear and enforced, they can help governments free up money and create jobs, support private businesses, and improve service delivery.

Moreover, the fact that public procurement occurs within a highly regulated environment presents an opportunity for it to be used as an instrument for realising sustainability as a policy objective, says Quinot. "When one starts looking at ways in which to change market behaviour on both the supply and demand sides toward a more sustainable approach, the intersection between the market and the state — as the biggest market player — becomes an important site of engagement."

In an era defined by environmental degradation and climate change, the role of governments in promoting sustainability has become crucial. The sheer scale of government purchasing gives it the potential to shape markets, encourage responsible business practices, and drive sustainability across industries.

Governments could have a significant influence on industries that are heavily dependent on public spending. Public procurement activities produce seven times more greenhouse gas emissions than the entire global aviation industry. Up to 75% of these emissions stem from the activities of only six industries: defence and security, waste management services, transportation, construction, industrial products, and utilities.

To illustrate how a procurement decision can influence consumer behaviour, Quinot refers to the choice of many public authorities, worldwide and in South Africa, over the last few years to stop buying incandescent and regular fluorescent light bulbs. Naturally, because of the higher price of more energy-efficient options such as light-emitting diode (LED) bulbs, there was initial resistance from consumers to do the same, says Quinot.

But, he says, when you get the state to say that they are committed to this, they see the long-term policy objective, and they are willing to pay for it, the effect is that of changing the demand for alternative, greener options overnight. In turn, this impacts on both the cost and the availability of these options to consumers at large. Eventually, they become the dominant options in the market, displacing the old, energy-inefficient ones. In this way, public procurement becomes one of a range of mechanisms that the government can use to realise its sustainability objectives.

Quinot says his interest lies in understanding how the law should be applied to make sustainability one of the policy objectives of public procurement.

The global north versus the global south

In a co-authored article on the concept and effects of sustainable public procurement, Quinot notes that sustainability has long been little more than a 'buzzword' or 'fuzzy concept'

interpreted differently by government agencies, political leaders, and interest groups.

It is only recently that environmental considerations have started to feature in public procurement objectives. This is more prominently the case in the northern hemisphere, particularly in Europe where the link between the environment and procurement is better established. In contrast, in sub-Saharan Africa the focus has been primarily on the link between procurement and social objectives such as wealth redistribution, opportunities for small businesses, gender equality, and job creation.

However, since the adoption of the United Nations' 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs) by governments worldwide, there has been a noticeable shift towards a combined perspective. It's no longer environmental, or economic, or social considerations that must be taken into account during procurement, but environmental, and economic, and social ones, says Quinot. "The trick now is to try and balance these considerations so as to get to a point where we talk about sustainability as an [overarching] objective as opposed to environmental, social, and economic objectives. They're inextricably linked."

Adding legitimacy to scholarly claims that sustainability is integral to public procurement is the inclusion of the latter in the foundations of the SDGs. Goal 12 focuses on ensuring sustainable consumption and production patterns, and explicitly states that governments must support sustainable procurement policies.

> "Governments need to implement and enforce policies and regulations that include measures such as setting targets for reducing waste generation, promoting circular economy practices, and supporting sustainable procurement policies," says Quinot.

The SDGs have liberated public procurement from the Bretton Woods and Washington Consensus notions of trade as the only path to development, he emphasises. This is not to say that the adoption of a novel approach to sustainable public procurement has been without its challenges. "When you bring policy into the mix, you must sacrifice some [level] of competition. The idea of public procurement for policy is often in conflict with competition. However, since the adoption of the SDGs, sustainability and not trade has become the holy grail of public procurement."

Procurement by design

By far the biggest substantive point of contention in recent deliberations on South Africa's new *Public Procurement Act* (No. 28 of 2024) has come from the chapter dealing with preferential procurement, Quinot says. "The debate across the political spectrum has been around how to build social policy — wealth redistribution — into public procurement. Some role players insisted that race should remain the criterion, while others supported class." Moreover, the act does not deal with the pertinent question of whether there should be a preferential premium for this policy, he says. "How much more should you pay for an item if there is a social policy objective built in?"

These issues highlight the importance of designing laws that make it possible to include policy objectives into public procurement. "The design, for me, is the interesting part. How do you design a system that will deliver on this? It becomes interesting when you consider other mechanisms as procurement criteria, not just race or wealth redistribution," says Quinot.

He adds that it's important to consider the sub-Saharan African context when designing procurement systems, as "there are very important distinctions between our public administrations and those of Europe, for example".

Take digital tools as illustration: Although they work well in supporting sustainable public procurement, many local municipalities simply don't have access to resources such as these. In places that don't even have a reliable electricity supply, it is unrealistic to expect smaller players to upload large tender documents onto a platform that may or may not work on any given day, Quinot argues. "We simply don't have the digital depth that many other systems do." While there are certainly practices that work elsewhere, one must always ask whether they translate into the local reality, he emphasises.

Food for thought

To illustrate how sustainability can be incorporated into public procurement, Quinot references his work with the United Nations' Food and Agriculture Organization (FAO) on public food procurement for school feeding schemes. Regarding the FAO's pilot projects, he says: "It is astounding to see how you can connect dots across many different fields. In Ethiopia, for example, they have shown how various government departments — including those for education, health, and agriculture — as well as local subsistence farmers and small businesses can work together. So, you are rewarded with not only the substantive outcomes on half a dozen different policy objectives, but the way in which the procurement process works is also sustainable."

As an added bonus, this approach also indirectly reduces the risk of the procurement process being abused, he adds. "Now, when the children show up at school and there isn't a meal, it's not a matter of a bad contractor somewhere not doing their bit. It's the mothers and fathers of that very community. So, that farmer or the small business preparing the food internalises the cost of non-performance." He goes on to explain: "If it's my own child I'm feeding, and I'm known in the community, why would I be corrupt?" Quinot describes this kind of alignment between the regulatory instrument and the objective, with a built-in mechanism to minimise corruption, as "a thing of beauty".

On your marks

The 2024 Olympic and Paralympic Games in Paris present a good example of how a responsible procurement strategy can help make large events more sustainable. With the aim to reduce their carbon footprint by 55% compared to the 2012 London games, and to be the first international sporting events to achieve carbon neutrality, the Paris games adopted a comprehensive purchasing strategy. The latter saw all procurement contracts structured around a commitment to five actions that drive environmental and social innovation.

> Another one of the ways in which the events reduced their negative environmental impact was by prioritising renovation over new construction — 95% of the buildings in the Olympic Village were existing, repurposed ones.

Although many of the socially responsible, green, and circular economy public procurement targets were met, a recent report by the international network RREUSE states that there are still barriers to leveraging public procurement for environmental, climate, and social benefits. For example, more than half of all public tenders in the European Union still use lowest price as the only selection criterion.

The future of public spending in South Africa

The *Public Procurement Act* (No. 28 of 2024) standardises procurement practices across all organs of state. This new legislation states that it will "promote innovation, sustainable development, and the environmental rights in section 24 of the Constitution".

This explicit mandate for the pursuit of sustainable public procurement is meaningful, says Quinot. "Internationally, research has shown that the presence or absence of an explicit legislative mandate for sustainability is a major factor in the uptake of sustainable public procurement."

For example, UNEP's *Sustainable Public Procurement 2022 Global Review* reports that policy commitments, goals, and action plans, as well as mandatory sustainable procurement rules or legislation are the top drivers of sustainable public procurement among the countries surveyed. Conversely, a lack of mandatory sustainable procurement rules or legislation was cited as the second biggest barrier to the implementation of sustainable public procurement.

"It follows that the inclusion of sustainability in our new legislation is a critical first step toward greater inclusion of sustainability considerations in our public procurement practices," Quiniot says. He adds that the next step is to define regulations under the new act that will give it substance.

The act also aims to address the widespread corruption in public procurement, as highlighted in the findings of the Zondo Commission of Inquiry into allegations of state capture. The act sets up a public procurement office under the National Treasury that can issue binding instructions to all organs of state, excluding municipalities.

Although the new act is but one part of the bigger sustainable public procurement picture, it is a useful tool in ensuring a connection between policy decisions and outcomes, concludes Quinot.

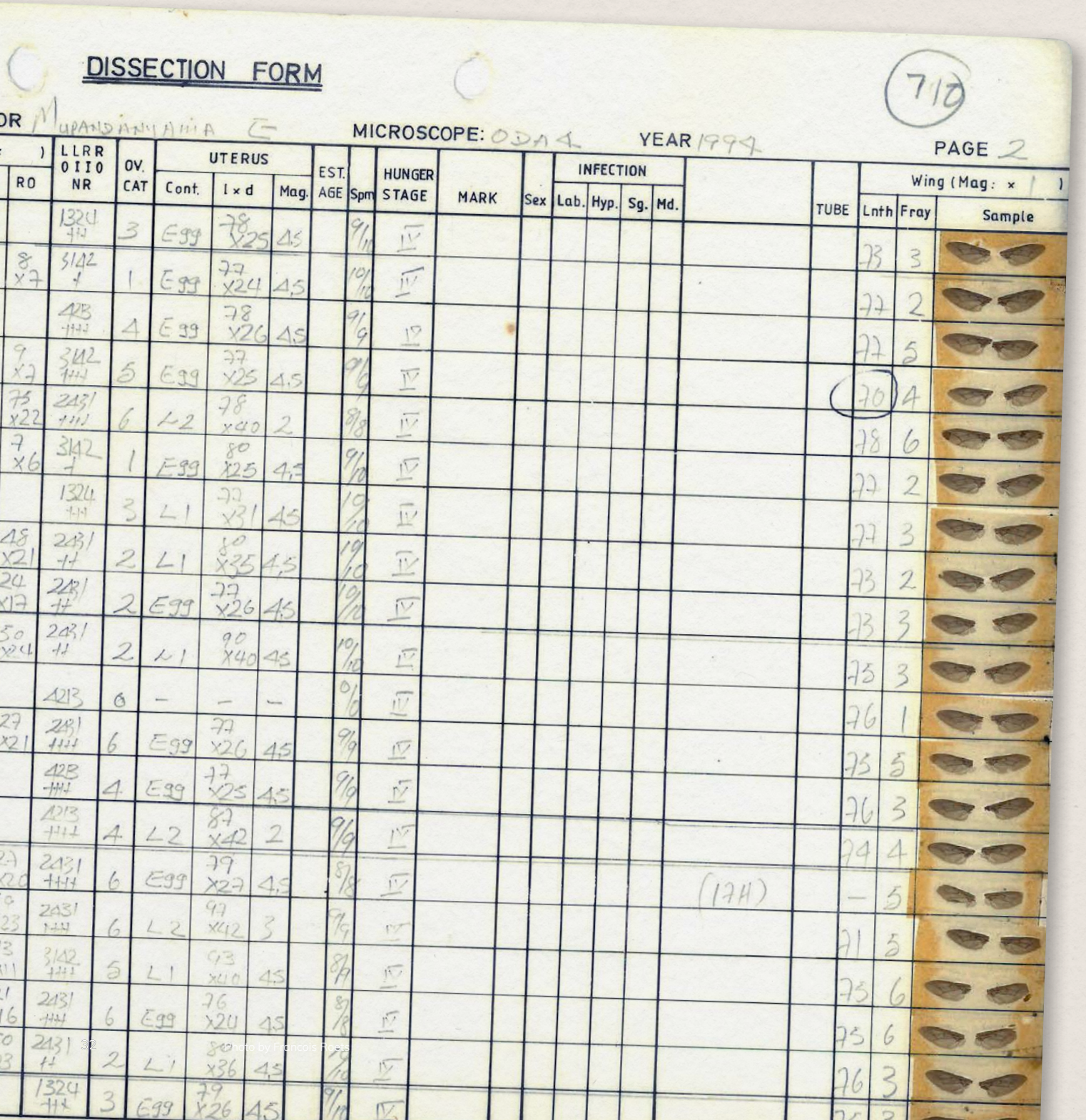
Greening healthcare

Closer to home, the George Regional Hospital in the Southern Cape recently incorporated environmental objectives into its procurement processes. This hospital is one of three institutions nationally that were identified to pilot the Global Green and Healthy Hospitals carbon footprint tool, designed by the organisation Health Care Without Harm. This tool made it possible for the hospital to measure its carbon footprint across its supply chain.

