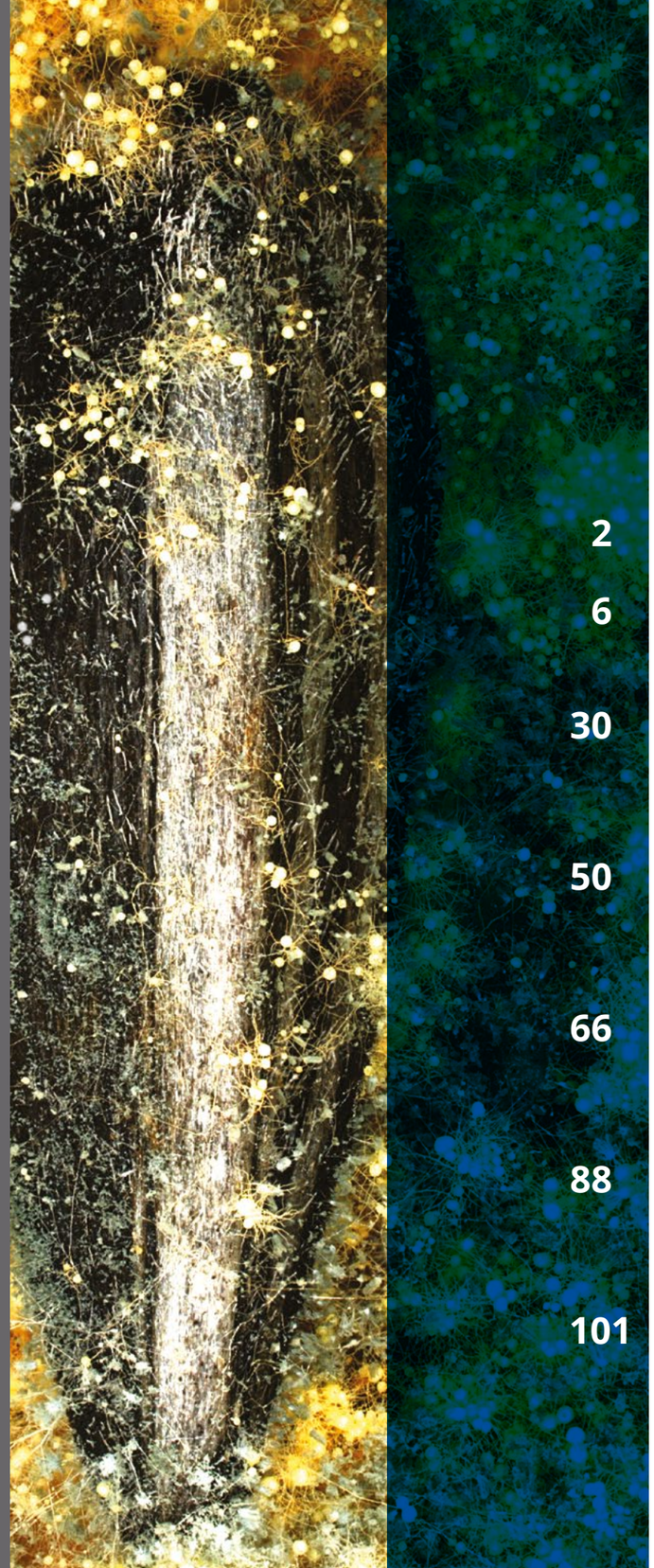
UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

RESEARCH REVIEW 2018

Through the lens of a microscope, science and art fuse in a beauty that was previously invisible. The cover image is that of *Aspergillus westerdijkiae* conidiophores, named after the first female professor from the Netherlands who, as a mycologist, trained students from around the world, including in South Africa. The image on the opposite page is of a sunflower seed covered with *Aspergillus chevalieri*.



UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Foreword

The University of Pretoria is proud to be closely focused, through our research, on our place in Africa and the contributions we make to our collective futures.

Each year the University publishes a Research Review that showcases a selection of people and projects that make up the vibrancy of our varied research contexts, and of the ideas and questions that are being pursued at UP. While only a selection of UP's research endeavour can be presented, the theme narratives illustrate both the diversity of people and knowledge fields, and the synergy in contributing to new understanding of our the social and natural worlds.

The profiles included in the 2018 Research Review are grouped under five broad themes, each theme illustrating different dimensions of the nature and process of research that deliberately collapse disciplinary silos and institutional structures, while acknowledging the unique strengths that each knowledge field brings to the specific issues being investigated. The themes and sub-themes are: i) Texts and context – *ways of seeing*; ii) Technologies, tools and big data – *visualising the unseen*; iii) Biodiversity and biotechnology – *identifying the patterns*; iv) Health and place – *finding solutions*; and v) Markets and development – *acting in context*.

In broad terms, research is about ways of knowing, and methods or techniques used in pursuing specific questions or problems. The profiles included in this Review illustrate both the distinctness and the confluence between different knowledge fields.

What ties this all together, and is a recurrent theme throughout the Review, is the role of research in examining the world in which we live – from the humanities and the sciences, to new technologies and tools used in the process of research. In short, the Review celebrates the new ways of seeing, analysing and understanding, and the actions emerging from the University.

The University has a wealth of academics and research teams who have excellent projects and have produced noteworthy results. Our objective, each year, is to foreground emerging researchers, as well as research leaders and teams, and in this combination, to capture the immense talent we have at UP.