The case study revealed some of the challenges that the healthcare facility faced. For example, suppliers were hesitant to get involved in the project and many assumed more sustainable options would not be cost effective. But there were also many positive outcomes, including the identification of 14 green suppliers with 100% recyclable packaging and a reduced use of harmful chemicals.

TSETSE FLIES
IN THE TIME OF CLIMATE CHANGE
WHAT MACHINE LEARNING PREDICTS

WIIDA FOURIE-BASSON



Modern machine learning methods may be key to unlocking valuable insights from a dataset of over 200 000 tsetse fly wings, collected during an 11-year study carried out at the Rekomitjie Research Station in the Zambezi Valley, Zimbabwe.

Emeritus Professor John Hargrove in front of a part of the Rekomitjie dataset stored in the director's office at the SACEMA, hosted at SU. Photo by Wiida Fourie-Basson

This invaluable dataset may hold the answers to what has caused the dramatic collapse of tsetse fly (*Glossina pallidipes*) populations in the valley over the past 30 years, and whether we'll be faced with their possible re-emergence in areas such as the Kruger National Park (KNP) in a warmer climate.

Guardian of this treasure trove of biological data is Emeritus Professor John Hargrove, founding director of the South African Centre for Epidemiological Modelling and Analysis (SACEMA), hosted at Stellenbosch University (SU).

Between 1969 and 1999, Hargrove worked as a research scientist at Rekomitjie alongside field biologist Dr Glyn Vale. Through his groundbreaking work on tsetse flies, Vale paved the way for the design of a prodigious number of innovative field experiments that sparked a revolution in researchers' understanding of tsetse fly biology. Still working in Zimbabwe today, Vale is a SACEMA research associate. Together, the pair continues to analyse and publish papers based on the tsetse fly dataset.

Why is the Rekomitjie dataset so special?

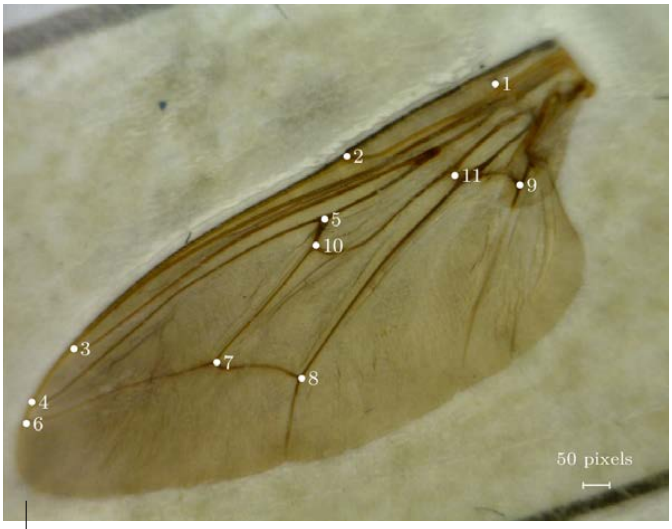
A 2020 paper describes the Rekomitjie records as "one of the most comprehensive longitudinal datasets of tsetse fly count data available to date". Apart from the over 200 000 tsetse fly wings, it also contains ovarian dissection data from more than 180 000 female tsetse flies, nutritional data from 40 000 tsetse flies, and catches from more than 10 sampling systems used since 1960. There are also valuable temperature, humidity, and rainfall records, as well as other meteorological data, collected from the same area since 1959.

So, what can the Rekomitjie dataset tell us about what to expect from a warmer climate? Unlike mammals and birds, insects such as tsetse flies cannot regulate their own body temperature. As such, their rates of development and mortality are strongly influenced by environmental temperatures. Pupae cannot survive at sustained temperatures below 16 °C or above 32 °C.

A 2018 study, based on 27 years of data from Rekomitjie, suggests that temperature increases over the last three decades have already caused major declines in tsetse fly populations in those areas where they traditionally occurred. The study was based on laboratory and field measures of fly densities taken since the 1990s, and nearly continuous records of climatic data collected since 1975 by the Rekomitjie researchers.

Catches of tsetse flies from cattle in Zimbabwe's Mana Pools National Park have declined from more than 50 flies per animal per catching session in 1990, to fewer than one fly per 10 catching sessions in 2017. Since 1975, mean daily temperatures in the study area have risen by nearly 1 °C. In November, the hottest month, this number is almost double.

Scientists are now trying to understand how increases in temperature may change the distribution and relative abundance of tsetse flies across Zimbabwe and neighbouring countries.



The numbered points in white on this image of a tsetse fly wing indicate 11 landmarks that may be used to compute the length, width, and various other shape measures of the wing. | Image courtesy of *PLOS Computational Biology*

Tsetse flies are blood-feeding insects that transmit trypanosome pathogens, which cause sleeping sickness in humans across sub-Saharan Africa. Without treatment, the disease is fatal. In livestock, parasites of this genus cause nagana. | Photo by Judy Gallagher

Hargrove says the effect of recent and future climate change on the distribution of tsetse flies and other vectors is poorly understood. (Vectors being organisms that transmit a pathogen, disease, or parasite from one animal or plant to another.) "We don't know, for example, whether the resurgence of malaria in the East African highlands in the 1990s was caused by rising temperatures or by increasing levels of drug resistance and decreasing control efforts. In general, the ways in which climate change will affect the spread of infectious diseases in sub-Saharan Africa are poorly understood because of a lack of empirical evidence."

He regards the 2018 study mentioned above as one of the first to indicate a link between higher temperatures and an increased susceptibility in certain African regions to sleeping sickness (African trypanosomiasis), transmitted to humans by infected tsetse flies.

Both the Hwange National Park in Zimbabwe and the KNP in South Africa are examples of large conservation areas in which suitable hosts and habitats for tsetse flies abound, Hargrove warns. "Tsetse did occur in these areas in the 19th century, but their numbers were always marginal because the winters were rather too cold. With the massive rinderpest outbreak of the middle 1890s, when the vast majority of ungulates [hoofed animals] died, tsetse disappeared from these areas and have never re-established themselves again. But, if temperatures continue to increase, there is a danger that they may re-emerge."

To date, however, no one has had sufficient data to model the risks of such an eventuality.

Bringing the Rekomitjie dataset into the 21st century

In 2017, with one of the 27 boxes of valuable tsetse fly data under his arm, Hargrove approached machine learning experts in the Applied Mathematics Division at SU. His objective: automating the measurement of wing shape in tsetse flies.

But why focus on wing shape? To date, researchers have been unable to ascertain whether variations in tsetse flies' wing shape and size are attributable purely to genetic differences between populations, or also to environmental factors.

Questions such as this can only be answered on grounds of a large sample size representing several seasons. While SACEMA holds by far the largest collection of tsetse fly wings ever amassed, it is extremely time consuming to manually measure small, fragile things such as insect wings. As a result, previous studies have been limited to sample sizes of a few hundred wings at most.

This is where machine learning comes in. This branch of artificial intelligence enables systems to extract patterns and dependencies from data without being explicitly instructed on how to do so. Applied mathematicians often use it for modelling purposes, which is exactly how the data locked away in those 27 boxes was exploited. The process consisted of a number of steps.

Step 1: Photograph the tsetse fly wings with a high-resolution microscope camera. Once the wings have been digitised and numbered, capture the rest of the data associated with each pair in an Excel spreadsheet.

To date, Dr Pietro Landi, Prof Cang Hui, and their students in SU's Department of Mathematical Sciences have photographed about 90 000 pairs of wings from 13 of the 27 boxes.

Step 2: Train a machine learning model to automatically locate 11 anatomical landmarks in any given wing image. For the purposes of machine training data, Prof Willie Brink from the Applied Mathematics Division built a custom annotation tool that allowed him to manually pinpoint landmark positions on 2 000 wing images, all in just a few hours. This initial phase of manual categorisation is vital to the accuracy of the end product.

> "A model is only as good as the quality of data it is trained on. If I do 1% of the work well, we can train a model to do the remaining 99%," Brink explains.

To this end, Brink and two of his MSc students, Shane Josias and Mulanga Makhubele, experimented with a number of deep learning architectures.

Step 3: Have postgraduate students perform a morphometric analysis of tsetse fly wings by quantitatively analysing their form and shape. This involves studying how wing shapes change between males and females, over time, and with the seasons.

Then MSc student Dylan Geldenhuys first became involved with the Rekomitjie dataset project when he volunteered to take digital photos of the tsetse fly wings for his graduate student project. This led to a growing interest in the morphometry of the wings — extracting certain features would, he hoped, help machine learning models expose how this morphometry reacts to changes in weather and climate.

For his MSc in applied mathematics — under the guidance of Hargrove, Dr Marijn Hazelbag, and Jeremy Bingham — Geldenhuys used deep learning approaches to detect and accurately position identifiable landmarks on images of tsetse fly wings. Using more than 28 000 images of wings, he developed a landmark dataset that can be employed in future morphometric analyses of tsetse fly wings, and potentially as a starting point for studies on the wings of other insect species, particularly those that transmit diseases to humans, livestock, and plants.

In practice, modellers can use this dataset to distinguish between populations of tsetse flies from different geographical areas, based on differences in wing shape. The objective is to be able to locate 'biological islands' of tsetse fly distribution so that they may be targeted for control.

At present, BScHons student Nuhr Ryklief is investigating whether Geldenhuys' landmark dataset can be extended across the full set of photographed wings. He is also working on the morphometric analysis of changes in wing shape over time. Another BScHons student, Leandru Fleidl, is using the Rekomitjie dataset to quantify the predicted effects of climate change on the future distribution of tsetse fly populations, and to determine whether the flies are likely to pose a threat to animals and people in the KNP. Predictive models such as this one can help scientists understand where and how quickly, under changing climatic conditions, tsetse fly populations are likely to increase in number and also spread.

Safeguarding the Rekomitjie dataset for the future

"It is crucial that all the data from the Rekomitjie Research Station is archived — with the fullest and clearest possible notation — to ensure that it will be of optimal use to future generations of biologists", says Hargrove. So far, the team has barely scratched the surface. Only two of the 27 boxes (about 14 000 of the 205 000 wings) have been fully digitised.

According to Hargrove, the collection holds enough data to support at least 50 doctoral theses on subjects ranging from birth and ageing processes, physiology, and insect demography to population dynamics, mortality, and extinction probabilities, not to mention the effects of meteorological changes on all of these topics.

> "It is fair to say that we have more high-quality field information available on tsetse than anybody has on any other insect species on the planet. This information could, and should, be used to inform studies on other insects.
>
> "If the Rekomitjie data were to be lost, it could never be reproduced. It would be lost to everybody, for all of time," Hargrove cautions.