With Africa's people already representing around 20% of the world's population and growing, the future of the world is predominantly African. A deliberate dimension in this Review is therefore to foreground the future research leaders who need to ensure that the impact we have today will build the research, innovation and development capacity that Africa needs, to address the big challenges faced by Africans. I would like to extend my congratulations to the Vice-Principal, Professor Stephanie Burton, for her leadership role in research, and her contribution to the development of our future research leaders.

Professor Cheryl de la Rey, former Vice-Chancellor and Principal of the University of Pretoria (2009–2018) was the custodian of 2018. I wish to acknowledge my predecessor's immense contribution to the University, and finally, all the researchers whose work are profiled in this Review.

Professor Tawana Kupe,
Vice-Chancellor and Principal, University of Pretoria

Introduction

UP's research strategy is centred by our commitment to pursue research that matters, and in this way to contribute to a sustainable future for Africa.

Embedded in the University's long-term strategic plan, UP 2025, is our vision to become a leading research-intensive university in Africa. As the performance results for 2018 have shown, there has been a consistent strengthening of the University's research capacity: the increase in research productivity, the percentage of staff with doctorates and those who have achieved National Research Foundation (NRF) ratings, the number of postdoctoral fellows, and the number of Master's and doctoral graduates. Taken together, all these have contributed to UP's research-intensive identity, and to strengthening our pipeline of the next generation of researchers and science leaders.

In 2018, the percentage of academic staff with PhDs stood at 67%, and the number of NRF-rated researchers at 507, which is 37% of academic staff at UP and 13% of all NRF-rated researchers in South Africa. Postgraduate student enrolment made up 33% of the overall enrolment at UP, while the number of postdoctoral fellows were 253, of whom 118 (47%) were female, and 164 (65%) were from international destinations.

In 2018, 36 new and renewed agreements were concluded with regional and international partners, taking the total number of active agreements to 204, across 70 countries and six continents. A good proxy for the effectiveness and extent of UP's networks of collaboration is the number of internationally co-authored papers. Over a five-year period (2014–2018), 44% of UP's research publications were co-authored with regional and international scholars. Furthermore, 1 392 publications (or 10,6%) were positioned in the top 10% globally, based on citations. Further evidence of UP's international standing are the number of researchers and papers positioned in the top 1% globally. In 2018, 53 UP researchers were positioned in the top 1% internationally, with 145 papers.

UP's focus on research partnerships in Africa is closely related to pursuing science that transcends disciplinary and institutional divides, and advances the type of science leadership needed to address key challenges in Africa. To this end, UP is a partner in a number of research consortia in Africa and contributes actively to the region's knowledge base and planned intervention strategies.

There were a number of new developments in 2018. In line with the University's strategy to prioritise areas of research strength, three major research platforms will shape the future direction of research: the Future Africa Institute and campus, the Javett-UP Art Centre, and the start of the Engineering 4.0 development and Future Transportation Hub. These are briefly reported on in the conclusion to this Review, illustrating the nature of research that underpins convergence science and translational research, and thereby maximising relevance and impact.

I would like to extend my sincere appreciation to those who are doing the excellent research we have showcased here, and to all who have contributed to this 2018 Research Review.

Professor Stephanie G Burton,
Vice-Principal: Research and Postgraduate Education

Acknowledgements

The Research Review is one of the important projects of the Department of Research and Innovation, and a highlight in our calendar. Its production involves many people, from inception to conclusion and in the final dissemination of print and electronic copies.

I would like to acknowledge the contributions of the following individuals and departments:

- First and foremost, the researchers who are profiled in this Review, and those who prepared texts but whose work could not be profiled due to space constraints.
- The panel of expert editors who served as critical readers and gave generously of their time: Professors Don Cowan, Robin Crewe, Christof Heyns, Michael Pepper, Corinne Sandwidth, Bernard Slippers and Brenda Wingfield; and Dr Cheryl Tosh who prepared the texts for the Health Sciences.
- Sunette Steynberg in the Department of Library Services for her expert assistance with data sourced from international indexes on UP's research performance.
- Hugo Mouton and colleagues in the Department of Institutional Planning for their willingness to check the accuracy of data, and to generate new data where this was not readily accessible from the University's Higher Education Data Analyzer system.
- Colleagues in the Department of Research and Innovation for their support, and for preparing the detail on UP's research publications in 2018, and colleagues in the Department of Library Services for linking the research outputs to UPSpace.
- Melandré Frost for locating and cataloguing images received, and for her sterling administrative support to the project.
- Hanlie Griesel who planned, edited and coordinated the production of the Review.
- Ingrid Clarke and her team at Words'worth for the design and production of the Review.

Finally, I would like to extend my appreciation to Professor Stephanie Burton for her leadership role in the production of the 2018 Research Review. We look forward to receiving your feedback – be it in person or by email.

Dr Nthabiseng Taole
Director: Department of Research and Innovation

2018 Research overview

NEXT GENERATION RESEARCHERS

1 993 Master's graduates

427 Doctoral graduates

253 Postdoctoral fellows

58% Black M and D graduates

33% Postgraduate students as % of overall enrolment

65% International postdoctoral fellows

RESEARCH CAPACITY

507
Total UP researchers with NRF-rating: A-rated 14; Y-rated 88

67% Staff with PhDs

37% Academic staff are NRF-rated

13% of all NRF-rated researchers in South Africa are at UP

RESEARCH ENTITIES

72 UP Research Institutes and Centres

33 Industry and public sector Research Chairs

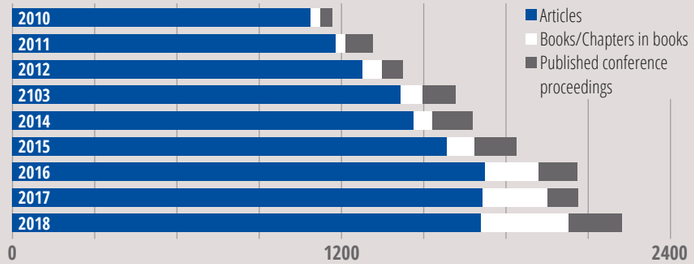
19 DST-NRF SARChI Chairs#

4 Centres of Excellence

South African Research Chairs Initiative (SARChI)