DISHING UP FOOD SECURITY

UFRIEDA HO

Photo by Michael Ali

It doesn't add up — on the one hand, we have established food production and supply chains and massive food surpluses; on the other, we have pervasive hunger and growing levels of malnutrition affecting more and more households.

Together, fruits, vegetables, and cereals account for 70% of food wastage and loss, which mostly occur early in the food supply chain. | Photo from Unsplash

According to the 2022 national census and StatsSA's analysis, 2.1 million (11.6% of) South African households reported experiencing hunger in 2021. This statistic has spurred researchers at Stellenbosch University (SU) to expand their approach to levelling this imbalance.

Through transdisciplinary research, these scientists have come together in a public square initiative to focus on a systems-based approach to tackling malnutrition. This approach allows for consideration of the multiple drivers of malnutrition in society, and for roleplayers to respond with greater urgency in order to limit the long-term burdens of this condition. Importantly, the approach is deliberate in driving collaborative solution-finding to address the intersecting challenges around food systems.

Food security statistics highlight SA's challenges

Prof Scott Drimie of the Division of Human Nutrition in SU's Faculty of Medicine and Health Sciences is also the director of the Southern Africa Food Lab, co-hosted by the University. Drimie summarises South Africa's food security dilemma: "The issue here is that this is not a linear problem that an economist or a nutritionist can solve on their own. Look at the problem of stunting, for instance: On one level it's about food, but on others it's about care, sanitation, hygiene, and the health system. We need to have all of these things in the same place at the same time."

Building a clearer, more nuanced understanding of the situation is critical, Drimie argues. "It is an indictment [of South Africa's commitment to establishing food security] that we don't have more platforms in the country that encourage collective, broad approaches," he says. "We need more innovation and solutions emerging from sustained dialogue and a commitment to action — whether it's through policy, shortening value chains, incorporating indigenous food systems, or any of a range of other possibilities."

Ultimately, Drimie says, the alarm bells should have already rung as the looming crises are damning. Statistics show that 28% of children in the country are afflicted by stunting, a situation that has worsened over the past 30 years. Children who suffer from stunting do not timeously reach standard height milestones. This puts them at risk of developing chronic diseases, weakened immune systems, impaired cognitive abilities, high blood pressure, and obesity.

Despite important nutrition-related policy and programme improvements in South Africa, the rates of stunting among the country's young children remain unacceptably high — much higher than in several other low- and middle-income nations.

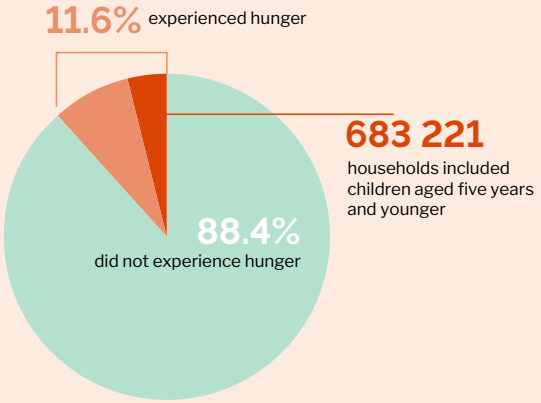
But stunting is not the only condition that points to a larger nutrition crisis. Drimie explains that there are rising numbers of children presenting as underweight or suffering from severe acute malnutrition (marked by a very low weight-for-height, bilateral pitting oedema, or a very low mid-upper arm circumference). "In all of these [malnutrition] conditions, physiological growth is impacted and so are brain function and brain development. In cases of severe acute malnutrition, it can lead to death.

"On the opposite end, the nutrition challenge is that we see high rates of people who are overweight or obese," Drimie says. Right now, 50% of adults in South Africa — more than the percentage two decades ago — fall into this category. Compared to other low- and middle-income nations, South Africa's progress in addressing these issues falls short.

Pressures on the modern diet

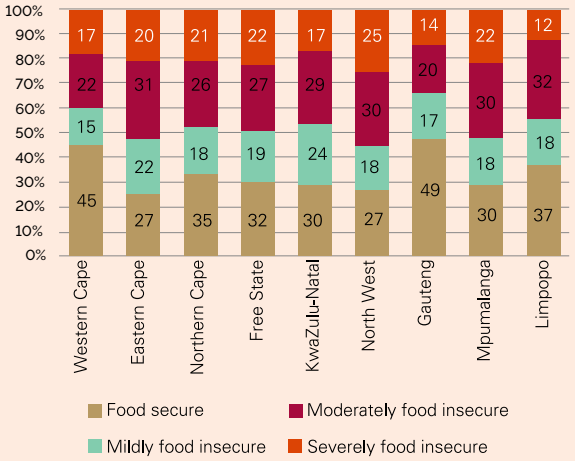
Modern diets and food systems have undergone a rapid, drastic transformation in the past 50 years. Joelaine Chetty, a PhD student in the Division of Human Nutrition and a research dietician in the South African Medical Research Council's Biostatistics Unit, is connecting the dots. She points out that the

Households that reported experiencing hunger in South Africa in 2021



South Africa has enough food and numerous food programmes, yet millions of people still go to bed hungry. | Source: StatsSA

Food security status disaggregated by provinces in South Africa



Source: HSRC *Review*

deterioration of our nutrition system over the past five decades can be attributed to two factors: the industrialisation of food production and the accelerating impact of climate change.

"The highly processed, energy-dense foods we have now are often low in essential nutrients and high in sugar, salt, and unhealthy fats. This shift in dietary patterns contributes to the global rise in obesity and diet-related diseases, while exacerbating malnutrition and micronutrient deficiencies," she explains.

But that's not all: The unfolding climate crisis is adding food production and security pressures to the mix. Chetty says: "The increasing frequency and severity of extreme weather events such as droughts, floods, and storms are disruptive and have adverse effects on food production. This, in turn, affects crop yields, livestock production, and distribution networks, leading to food shortages and price volatility."

Chetty believes, however, that reversing these trends is possible through interventions such as localising and diversifying food systems. "We have the potential to foster local food production, distribution, and consumption, thereby reducing our reliance on imported goods and strengthening community resilience. By supporting small-scale farmers, local markets, and food sovereignty initiatives, we can significantly enhance food security and economic stability at the grassroots level.

"Promoting agricultural diversification reduces the reliance on a limited number of crops or livestock breeds. Diverse farming systems build resilience against climate variability, pests, and diseases, and can buffer against crop failures and market fluctuations."

Chetty believes investment in research, innovation, and technology transfer is crucial to protecting our nutrition system against further deterioration. Moreover, she argues, there is a need for nutrition-specific interventions — efforts that not only ensure access to food but also promote diverse, nutritious diets. These interventions include micronutrient supplementation, promoting breastfeeding, and strengthening dietary guidelines that encourage the consumption of fruits and vegetables, specifically indigenous vegetables.

Giving back indigenous foods their seat at the table

Prof Xikombiso Mbhenyane, head of the Division of Human Nutrition, is a dietician with a particular interest in indigenous food systems. She is also the Faculty's DSI-NRF Research Chair in Food Environments, Nutrition, and Health.

Indigenous food systems, she says, have been excluded from mainstream ones and left to linger on the margins in terms of production, access to markets, and investment. Integrating indigenous foods into the broader markets, however, can strengthen local food systems, she believes.

That said, the challenges in the promotion, production, accessibility, and consumption of indigenous foods are plenty. For instance, Mbhenyane says, the availability and accessibility of indigenous foods still vary widely from province to province, and between the formal and informal markets. Without more consistent, reliable supply chains, consumers are less inclined to normalise indigenous foods into their everyday diets.

> "For indigenous foods to be promoted for cultivation and consumption, we need protection and accessibility in the market," she says. Land management must balance the importance of land for growth (through commercial or housing developments) with land for food security (through agriculture), Mbhenyane adds.

Mbhenyane also makes the case for subsistence farming and the promotion of urban food gardening. Growing your own food not only supplements your household food supply, she says, it also saves money, restores people's connection to how food comes to a table, and recovers the forgotten benefits of indigenous foods.

Finally, Mbhenyane believes more research into indigenous food systems can unlock traditional knowledge and ensure its preservation in repositories.

New perspectives, new solutions

Prof Sara Grobbelaar from the Department of Industrial Engineering has put engineering innovation at the heart of solving problems in our food systems. Her research interests include mitigating the severe consequences of wealth and income disparities.

"Industrial engineers take a systems approach [to problem-solving], and a systems perspective is particularly valuable when considering problems that have interconnected elements," she explains. "Some of our [research team's] work considers how we can help integrate circular-economy principles into wholesale food markets to improve efficiency throughout the supply chain. Another project looked at food banks and how we can help them donate food to vulnerable people in the most efficient way."

Grobbelaar and her team recently collaborated with Africa's largest foodbank, FoodForward SA, which distributes around 950 000 meals a day across the country through its network of beneficiary organisations. Grobbelaar says: "This collaboration sparked our interest in growth stunting. It led us to work with a group of experts in fields that were new to us and, in turn, we could introduce them to experts we worked with on other projects. This created a virtuous loop of collaboration."

Another successful project by Grobbelaar's research team was undertaken in collaboration with the Massachusetts Institute of Technology. Together, the cross-continent teams worked on developing a system dynamics model to assess food supply chains in wholesale markets in Mercabarna in Barcelona, Spain.

This project highlighted the importance of having proactive infrastructure investment, ensuring adequate capacity and cold storage, and forming strategic alliances with food banks and charities to repurpose potentially wasted food. The researchers were also able to introduce processing capabilities to extend food shelf life by turning fresh vegetables into soups and vegetable pulp.

"I'm optimistic about the fact that we are beginning to see more transdisciplinary collaboration. We need to overcome the challenge of not seeing the potential in disciplines beyond our own," Grobbelaar concludes.

Subsistance farming in an urban setting | Photo from iStock

BESPOKE POLYMERS

PUT SU START-UP ON MAP

ALEC BASSON

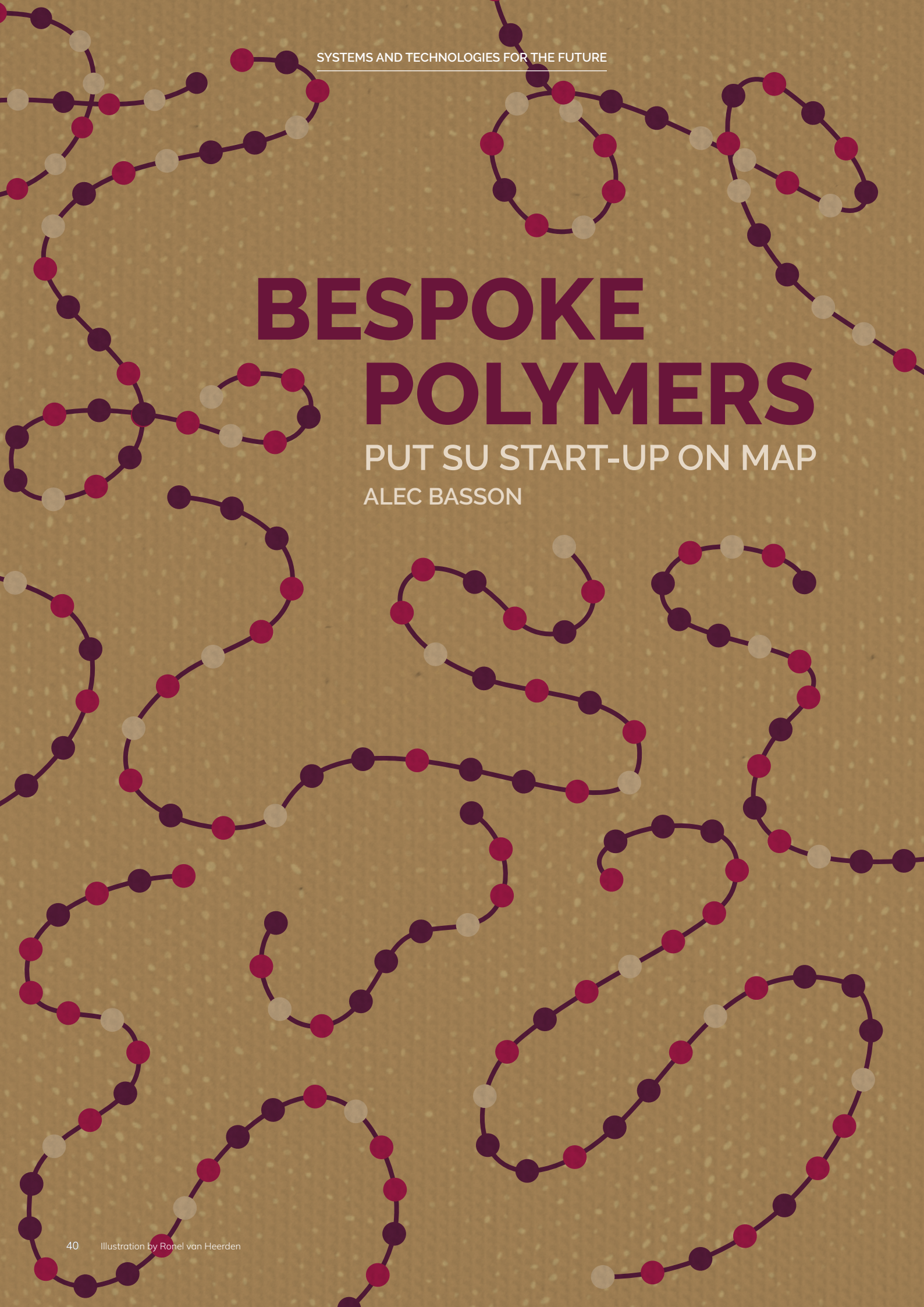


 Illustration by Ronel van Heerden

Imagine a world in which drug development is faster, more precise, and more affordable. As a scientific start-up company, Nanosene (Pty) Ltd is committed to ensuring just that.

The Nanosene team: Dr Elaine Barnard (left), Prof Bert Klumperman, and Dr Gestél Kuyler. | Photo by Stefan Els

Innovative polymer technology, developed during the PhD research of Dr Gestél Kuyler and licensed to Nanosene, is helping uncover knowledge that can inform the development of novel drugs, as well as their delivery in human cells.

The company, established in 2022 and based at Stellenbosch University (SU), is the first innovator and supplier of bespoke polymers in Africa. It is known for its development of the next generation of amphiphilic polymers, which are used to isolate membrane protein drug targets.

> "These polymers are the key to unlocking previously inaccessible biologically active proteins in the cell membrane, which can accelerate therapeutic discovery and lead to more effective treatments for a range of diseases," says Kuyler.

Membrane proteins constitute the most pharmaceutically relevant protein class. Being crucial in regulating physiological processes in the human body, they represent prime targets for nearly 70% of the drugs approved by the U.S. Food and Drug Administration.

"Diseases such as asthma, obesity, high blood pressure, Alzheimer's, and cancer are associated with the dysregulation of membrane proteins, making them important targets for drug discovery and development, as well as intriguing research subjects," Kuyler points out. Unfortunately, however, it is very difficult to obtain these proteins in pure, active form. This is where Nanosene's novel polymer technology comes in.

Polymer research for the future

In 2024, Kuyler received a joint PhD in polymer science and molecular pharmacology from SU and Coventry University in the United Kingdom. Under the supervision of Prof Bert Klumperman and Prof Mark Wheatley, she conducted research at both institutions. Her dissertation focused on the design, synthesis, and characterisation of novel polymers intended for the isolation and investigation of membrane proteins, particularly G-protein-coupled receptors.

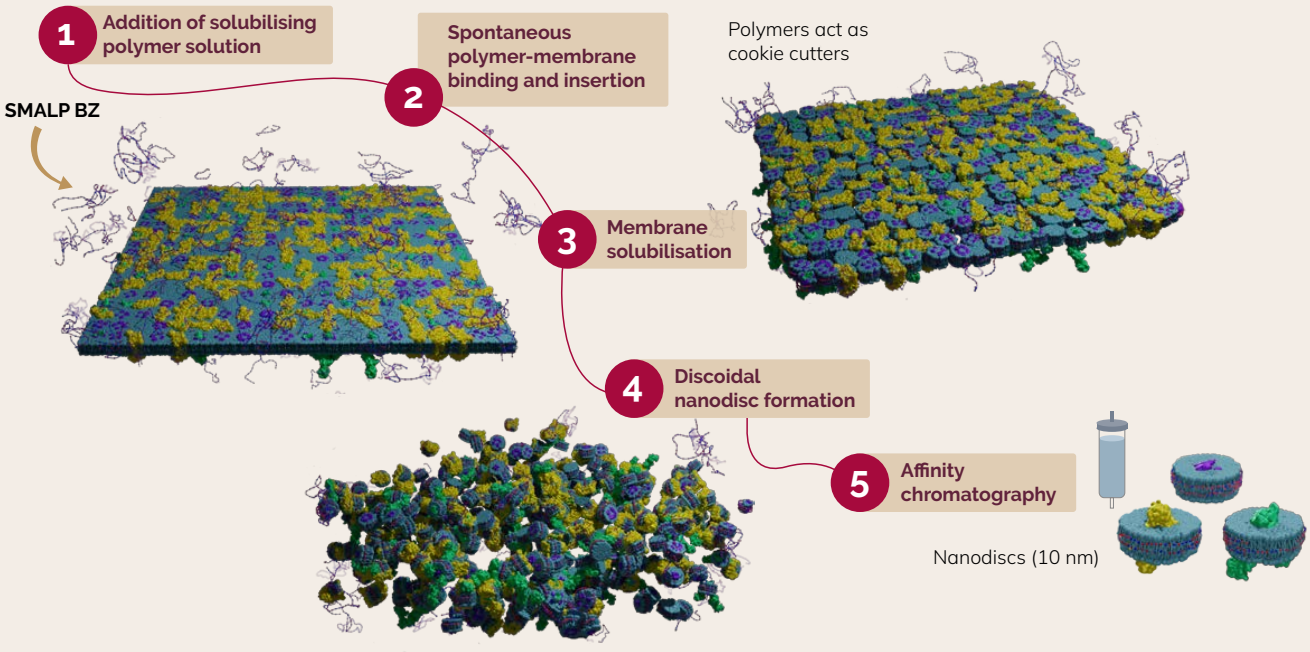
Kuyler's PhD research led to the filing of a patent that became the core technology used by Nanosene, the company that she went on to co-found with Klumperman, a professor in SU's Department of Chemistry and Polymer Science. As a leading international polymer scientist, Klumperman held the SU-hosted DSI-NRF South African Research Chair on Advanced Macromolecular Architectures from 2007 to 2021.

Today, Kuyler finds herself at the helm of Nanosene as its chief executive officer. She also serves as the research manager of SU's Klumperman Research Group, which is dedicated to developing next-generation polymers for the successful isolation of membrane proteins, as well as for other applications.

Along with Kuyler and Klumperman, the other core team member of Nanosene is operations manager Dr Elaine Barnard, who has a notable background in polymer science and has conducted postdoctoral research overseas. The three scientists are supported by the researchers in the Klumperman Research Group.

This group is focusing on the biomedical applications of functional polymers, including drug delivery, antimicrobial coatings, and hydrogels as reversible male contraceptives. Its multidisciplinary

How to stabilise membrane proteins in a native-like environment using polymer nanodiscs



The synthetic polymer chain stabilises the membrane proteins within nanodiscs. This enables the analysis of these proteins in a native-like (cell) environment, while retaining their physiological properties. | Image courtesy of Nanosene (Pty) Ltd

projects are conducted in conjunction with various researchers that complement the knowledge within the group. Nanosene is the commercialisation avenue for potentially profitable innovations developed within the group.

Spotlight on membrane proteins

Membrane proteins make up approximately one third of living cells' proteome (that is, the total protein content encoded by the genome). Many diseases commonly associated with mutations are linked to the malfunctioning of membrane proteins, underscoring their medical importance.

> "These proteins facilitate a range of biological processes, such as the flow of molecules through and across membranes, responses to chemical messengers, and cell-to-cell communication within the human body," Kuyler points out. "They function almost like 'locks' that only the right drug can open so as to access the cell and activate a response."

The crucial role of membrane proteins in drug development is evident in the fact that they comprise such a large portion of all drug targets. But why, then, do we know so little about them?

"The problem lies in how difficult it is to isolate or remove membrane proteins from the cell membrane in order to study their structure and function in a biologically representative state," Kuyler explains.

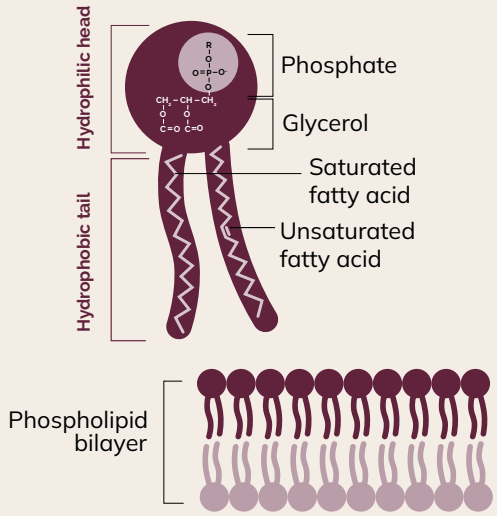
For the accurate design of new therapeutics, membrane proteins must be extracted in their unaltered, stable, and fully functional form from the lipid environment that makes up the cell membrane.

This native environment in which membrane proteins are embedded consists of two layers of amphiphilic phospholipids — molecules that each have a hydrophilic head and two hydrophobic tails. Their unique structure enables them to form the foundation of biological membranes.

"The difficulties arise from the amphiphilic nature of membrane proteins and the consequent need to extract them in a way that stabilises both the hydrophobic and hydrophilic parts," Kuyler explains. "If this is not achieved, the protein can lose its true structure and function. Understanding these aspects of drug targets can not only reduce the time and cost of drug development but also holds the potential to enhance the efficacy of drugs, ultimately minimising side effects and reducing costs."

Phospholipids

The cell membrane in which membrane proteins are embedded consists of two layers of phospholipids — molecules that each have a hydrophilic head and two hydrophobic tails. Their unique structure enables them to form the foundation of biological membranes.



Isolating membrane proteins, innovatively

With the advent of new polymer-stabilised nanodisc technology, much focus is placed on low-volume, high-value products with a specific application.

The term 'nanodisc' describes a disc-shaped particle, composed of phospholipids that are held together by a synthetic polymer belt. These tiny structures have dimensions as small as one-billionth of a metre (a nanometre) — invisible to the naked eye and to most microscopes.

Nanodiscs make difficult-to-study membrane proteins amenable to analyses previously restricted to soluble proteins only. This is because the water-insoluble component of the amphipathic polymers in these discs can interact with and destabilise the cell membrane to isolate and stabilise membrane proteins along with their surrounding lipids.