RESEARCH PRODUCTIVITY AND QUALITY

UP Research Outputs, 2010–2018



296 International staff

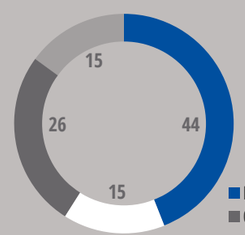
53 Researchers in top 1% of ESI fields †

145 Papers in top 1% internationally, based on citations ‡

2 UP researchers of 10 in SA among most highly cited in the world *

NETWORKS AND COLLABORATION

Co-authored papers over five years, 2014-2018§



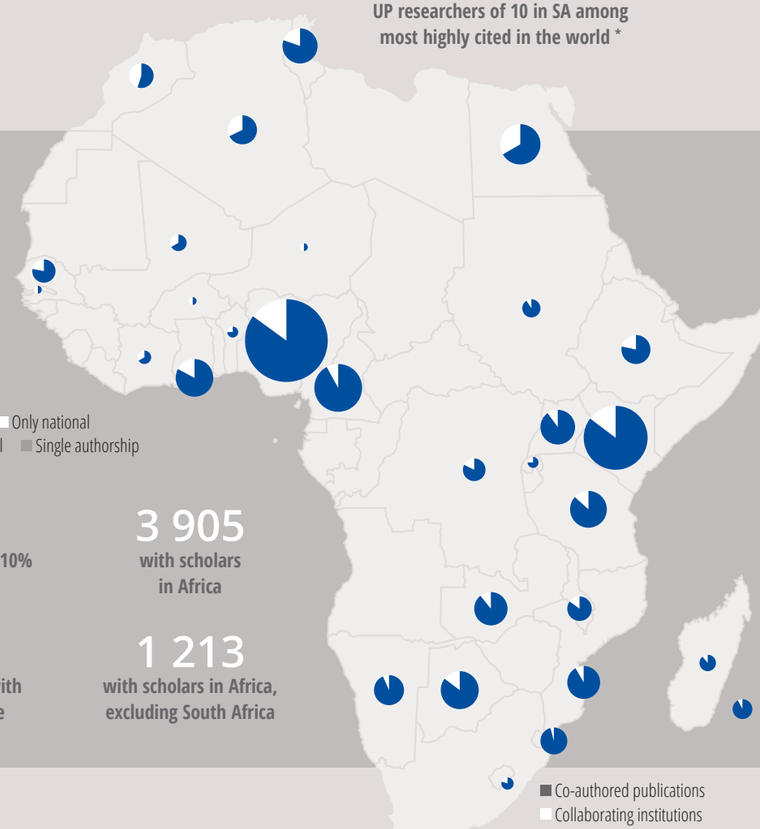
44% of publications co-authored with international scholars

1 392 publications in the top 10% most cited (10,6%)