The Nanosene team uses polymer-based molecular 'cookie cutters' to isolate the complex membrane proteins and keep them embedded within the given portion of the cell membrane, thus preserving its molecular structure in its near-original context and stable form. This offers researchers the unprecedented opportunity to access some of the most valued proteins in a biologically active state.

The nanodisc serves as a snapshot of the native environment that the membrane proteins had in the cell membrane. This is because water-soluble amphipathic polymers can interact with and enter the cell membrane to isolate and stabilise intact and functioning membrane proteins, along with their surrounding lipids, within these discs.

Nanosene produces polymers that have predetermined molecular weights with narrow chain length distributions and the possibility of having their hydrophilic-hydrophobic balance precisely fine-tuned. Kuyler says: "This breakthrough technology can outperform conventional detergent-based methods [of isolating protein membranes] and holds the potential to empower researchers and drug developers to explore new avenues for treating various diseases."

"Compared to other current materials, our material offers the possibility of introducing additional functionalities such as fluorescent labels, affinity tags, and tethered surfaces," Klumperman explains.

Barnard adds: "We believe that by adopting our customised polymer solutions and substituting traditional techniques with our innovative methods, researchers will enhance the efficiency and effectiveness of identifying potential drug targets for new therapeutic development."

Nanosene's innovative nanodisc technology also opens up collaborative opportunities within the research community and in commercial partnerships. "The advanced synthetic strategy that we employ is highly customisable, allowing for dedicated polymer design and various specialised applications," Kuyler says.

Leading the (polymer) pack

By developing novel polymers to isolate membrane proteins in a highly stable and functional form, Nanosene is positioned to make a significant contribution to the drug development industry.

Going forward, Klumperman says, they will focus on two overarching research areas: "One is the expansion of conditions under which our polymers can do their job. These conditions relate to the acidity or basicity of solutions and the presence of certain salts.

"The other area is the inclusion of additional functionalities in our polymers that will expand their use in common drug development techniques."

Barnard adds that their ongoing research and projects are focused on creating amphiphilic copolymers (made from two or more different kinds of building blocks that are joined together) to address the limitations of the polymers currently available on the market.

"We're also planning to expand our capabilities with customisable chemical modifications, which will open up new avenues and applications in drug discovery and development."

MACHINE LEARNING

ONE FIELD GIVING VOICE TO MANY

WILLEM DE VRIES

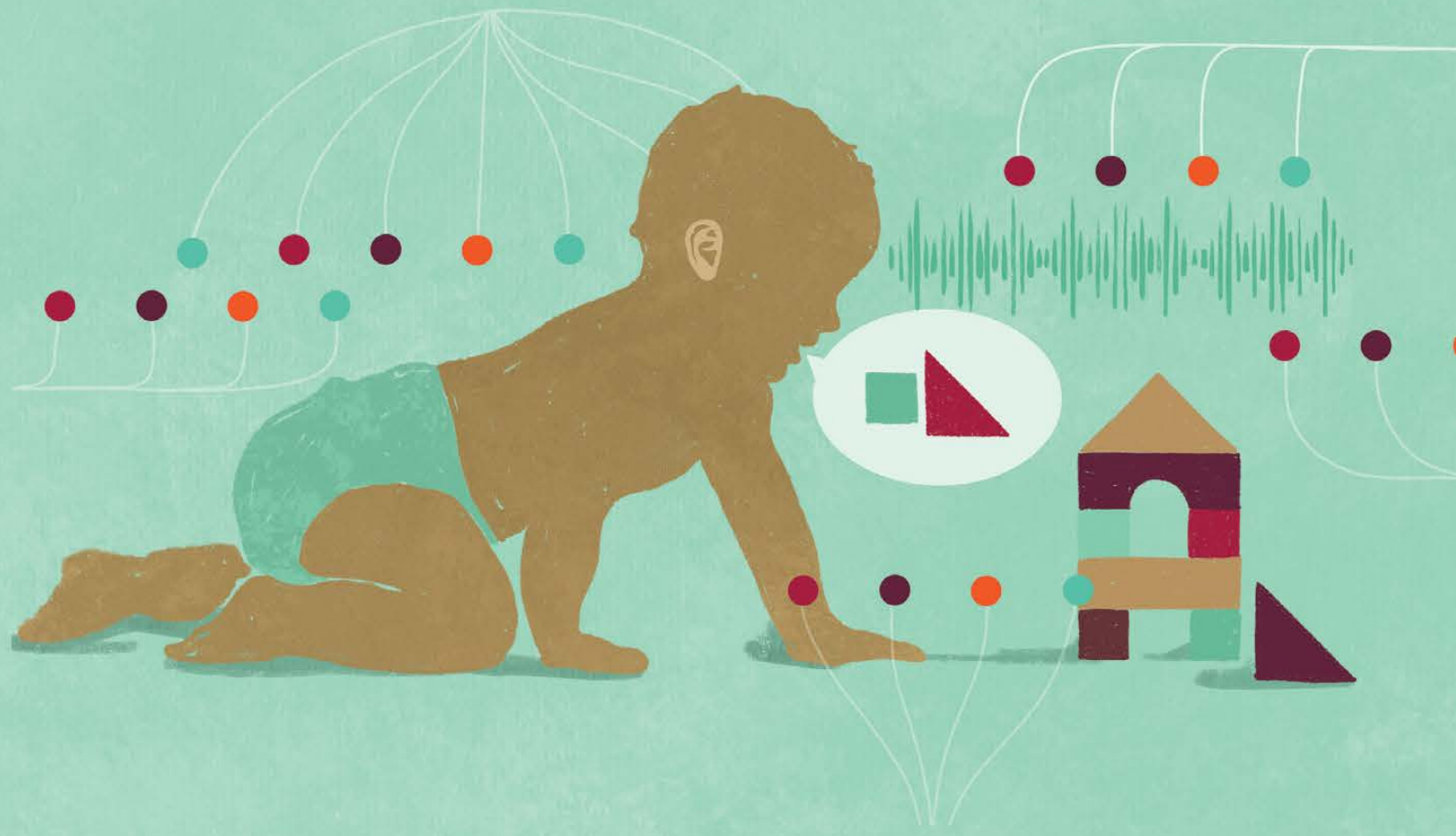


 Illustration by Roulé le Roux

When Herman Kamper, a professor in the Department of Electrical and Electronic Engineering at Stellenbosch University (SU), speaks about his research on speech processing, its interdisciplinary nature is immediately evident.

The lens through which he regards his research is that of machine learning — a branch of artificial intelligence (AI) that enables systems to extract patterns and dependencies from data without being explicitly instructed on how to do so.

Humanising machines

Kamper's research is primarily focused on addressing engineering-related problems in the field of machine learning, rather than on the end applications.

More specifically, he aims to understand the nuts and bolts of advanced modelling to see whether existing algorithms may offer more to the field than previously thought. At the same time, it reveals how machine learning is being understood in increasingly humanising terms. In fact, the concept has become so prevalent that the Oxford Dictionary of English uses no inverted commas when describing the use and development of computer systems that are able to 'learn' and 'adapt' without following explicit instructions, purely by using algorithms and statistical models to 'analyse' and 'draw inferences' from patterns in data.

In Kamper's work on language, technology moves even closer to mimicking human cognition as he joins other researchers in creating and refining advanced models that 'learn' language without intervention, in a way seemingly similar to a child's acquisition of their first words.

Pathway to AI research

Kamper completed his master's degree at SU under Prof Thomas Niesler, whose research focus includes speech and language processing, especially for under-resourced languages. (At present, English-language datasets disproportionally populate the field of machine learning.)

For his PhD, he chose a topic that would force him to explore these interesting fields. A very specific engineering problem soon caught his attention: How do you get a machine to learn in a way that resembles the process of human language acquisition?

The scope of his studies widened when he connected with one of his supervisors in Edinburgh, Prof Sharon Goldwater, "who came from a more psychological and cognitive modelling background and was interested in pivoting towards speech technology".

Kamper went on to obtain his PhD in 2017, at the University of Edinburgh. The topic of his dissertation was unsupervised neural and Bayesian models for zero-resource speech processing. After his doctoral studies, Kamper did postdoctoral research at TTI Chicago, working on unsupervised speech processing and machine learning that combine speech and vision.

Today, Kamper's research focus is on using machine learning for speech processing so as to allow machines to acquire human language autonomously, with as little supervision as possible.

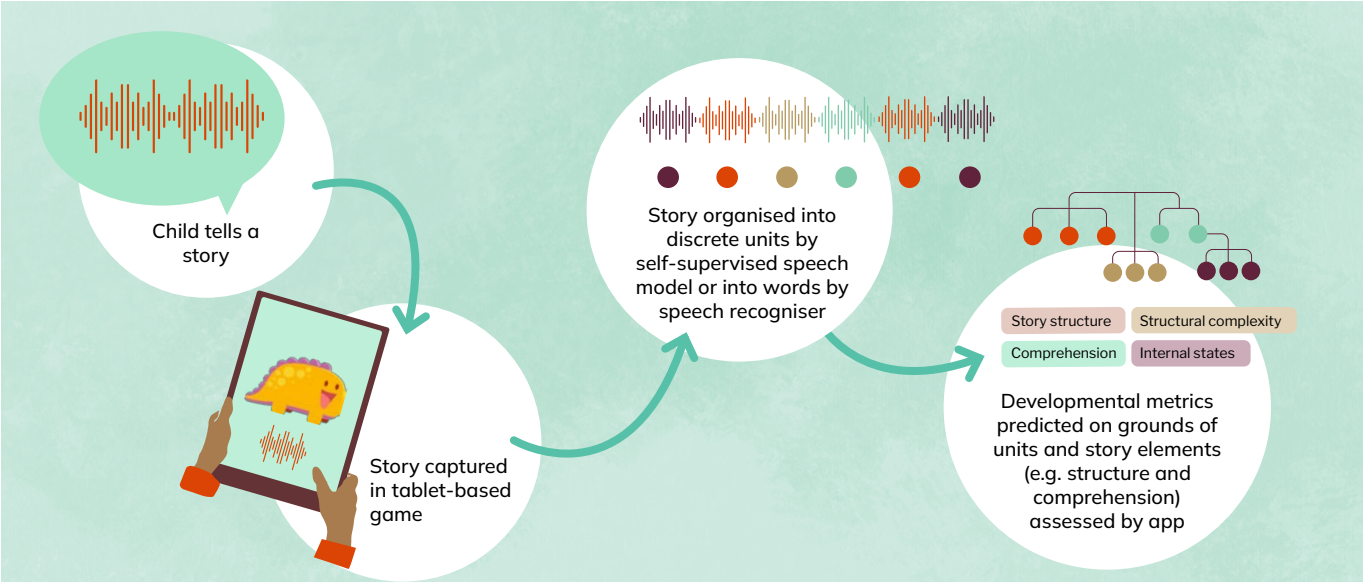
He explains this process as follows: "One of the things we often do — and this is a very basic example — is give the model a piece of speech and tell it to compress this in some way and then try to reconstruct that same speech for us. This is what is called 'reconstruction loss'. Or we tell the model: Here's a piece of speech; predict what comes next. This works very well, and it's basically how, for example, ChatGPT functions. Except we do this with a speech signal instead of text.

"We try to figure out what we need to put or build into the model, or what problem we need to get the model to solve. Then the model learns to solve that task, and we see what additional things the model can do."

Computation and cognition

What does cognition mean in the context of computer science, and how does it relate to Kamper's work?