3 905 with scholars in Africa

7 426 co-authored papers with scholars world-wide

1 213 with scholars in Africa, excluding South Africa

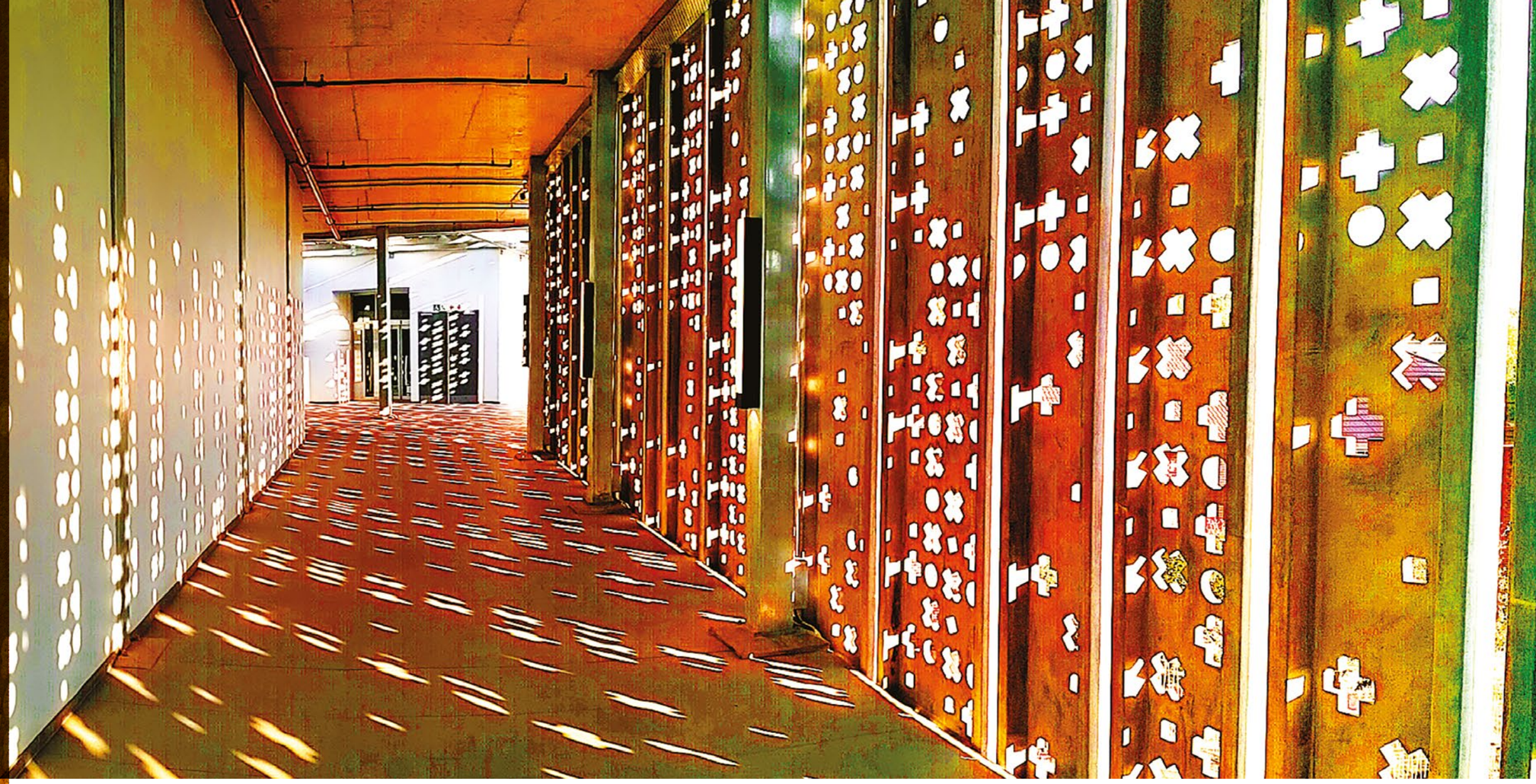


# of UP co-authored papers with international scholars §

2010	2011	2012	2103	2014	2015	2016	2017	2018
527	624	725	875	885	1 034	1 210	1 275	1 365

* Clarivate, Web of Science (WoS). † Essential Science Indicators (ESI), Clarivate, WoS. ‡ ESI. § SciVal, Scopus.

The first theme introduces ways in which the tools of analyses and interpretation of people and contexts bring into focus new 'ways of seeing': from identity, history and the archive to short stories and novels, and analyses of the cultural, political and legal practices as the objects of research that frame our understanding of what is, or may become, possible.



WAYS OF SEEING

Texts and context

Ways of seeing

What is Africanness?

Charles Ngwena, Centre for Human Rights

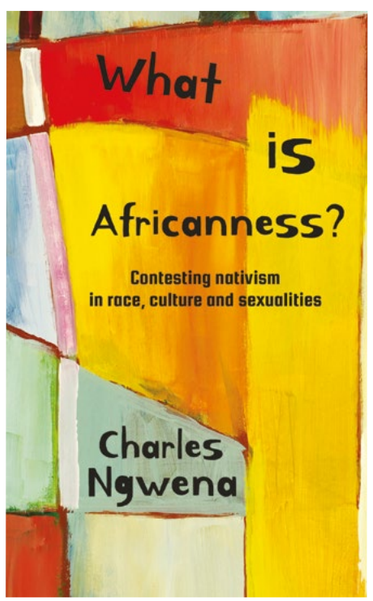
Without the benefit of a theory to articulate Africanness, we are left only with uncritical dogma and its studied repetition.

Professor Charles Ngwena's book, *What is Africanness? Contesting nativism in race, culture and sexualities* (PULP, 2018) was written as an intervention in contemporary debates on the making of the African 'race', cultures and sexualities. More particularly, it is a counter-discourse to articulations of Africanness that essentialise – or what he calls 'nativise' – African lifeworlds.

Hence the main question the book addresses is: Who/what is African? The book treats this question as a discourse question; instead of setting out to answer the question, it develops an interpretive method – the hermeneutics of Africanness – as its theoretical contribution towards deciphering inclusive Africanness.

The book draws its theoretical strands from the work of Stuart Hall and other cultural theorists to argue that when thinking about Africanness, dichotomous categories do not serve us well. Africannness is extraordinarily diverse precisely because it is situated in a multiplicity of histories, cultures and subjectivities that speak less to African identity in the way it has been espoused in colonial discourses and by ideologues of identity, and more to African *identifications* in the sense intended by Hall.

The conceptual framework for Africanness presented in this book is a deconstructive tool that should incline us towards detotalised enunciations in order to register radical historicisation and the constant process of change, transformation and positionality. It is a concept of identity better understood as *identification*; a situated constellation made up of multiple subjectivities, and an open, as opposed to closed, category.



Charles Ngwena with Satang Nabaneh, a doctoral student at the Centre for Human Rights.

Apart from serving as a counter-discourse to nativising discourses, *What is Africanness?* is also an attempt to fill a theoretical gap in African identity discourses. Much has been written about the generality of the African subject – its shared 'public identity'. However, very little has been written about the African subject and its experience of radical uncertainty – its 'lived subjectivity', specificity, complexity and, above all, its plurality which, as Achille Mbembe emphasises, defies convergence towards a single trajectory. Moreover, little has been written about the commensurability of mutual recognition between different social identities.

This book is about developing theory and method for closing this gap. It advances a theory of African social or cultural identity in ways that account for, rather than erase or gloss over, historical agency and fluidity, multiplicities of cultural repertoires and the commensurability of differences within African identifications. Ultimately, *What is Africanness?* seeks to develop a theoretical archive of self-naming that enlarges the human freedoms of Africans.

In 2018, Pretoria University Law Press published its 200th title, a landmark publication by Charles Ngwena, a staff member in the Centre. His book, *What is Africanness? Contesting nativism in culture, race and sexualities,* fits squarely into contemporary discussions on race and identity in South Africa.

Open access scholarship and human rights

Through its regular academic journals, edited and published from within the **Centre for Human Rights** in the Faculty of Law, and through the Pretoria University Law Press (PULP), the Centre has been advancing accessible and quality human rights African scholarship.

All Centre and PULP publications are available online in electronic format at no charge. Professor **Frans Viljoen**, Director of the Centre, writes that 'Open-access publication in Africa is both an ethical and practical imperative. Such publications remedy the defect of inadequate libraries on the continent, and allow greater inclusion of Africans in the use and production of scholarship'.

Through PULP, the Centre publishes three journals with a focus on human rights in Africa: the *African Human Rights Law Journal*, now in its 18th year; the *African Disability Rights Yearbook* which, in the six years of its existence, has established itself as a unique and important source on disability rights in Africa; and the *African Human Rights Yearbook*, of which two volumes have already appeared. The three African Union human rights bodies – the African Court on Human and Peoples' Rights, the African Commission on Human and Peoples' Rights, and the African Committee of Experts on the Rights and Welfare of the Child – collaborate in this joint publication.

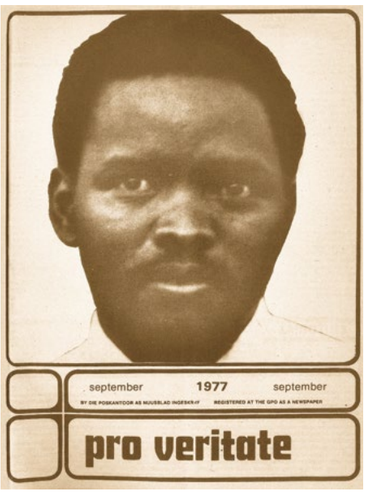
In addition to publishing books, and the three journals, PULP also publishes *Pretoria Student Law Review* and *De Jure*.

Understanding the past –

the craft of historians

Ian Macqueen, Department of Historical and Heritage Studies

In the context of heated, often ill-informed, public debate in South Africa, the craft of the historian is to challenge fiercely-held assumptions and to point to the importance of a firm grasp of history.



A case in point is the history of Black Consciousness in South Africa, which is too often cast as anti-white. In so doing, its humanist dimensions are obscured and its ecumenical origins forgotten.

Dr Ian Macqueen's recent book titled, *Black Consciousness and Progressive Movements under Apartheid* (UKZN Press, 2018), foregrounds the cross-racial relationships in South Africa that characterised Black Consciousness at its inception, and which persisted until its banning by the apartheid regime in 1977. The book tells the story of the life and work of Steve Biko and, among others, his friendship with the philosopher and lecturer at the University of Natal, Dr Rick Turner, who was assassinated in January 1978, four months after Biko's death. The 1970s was a period of intense activism when strong global connections – with movements such as ecumenism, feminism and the New Left – were forged. It was in this rich context that Black Consciousness emerged in dialogue with competing visions of freedom espoused by progressive movements elsewhere. Although these were never easy relationships, the dialogue sharpened ideas.

According to Dr Macqueen, it is often forgotten that churches played an important role in providing the space, protected to some degree from the apartheid state, in which activists and students could meet and organise. For example, the University Christian Movement was instrumental in helping to facilitate early contacts among students who were segregated by the apartheid state.

The impact of Black Consciousness on white-dominated progressive organisations is also highlighted, including the National Union of South African Students (NUSAS) and the Christian Institute. Founded in 1963 by predominantly dissident Dutch Reformed clerics, and led by Beyers Naude, the Christian Institute was radicalised in part through its contacts with Biko and other Black Consciousness activists. The newspaper *Pro Veritate*, which was associated with the Christian Institute, featured Biko on the cover of its last issue before it was closed by the apartheid state; what had begun as an ecumenical church newsletter in the early 1960s was significantly transformed, both theologically and politically; this, in no small measure, due to the influence of young black students.

In 2018, Dr Macqueen drew on his research to publish a review article in the *Journal of Southern African Studies* and in the online journal *Thread*.

On method and archival evidence

Thula Simpson, Department of Historical and Heritage Studies

The challenges facing post-apartheid South Africa require more than a chronological extension of existing narratives to the present; they force a reconsideration of the past in its entirety, based on what contemporary developments reveal to be its most enduring legacies.

Over the past few years, Professor Thula Simpson has been working on a book project focusing on the history of South Africa from the aftermath of the Anglo-Boer War to the present. The manuscript follows his earlier work on the history of the ANC's military wing Umkhonto we Sizwe (MK) which was published in a number of journals, as well as in edited book collections. The research culminated in *Umkhonto we Sizwe: The ANC's Armed Struggle*, published by Penguin Random House in 2016.

His present work follows from his research on MK, which showed that the existing archives contain material that enables a reinterpretation of the broader history of South Africa. The current project directly preceded the emergence of the Fallist movement on university campuses nationwide, one which raised questions regarding the curriculum and the history curriculum in particular. The call to return to the archive therefore comes at an important moment. Accordingly, the resulting manuscript is based on extensive primary research in domestic and international archives, and offers fresh perspectives on many key events that have marked South Africa's development.