In the late neuroscientist David Marr's work in cognitive science, he isolated three levels of cognition. First, there's the computational level at which the problem the system is trying to solve is defined and its goals are set. Next, the algorithmic level describes the algorithms used and in what method. Finally, the implementational level deals with the hardware — the realisation of the system — whether it's biological or a computer. "You really need to specify at which level you are conducting research," Kamper says.



Storytelling metrics: One of the applications of the storytelling analysis is to use what the researchers learn and subsequently develop to assess children's language development annually. This diagram illustrates one approach to analysing stories told by kindergarten children. | Illustration based on image supplied by Prof Herman Kamper

"Also, you must remember that the insights you gain at the different levels enforce each other. A simple example of this is a calculator. An abacus can perform addition and subtraction, just like my silicon computer does, in the sense that it can achieve the same thing. The algorithm could even be the same. I could write a little program in Python [a programming language] that precisely follows the path of the abacus, but the hardware is completely different — there are electrons flowing through it, whereas with an abacus, I'm sliding objects around.

"Most machine learning researchers would still say that we don't really have anything substantial to say about consciousness, though. It's poorly defined, and we don't really know what the definition is, but the fact that many people are thinking about it is true. It's really a fascinating question. But at the same time, we still need to be concrete, both when doing scientific work and when building engineering applications."

Academia an essential laboratory for ideas

With regards to AI and machine learning in an academic engineering context, Kamper acknowledges that it is simply impossible for the modern university to compete at scale with the advances in industry.

For him, the strength of his academic work lies in its mostly experimental nature and focus on new or under-resourced avenues of research that the OpenAIs and Googles of the marketplace aren't yet capitalising on.

Even though industry's walled garden and intellectual wealth place it at a remove from the academic world, it is vital that research and engineering academics stay the course and embrace engineering as a laboratory for ideas, he says.

Kamper is especially interested in the role of simple foundational approaches as key in the methodology of researching algorithms as these become ever more complex, and knowledge and datasets' quality are distributed through various channels. What Kamper is also saying is that the faster and more complex it becomes, the more necessary it becomes to see if simpler approaches can be applied on top of these complex models in order to solve new tasks.

Tackling literacy in South Africa

Kamper is also involved in a literacy project with a company called Trackosaurus, in which they analyse the way preschool children tell stories as an indication of their likelihood of having learning problems later in life.

"Young children's storytelling abilities can be good predictors of whether or not they will have reading problems later on. The big problem is if you can't tell a story and you don't understand the flow of a story — the beginning, middle, and end — then it becomes difficult to read effectively later on."

The project is aimed at preschool children in large classrooms in Mpumalanga's SiSwati communities. Teachers there can have more than 40 children in front of them and not know who is struggling with what. "The idea [of the project] is that the children must tell a story to a tablet. Trackosaurus specifically has a maths game. The project allows the children to spend 20 minutes with the maths game once a week, and it then tells the teacher which children are struggling with specific things.

"What we're now trying to do is to get the children to tell a story within the game as part of a storytelling exercise with guidance.

"We're working with [education specialists] Prof Daleen Klop and Annelien Smith at SU. Currently, we are creating prototypes [of the literacy testing software for the Trackosaurus application] built on the Afrikaans and Xhosa datasets that Annelien and Daleen have collected. Then we'll redo it in SiSwati. Trackosaurus works very closely with the Department of Basic Education in Mpumalanga. We're currently trying to involve other people from other universities as well."

Turning theory into application

Although Kamper is excited to see how aspects of research into human language acquisition by machines (with minimal intervention) gain a foothold in other disciplines, his interest in this specific topic remains scientific as he focuses primarily on problem-solving in the field.

"My big research agenda essentially is that I want to build a 'box' that takes in spoken information from all over, and then starts making sense of it. That agenda is a very scientific one because if we get such a box and we know that the mechanisms inside it are similar to those that children use, then we can study that box as a model in ways that we can't study children.

"It's a very scientific endeavour, and to be successful, you must solve difficult engineering problems."

Kamper and his student teams' research has had some unexpected results. "For example, half of my students work on tasks like voice conversion or voice generation, which involves creating unique voices for characters in games. So, we work with Ubisoft, a gaming company and we're addressing incredibly challenging speech technology problems. We have, for example, models that try to learn small bits — the phonetic units of a language — and then we realised, 'Oh wow, we can actually use these phonetic units to convert one voice into another!' And you don't need a super complicated system to do it. So, we have written a paper, 'Voice conversion with just nearest neighbours', which describes a super simple technique. We wouldn't have been able to do that if we didn't have this kind of experimental research agenda.

"In South Africa, for a relatively small academic community, we used to have a very large research cluster for speech recognition and speech synthesis. In the past, people from the signal processing engineering field who were interested in those topics then also started taking an interest in machine learning and AI before gradually moving into these fields.

The big shift

"If you look at developments [in generative AI] over the last three years, everything is coming out of enormous research labs like Google DeepMind and OpenAI.

"The big shift happening now is that we [in academia] take what these big players are doing and try to see how we can use and adapt it and figure out what the strategies and techniques are, the modelling approaches and the mathematics behind it — everything needed to take what these big players are doing, bring it here, and then use it to solve [engineering] problems, whether they are things like voice conversion with very little data or figuring out how the methods could be used to set up a cognitive model of how a person learns."

Kamper is of the opinion that GPT [which is short for 'generative pre-trained transformer', a kind of AI language model] "is not a complicated model compared to some of the other stuff, but I think we in academia shouldn't try to do the same things that people in industry are doing. We don't have the big computers needed to train these models. So, we can take what they're doing, but then, crucially, we need to explore it widely. We must try weird, strange things, all over the place. And then the industry must hyper-optimise and fund it, and make that model super good."

As an undergraduate student, Kamper liked the idea of a machine that improves with experience, so there were two fields he considered for further study: machine learning and computational electromagnetics. "So, I went on and started with speech recognition, and from there I was very fortunate to continue exploring. I never thought I would work on anything involving the generation of language. My students started digging into that, and suddenly I learned new things and made it look like I knew something about it. It was entirely accidental and very rewarding.

"I'm currently on my sabbatical, and one of my students is now my advisor. He tells me what to do, and then I implement it and I find this really rewarding."

Though undergraduate students change course time and again, his postgraduate students "are all quite excited" about the possibilities and research in the field. "I think it's a very exciting time because I think we're going to be able to solve problems that we couldn't before. We must ask ourselves what the blind spots are. The process of figuring out where we need to look is fascinating. Students like it too.

"And it doesn't have to be engineers. With GPT someone who knows nothing about machine learning can solve a problem. I'm quite excited to see how people are going to use it."

BIG DATA
FOR SMARTER POLICY DECISIONS

ANÉL LEWIS

Illustration by Ronel van Heerden

Artificial intelligence (AI) and data science have a critical role to play in policy decisions around an array of topics, be it public health, smart cities, or sustainable development.

Stellenbosch University (SU) — through a partnership with the Presidency, the German government, and the Bill & Melinda Gates Foundation — has established Africa's first Policy Innovation Lab. Housed within SU's School for Data Science and Computational Thinking, the Lab is led by Prof Willem Fourie, an associate professor in the School and Chair of Policy Innovation at SU.

Researchers in the Lab are exploring how data science and AI tools can be deployed within a policymaking environment to accelerate the achievement of the United Nations' 17 Sustainable Development Goals (SDGs) in South Africa and beyond. "Our entry point to the SDGs is SDG 17, particularly its focus on the importance of policy coherence and policy coordination. This is why the Lab's current projects focus on improving coordination and efficiency in the country's policymaking, and on reducing duplication and policy conflict through the application of data science and AI tools and approaches," explains Fourie.

The Policy Innovation Lab is in expert hands as Fourie is the founder of one of the world's largest AI-powered knowledge resources on the SDGs: the South African SDG Hub. This metaplatform aggregates the most relevant research on the SDGs from both local and a selection of non-South African universities.

Big data and public service

Although it has only been a few months since its official launch, the Lab's contribution to society is already evident across several fields, from politics and digital transformation to sustainability. Many of the Lab's projects are conducted in cooperation with the Policy and Research Services branch of the Presidency, its government partner.

In a recent study, Stellenbosch Business School graduate Jan Hofmeyr noted that, if applied correctly, AI can significantly improve government services.

"The rapid growth in the range and capabilities of AI will, in coming years, present the government with ever-expanding opportunities to improve the reach and quality of services to South Africans. If they leverage it wisely, this could hold promise for South Africa, and other developing countries, to leapfrog stubborn, often structural developmental challenges," Hofmeyr said.

Using the study as a platform to make recommendations to the government on its approach to AI, he calls for research and development initiatives to "nurture national expertise in the development of AI applications that can respond to these challenges".

The Policy Innovation Lab has already identified several applications of AI tools for policymakers in South Africa that could have far-reaching implications for communities.

> For example, millions of litres of water could be saved by using monitoring hardware that alerts authorities when water leaks need to be repaired. Similarly, AI systems could be used to balance intermittent energy supply and demand. AI can even play a role in road maintenance — video footage from police dash cameras could be used by AI systems to identify potholes and other infrastructure issues.

Multiple applications

The work being done in the Policy Innovation Lab has multiple applications across disciplines. The Lab recently released a briefing note to the national government, proposing a framework for digital transformation in South Africa's public sector to accelerate the achievement of the country's SDGs.

To increase public sector trust in the use of AI, one of the Lab's teams, led by Dr Gray Manicom, has compiled an online catalogue of AI tools. "This searchable catalogue benefits both the government and businesses seeking to leverage AI in the South African public sector by helping them find cases in which AI is currently being used overseas," explains Manicom. "By primarily considering AI tools currently used in the EU, which is renowned for having the best regulations for AI, and by citing real-life applications, we can increase public trust in and a better understanding of AI use in the public sphere."

The catalogue, based on the Public Sector Tech Watch dataset of digital tools used in the European public sector, will be

updated biannually as more cases come to light during the Lab's work. It includes a filtered list of only those tools deemed relevant to the South African context.

The digital toolbox includes tools for communication between government and citizens, for analysis and monitoring, administration, and fraud detection, among many other applications. "We tried to be as pragmatic as possible, considering the relatively high needs of South Africa and the relatively low digital skills and infrastructure in government, and highlighted several noteworthy examples in our latest catalogue," adds Manicom.

In crime prevention, for instance, the potential gains of AI systems are "massive", he notes. Such systems may be able to predict instances of criminality without systemic or demographic bias.

> AI also has valuable applications in fraud detection. Comprehensive datasets of financial transactions in the public sphere can be used to train a model that can detect fraudulent transactions in near-real time. Fraud detection AI software is already used by banks and large corporations — the government could do the same.