In a different project, Thula Simpson and Nic Wolpe, the CEO of the Liliesleaf Trust, are lead investigators of a three-year research project aimed at developing the Archives at

Liliesleaf of the liberation struggle in South Africa. An initial conference in March 2019 brought scholars and veterans together to discuss the circumstances surrounding the ANC's turn to armed struggle in the early 1960s. The partnership reflects, in part, a concern flagged by Professor Simpson in an article published in the *Journal of Southern African Studies* in 2018. The article focused on Nelson Mandela's role in leading the formation of Umkhonto we Sizwe, and highlighted methodological principles that are necessary when working in the archives if one is not to distort the interpretation of causal historic moments. The ongoing collaboration with Liliesleaf will include workshops, seminars, conferences and interviews that will build the archive, and will culminate in a documentary fusing the archival material with historical scholarship and analysis.

A history of intricate connections

David Medalie, Department of English

The lives of South Africans have always been interwoven in complex ways. There is a long history of division; but also of profound (and often surprising) instances of mutual recognition.

Recognition is an anthology of short stories in which twenty-two South African writers render these intricate connections of recognition and misrecognition. The writers whose stories have been selected use the transformative power of the imagination and the unique appeal of the short story to illuminate aspects of our past and present. Cumulatively their stories tell of a history tainted by misrecognition but not, finally, bound by it.

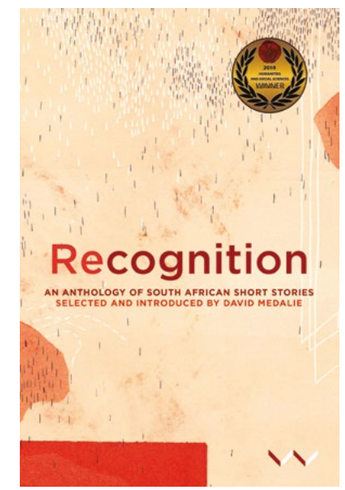
David Medalie, editor of the anthology, is the Director of the Unit for Creative Writing, and Professor in the Department of English at UP. He is a short story writer, novelist and anthologist whose own writing and publications have won or been shortlisted for awards in recent months.

Recognition, published by Wits University Press, includes an introduction written by Professor Medalie. It traces the motif of recognition, discusses the general characteristics of short stories (a genre in which South Africa writers have excelled) and the narrative devices used by writers, and offers a brief analysis of each short story. The anthology has just been reprinted for the third time and has been prescribed at a number of schools and universities, including the University of Pretoria. It has also won a prestigious award in March 2019 from the National Institute for the Humanities and Social Sciences, as the winner in the category of Best Fiction Edited Volume.

Among the twenty-two contributors are some of South Africa's best-known short story writers: Pauline Smith, Herman Charles Bosman, HIE Dhlomo, Can Themba, Nadine Gordimer, Alex La Guma, Dan Jacobson, Miriam Tlali, Ahmed Essop, Njabulo Ndebele, Mandla Langa, Chris van Wyk, Damon Galgut, Achmat Dangor and Zoë Wicomb. And there is also a selection of vibrant newer voices: Makhosazana Xaba, Nadia Davids, Mary Watson, Lindiwe Nkutha, Wamuwi Mbao and Kobus Moolman. Chronologically, the collection ranges from the 1920s to the 21st century.

A short story by Professor Medalie, *Borrowed by the Wind*, was shortlisted for the Gerald Kraak Award and subsequently published in 2018 by Jacana Media in the second anthology derived from the award, entitled *As You Like It: African Perspectives on Gender, Social Justice and Sexuality*. The events in Medalie's story span two time periods, the first part being set during the apartheid years and the second taking place during the post-apartheid period. The story explores a number of issues, including sexual identity, masculinity, violence and the manipulation of the past for expedient reasons.

Professor Medalie has published a novel, *The Shadow Follows*, and two collections of short stories, *The Shooting of the Christmas Cows* and *The Mistress's Dog*. The title story of the latter collection won the Thomas Pringle Award in 2008 and was shortlisted for the Caine Prize, the pre-eminent award for African writing, in 2011.



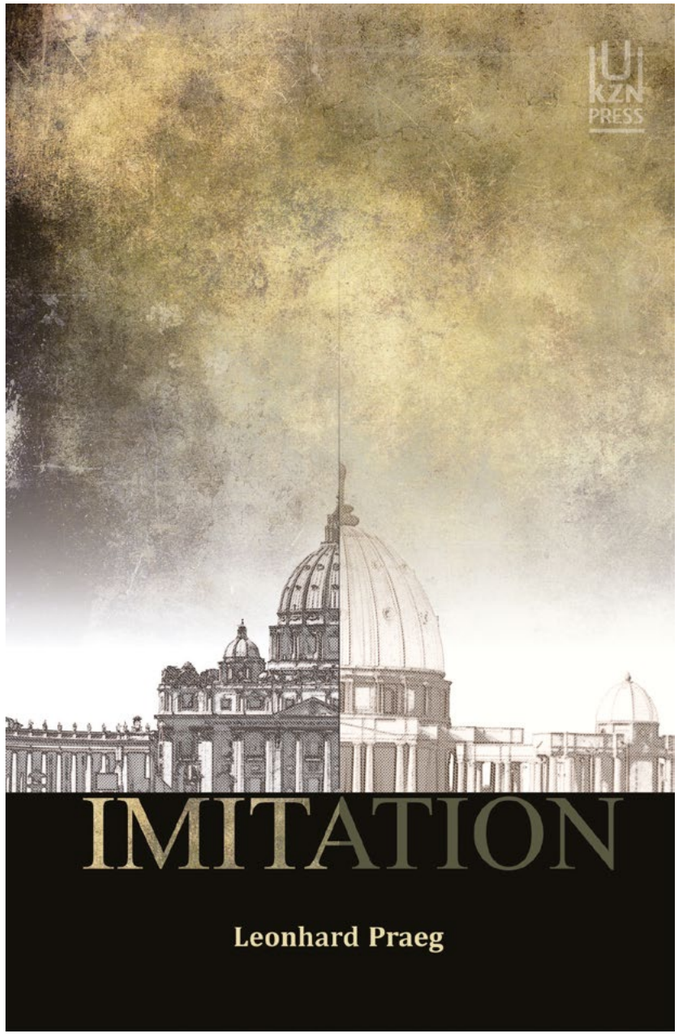
The Unit for Creative Writing

The Unit for Creative Writing has had rewarding results: there is great interest in this field of study, with a number of prominent writers enrolling for master's and doctoral degrees. Two of them – Dr Fiona Zerbst, an acclaimed poet, and Dr Terry Westby-Nunn, an award-winning novelist – received their PhDs in Creative Writing at recent UP graduation ceremonies.The current enrolment includes such literary luminaries as the playwrights Mike van Graan and Ashraf Johaardien and the novelists Fred Khumalo and Barbara Adair. In addition, Niq Mhlongo, an award-winning novelist and short story writer, was appointed a Mellon writer-in-residence at the University of Pretoria for the second semester of 2019.

On *Imitation*

Leonhard Praeg, Department of Philosophy

Imitation (2018) is a conscious intertextual dialogue with Milan Kundera's novel Immortality (1990). At times serious and melancholy but at other times light and playful, it is also an imitation of Kundera's novel, a replica of its textual floorplan and architectural design.



But the origin of *Imitation* does not lie in any conscious decision to imitate *Immortality* or even to engage Kundera in conversation.

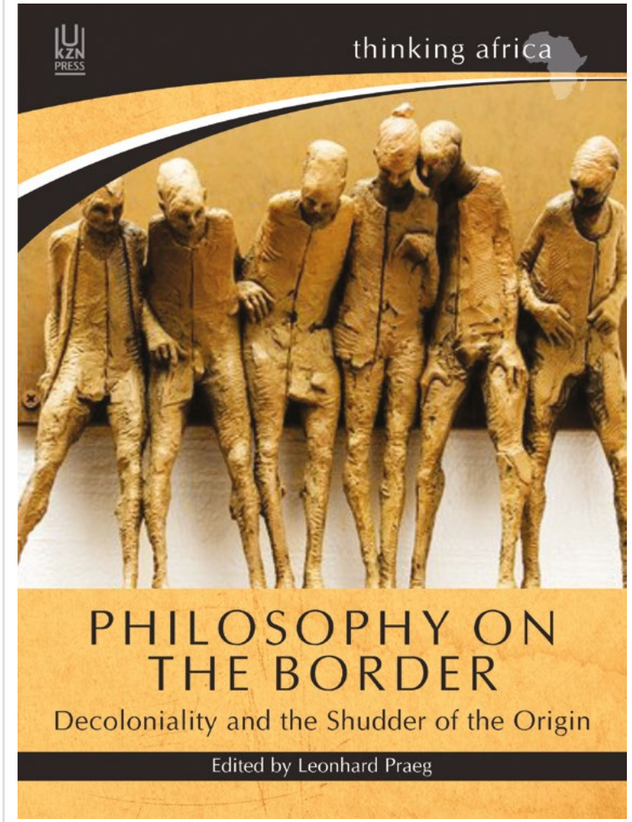
When the story of former president Jacob Zuma's Big Man building project at Nkandla broke, Leonhard Praeg was immediately fascinated. But, he writes, for all the wrong reasons: not by the impunity of excess, not even by the question of how a political party, built on a rhetoric of 'unity' and 'collective responsibility', would deal with such a flagrant violation of executive authority, or any of the other mainstream modulations of outrage. His fascination was fuelled by something entirely different: repetition.

Big Man building projects are no stranger to the human imagination. From the Great Pyramids of Giza to the Taj Mahal, from the now deserted and plundered palaces of Mobutu Sese Seko to the highest basilica in all of Christendom, Our Lady of Peace in Yamoussoukro, Côte d'Ivoire (itself an imitation of St Peter's basilica in the Vatican City), man's history is in many ways little more than a ruin of failed stabs at immortality. To stay with the metaphor, a basic building block of all these building projects was – and arguably continues to be – a conception of authority that found its clearest expression in the medieval legitimation of papal authority, namely *plenitude potestatis* or the plenitude of power.

Such building projects are always shadowed by the longing for the plenitude or fullness of power and the rulers who conceive and commission them are quite literally full of themselves. This is what fascinated Praeg about Nkandla: the possibility of writing a genealogy of *plenitude potestatis*; of tracing the history of its emergence through the vicissitudes of its pre-articulations and earlier embodiments which no doubt reached its most absurd apotheosis in that monument to imitation, Our Lady of Peace Basilica, which was consecrated by Pope John Paul II in the same year that *Immortality* appeared in print. But the writing of such an history would require more than one lifetime to complete. It was simply too big for one mere mortal. And so, the idea emerged of exploring what fascinated him in novelistic form.