Systems thinking, big data, and policy

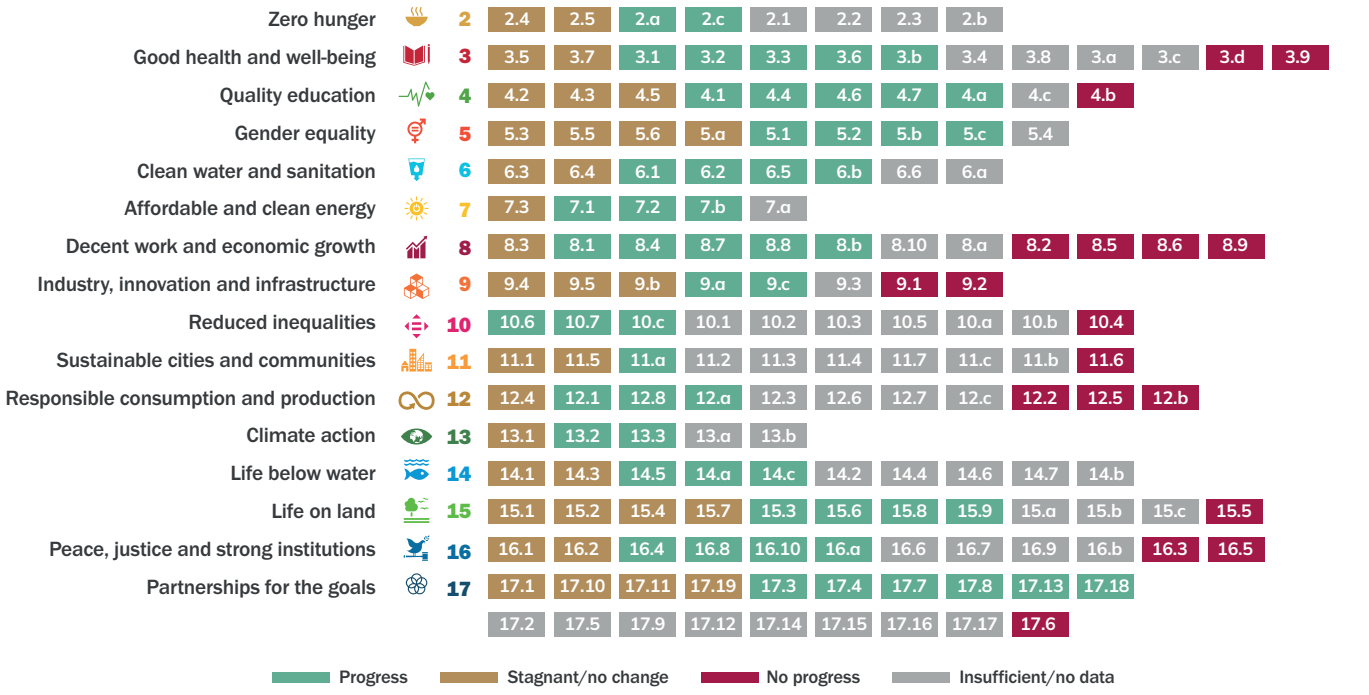
As the custodian of the South African network of the Bill & Melinda Gates Foundation's Goalkeepers initiative, a project aimed at amplifying stories on SDG impacts from across the country, the Policy Innovation Lab has a strong focus on the societal footprint of AI in policymaking.

By hosting events and workshops, the Policy Innovation Lab supports the South African Goalkeepers community in building a cohesive network to champion the SDGs. Its first session, held early in 2024, highlighted the importance of empathy and crafting solutions to meet the specific needs of one's target market. The focus was on how to incorporate design thinking — a collaborative process involving designers and users — into the Goalkeepers' processes.

Cross-border collaboration

Through the Policy Innovation Lab, SU has also joined one of three new Africa-Europe Clusters of Research Excellence (CoREs), launched by the African Research Universities Alliance and The Guild of European Research-Intensive Universities. The Lab is part of the cluster focusing on the politics of sustainable development.

One of the cluster's projects, proposed by Fourie, aims to harness the potential of machine learning tools in analysing publicly available South African policies and legislation on sustainable development. "By leveraging machine learning, the project aims



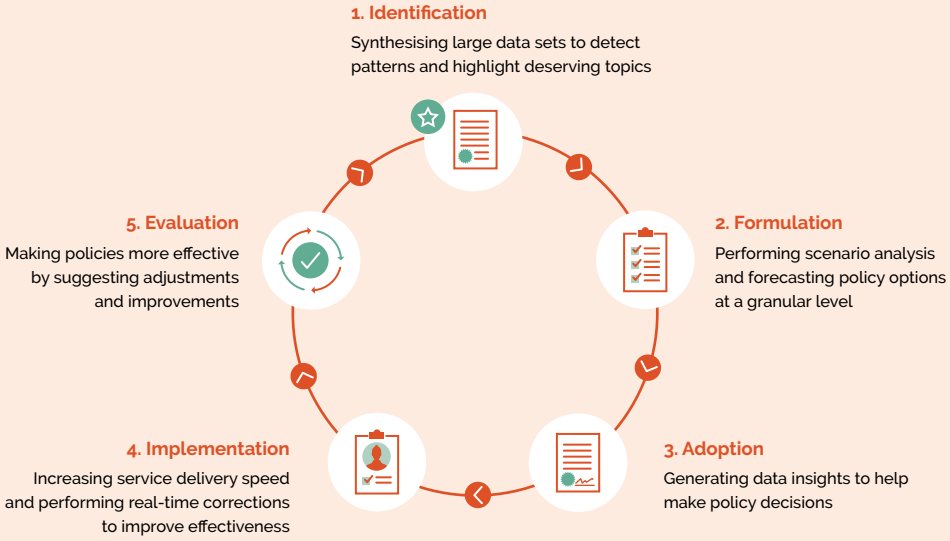
South Africa's progress towards meeting the UN's SDGs, as measured at the halfway mark of Agenda 2030. Positive trends have been observed in the case of 33% of the targets, 23% have seen no noticeable change, and 11% have not seen any progress. Note that 33% of the SDG targets did not have sufficient or new data for tracking progress. | Image courtesy of Statistics South Africa

to transcend traditional research methods and existing policy databases, enabling a comprehensive examination of potential synergies and conflicts within the policy landscape," noted the CoREs co-lead Prof Dan Banik of the University of Oslo.

Researchers will investigate the effectiveness of using machine learning to analyse sustainability policy coherence, identify priority topics that may promote policy coherence, and reflect on the relevant ethical considerations around responsible implementation and capacity building for future policymakers.

With the initial analysis completed, the team is now focused on interpreting the data.

"This partnership [of CoREs] exemplifies our shared commitment to leveraging research and innovation to address pressing global challenges. We look forward to working with Prof Fourie and colleagues on issues related to sustainable development so that we can shape a more sustainable and equitable future for all," says Banik.



Big data and policy directions

- Experts predict that the use of AI will contribute up to $15.7 trillion to the global economy by 2030.
- The results of a 2020 survey revealed that most Europeans (51%) supported the idea of reducing the number of parliamentarians in their countries and replacing them with an AI algorithm. Younger generations in particular supported this, with 60% of 25–34-year-olds having proved in favour.
- This shift is seen as a necessity, as policymakers are increasingly facing rapidly changing, complex global and interconnected challenges that are difficult to understand and tackle without relevant datasets, scientific evidence, scenario-analysis tools, and the help of AI.
- Digital transformation can support the achievement of local, national, regional, and global development priorities. It has been argued that 70% of all SDG targets globally will benefit from data and digital technologies, while 13% of the targets call directly for the use of these technologies.
- The question of whether AI could support policymaking is now more prominent than ever in governments around the world. A report published in 2023 showed over a third (37%) of United Kingdom government bodies to be actively using AI, and a further 37% to be actively piloting (25%) or planning (11%) the use of AI.
- In 2023, the Central Digital and Data Office of the UK estimated that almost a third of tasks in its government could be automated.

Sources: The Policy Innovation Lab, the Joseph Rowntree Foundation, and the Center for the Governance of Change

MIXING **MUSIC** AND **MATHEMATICS**

WAYNE MULLER

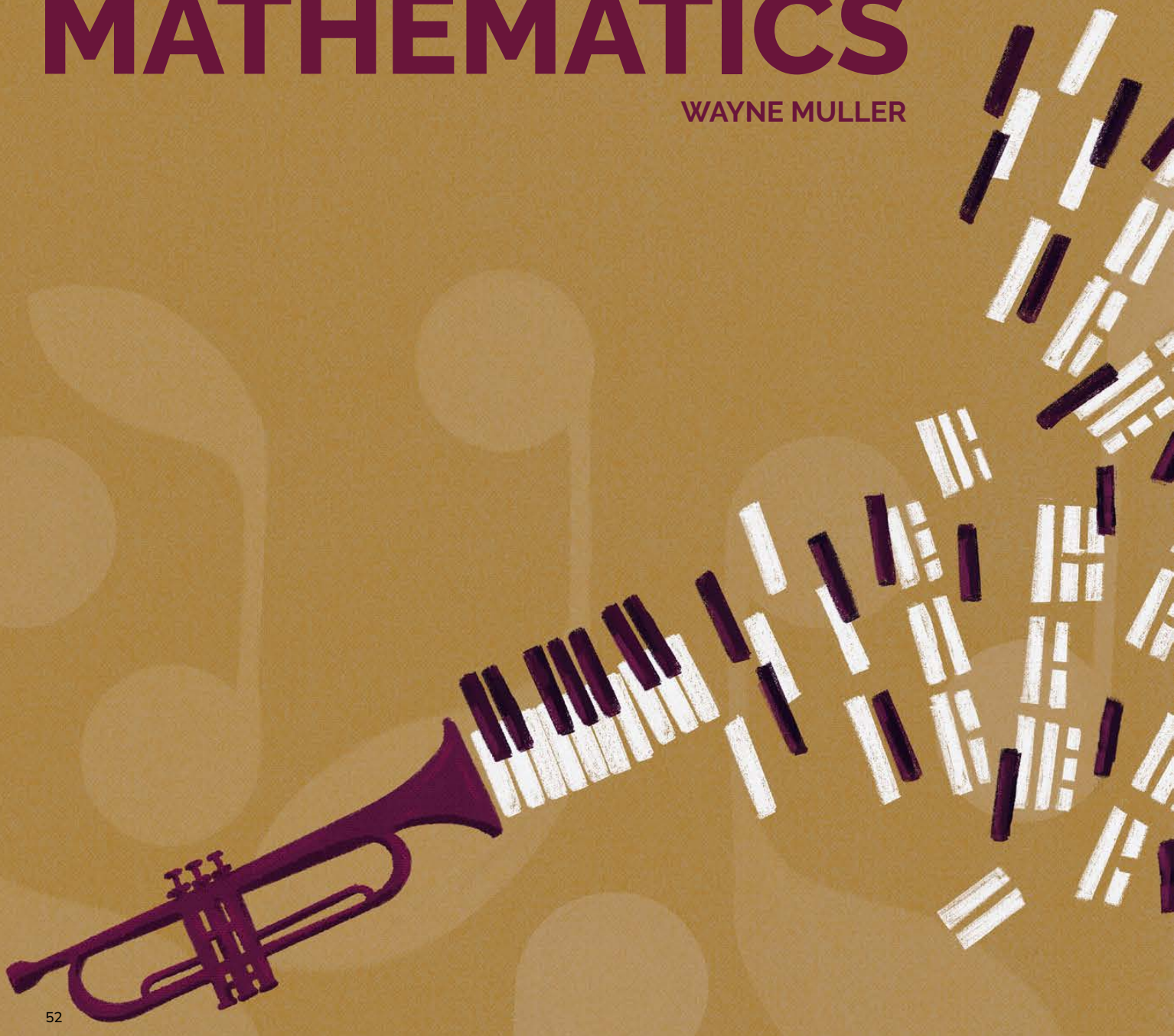


Illustration by Ronel van Heerden

Imagine attending a symphony concert, the sweeping sounds from the orchestra filling the hall while you feel the rhythm of the music resound within your body. You hear notes rising and falling in pitch, and becoming expressively louder and intimately softer.

Prof Hans Roosenchoon | Photo by Stefan Els

You hear the patterns in the music, the shaping of harmonies, and the intermingling of different melodic lines. At times, sudden changes in rhythm, pitch, and intensity surprise you. All these various elements interlock like small puzzle pieces to form a coherent piece of music.

Although we may listen to it daily, we seldom think of all the components that were combined to create our favourite piece of music. We don't think about each musical note individually but rather hear and experience the bigger structure — often something more than just the sum of these notes.

> Simply put, this is what Gestalt theory is all about: the whole being greater than its parts. Individual notes say nothing about the musical creation as a whole. They only make sense when a variety of them are organised rhythmically on various pitches and at different intervals to construct a melody.

This idea of structure in music is what brought together two neighbours, composer Prof Hans Roosenschoon and mathematician Prof Zurab Janelidze, during the COVID-19 lockdown period in 2020. What started as casual neighbourly conversations later turned into increasingly serious philosophical dialogues over coffee about the intersections between music and mathematics.

Musical conversations

Roosenschoon, an emeritus professor in Stellenbosch University's (SU's) Department of Music, is an award-winning composer whose work has been appreciated across the globe. As a lecturer, he enjoys teaching new generations of composers. His own body of work spans a variety of genres: works for orchestra, choral works with orchestra, solo works with orchestra, chamber works, keyboard works, solo vocal works, choral works, and electro-acoustic music. Interestingly, as he explained in a colloquium talk hosted by the National Institute for Theoretical and Computational Sciences (NITheCS) in 2022, some of his music has mathematical patterns at its base.

As a professor of mathematics in SU's Department of Mathematical Sciences, Janelidze's field of expertise is that of categorical algebra (algebra seen from, and generalised via, the category theory). He currently serves as the president of the South African Mathematical Society. But his interests do not stop with mathematics. Janelidze is also an avid musician who plays piano and composes his own music.

It was conversations about their own compositions that led the pair to talking about the touchpoints between music and mathematics. This sparked the beginnings of a project that would bring together their expertise in these two disciplines and explore how they intertwine.

The question of how the structure of a piece of music could be mathematically represented quickly became the duo's major interest. This is what led them to considering Gestalt theory.

There is already much literature on aspects of music and mathematics such as symmetry, geometry, and equations. The concept of Gestalt structures in music was first explored in the early 1980s, when certain rules for the application of the theory were devised, but the concept of a universal Gestalt underlying all music was not yet explored.

In search of the universal

In their joint project, Roosenschoon and Janelidze conceptualised a musical phrase or idea as a large Gestalt that can be broken down into different smaller Gestalts organised in specific identifiable patterns.

The pair, together with their research assistants, took Roosenschoon's piano solo piece 'Kriek/Cricket' and transformed it into Gestalts using a string of numbers. Janelidze says this relates to the mathematical concept of trees, which represent a graph or structure that can be broken down into the smaller units.

After 'Kriek/Cricket', they turned to Beethoven's popular 'Für Elise' with its opening bars of repeated sections. Their focus was on reflecting this repetition in a Gestalt structure that shows the bigger musical idea broken down into repeated patterns. A song by The Beatles followed, and eventually even death metal music. This was all done in an attempt at finding a Gestalt that represents a universal structure in music. However, they found that there is no single universally applicable structure.

Individual interpretations

With 'Für Elise', they found there were also different interpretations of the Gestalt structure, depending on the listener's experience. When the pair and their assistants asked each other to identify the piece's Gestalts and its patterns, each individual came up with a unique but valid structure. Moreover, different musical forms already identified, such as the sonata, also didn't conform to a uniform Gestalt structure.

> "Music is a mystery," says Roosenschoon, adding that Gestalts and other forms of codification do not explain the enigma of the human experience of music. There are many aspects of musical interpretation that are not codified and cannot be captured in notes written on paper.

It is only in hearing a piece of music, for instance, that one can experience its texture (the effect of different layers of sound, created through the particular combination of tempo with melodic and harmonic elements). Also, the same note, say C, sounds very different at different pitches. And although the musical text (or 'score') may remain the same, its interpretation can differ when the piece is played by different musicians or on different instruments.

Live experimentation

In July 2023, Janelidze and Roosenschoon did a presentation in the Department of Music's Jannasch Lecture Hall, where they experimented with musicians' interpretations of Gestalts. On a piece of paper, they drew a Gestalt structure that represented a musical idea and the patterns that make up the structure. Two music students and a musically gifted student in applied mathematics were then asked to look at the picture and interpret the structure by improvising on the piano and saxophone.

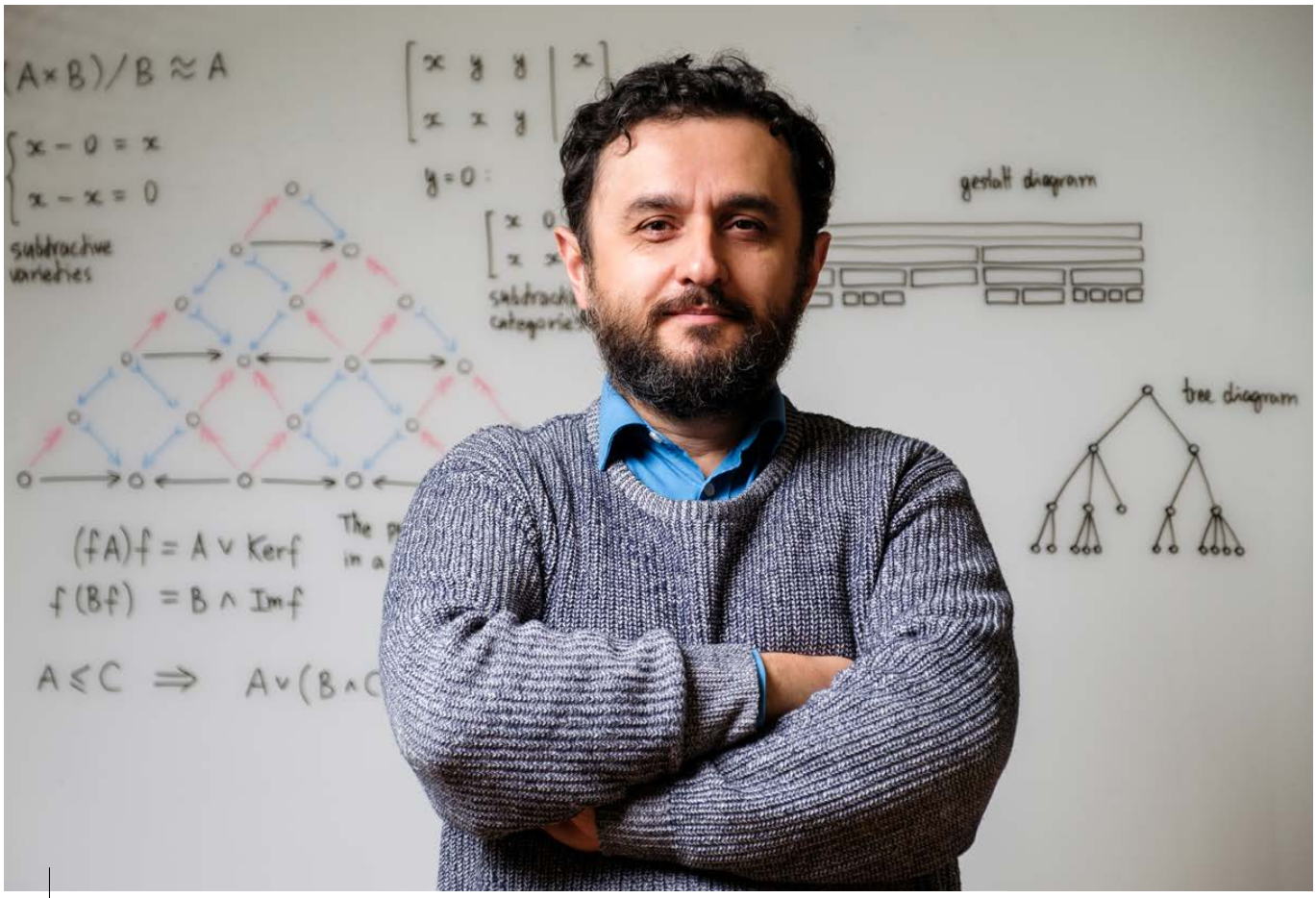
For audience members too it was an interesting exercise to participate in. During the lecture, Janelidze showed the structure drawn on paper to the audience first, and then only to the musician. This allowed time for the audience to imagine for themselves what type of music could be created with the given structure.

> When the pianist moved behind the piano and regarded the structure for the first time, he started an improvisation that was often quite different to what audience members had imagined. This indicates that, although a given piece of music necessarily has a set structure, there is much that can be improvised and interpreted within those boundaries, ultimately rendering each performance and interpretation thereof unique.

Subjectivity in analysing music

Roosenschoon explains that composing music is a life-long training process, and that seeing notes and hearing them are two very different things. A bar diagram cannot really explain this difference, he adds.

While the same Gestalt diagram can have different musical interpretations, as demonstrated in the lecture, the converse is also true: When listening to a piece of music and trying to draw a Gestalt representative of its structure, the result will depend on the listener's interpretation and experience of the music. Hence, there is subjectivity in the process.



Prof Zurab Janelidze | Photo by Stefan Els

One must decide what the parts are and which priorities you will use to compartmentalise the patterns. Do you consider the beats to be the deciding factor in where a Gestalt starts or ends, or do pauses in the music indicate those beginnings and endings?

In music theory, there are already different ways to analyse music, such as through the systems developed by Heinrich Schenker (Schenkerian analysis) and Allan Forte (atonal musical structure analysis). Still, what has been discovered through this experimentation around Gestalts in music can be useful in music training, says Roosenschoon.

Listening to music and then writing down the Gestalt structure can serve as a method for analysing music from an aural perspective rather than on grounds of the score. Roosenschoon reckons this creates an opportunity in music theory for a new approach to music analysis, as well as a means of developing young students' aural skills. A study of the score can follow afterwards, allowing for comparisons to be made between the aural and score analyses. This method can even be used in schools as a fun way of building bridges between music and mathematics, thereby sparking an interest in both subjects.

To this end, in December 2023, the theatrical production *Fundamano 2* at the Drostdy Theatre in Stellenbosch was dedicated to conveying the basic ideas of Gestalt structures to a wider audience, including school learners. This was done by means of an improvisatory play prepared by Janelidze, with the help of colleagues and students in mathematics and music.

Both professors believe the method of structuring music according to Gestalts holds future applications. They would like to employ it in analysing and creating structures for large works such as entire symphonies. Janelidze is particularly keen on exploring mathematical algorithms for generating, from music, a Gestalt hierarchy that takes into account the intuitive, subjective interpretations of Gestalts. Even for a seasoned composer such as Roosenschoon, the Gestalt method offers a means of better understanding the theory and practice of music in order to improve composition.

Recently, as a means to further test the sonic reach of the Gestalt method, Janelidze engaged with Dr Esther Marie Pauw and her team at SU's Africa Open Institute for Music, Research and Innovation in free improvisation sessions. Here, musicians improvised the performance of a piece of music on grounds of a mathematical tree representing a Gestalt hierarchy.

Janelidze and Roosenschoon plan to continue their collaboration in expanding the theory and applications of musical Gestalt theory under the auspices of the NITheCS.

Congratulations to psychologist and scholar Prof Pumla Gobodo-Madikizela, who has won the 2024 Templeton Prize for her insights into the mechanisms of trauma and forgiveness in post-apartheid South Africa that have created a globally recognised model for social healing.

#TempletonPrize2024

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