As a genre, the novel allows the writer to be sweeping; to present an impressionistic sketch of what would otherwise require the patient scholarship of many lives. The project was guided by two further imperatives: on the one hand, as Kundera repeatedly states, the novel has to do what only the novel can do. It shouldn't attempt to do history or philosophy. On the other hand, such a novel would need to do what philosophy cannot do, and that is to take a broad sweep at portraying the lived experience of some of the little human beings who get caught up in the drama that is the Big Man's quest for immortality. Rooted in a sense of impossibility, *Imitation* slowly emerged as no more than a gesture and an intimation of mortality.

Leonhard Praeg is Professor and head of the **Department of Philosophy** at UP.



Thinking Africa

What has since been established as the scholarly imprint of UKZN Press, published in association with the Department of Philosophy at UP, started out as a series dedicated to publishing the research outputs of the research-led teaching project, Thinking Africa – research produced through postgraduate courses that culminated in an annual conference in which students and scholars, both national and international, participated.

Since the publication of its first volume in 2012, the series has given priority to studies that offer a sustained interrogation not only of the themes of memory, alterity, African humanism, and violence but also of Western modernity itself. The volumes would be of interest to scholars who are intrigued by the possibility, and imperative, to think Africa from a position that is at once post-Area Studies and transdisciplinary. The most recent volumes are *Afrikaner Identity: Dysfunction and Grief*, by Yves Vanderhaegen (2018), and *Philosophy on the Border: Decoloniality and the Shudder of the Origin*, edited by Leonhard Praeg (2019).

The courage to be an absolute nobody

Duncan Reyburn, School of the Arts: Visual Arts

I'm not afraid to compete. It's just the opposite. Don't you see that? I'm afraid I will compete – that's what scares me... I'm sick of not having the courage to be an absolute nobody – JD Salinger, *Franny and Zooey*

Scholars have not always known how to interpret the work of Søren Kierkegaard (1813-1855) in relation to political thought, and so the recent release of the anthology *Kierkegaard and Political Theology* (Pickwick, 2018) is a welcome contribution, not just 'for those who want to get a better grasp of Kierkegaard, but ... for all those who want to understand our own predicament'.

One of the contributions is a provocative essay co-authored by Dr Duncan Reyburn in the UP School of the Arts, and American scholar Professor Roberto Sirvent, from Hope International University. Titled 'The spotlight and the 'courage to be an absolute nobody': Toward a Kierkegaardian-Chestertonian political theology of ego", the essay analyses what the desire to be in the proverbial spotlight means for ethics and philosophy today.

The essay takes as point of departure the observation that many of the egotistical impulses evident in global culture are in fact masks, and that common obsessions with identity, power, fame and fortune prevent more introspective forms of thought and contemplation – therefore giving rise to 'virtue-signalling' at the expense of actual virtue. Thus, Sirvent and Reyburn write that feelings of loftiness, godlikeness, and power often conceal despair and, consequently, that when the subject loses his or her place in the spotlight, what is experienced is not the despair of the loss itself but a 'moment of awakening to the true despair of being in the spotlight'.

Sirvent and Reyburn offer a way to think about the subversive and much-needed role of failure in the contemporary political milieu. The idea is not that we should simplistically aim to fail in order to challenge the normalisation of success, but that whatever successes we happen to be capable of, and whatever good we end up doing, must necessarily embrace and even appreciate those parts of our humanity that we often want to deny: our vulnerability, our dependence and interdependence, and, of course, our capacity for error and correction.

Voices from the South

Amanda du Preez, School of the Arts: Visual Arts

What does it mean to be human in an age of digital technologies? The question is by no means new, but by viewing the problem through the prism of popular self-depictions (selfies) and Digital Humanities, we create opportunities for powerful critical engagement.

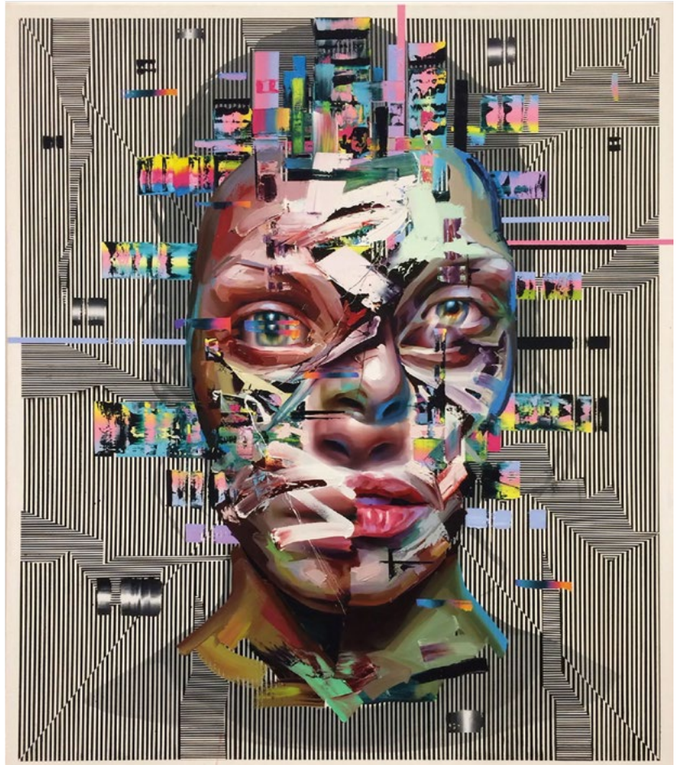
This is the project undertaken in *Voices from the South: Digital Arts and Humanities* (AOSIS, 2018), edited by Professor Amanda du Preez in the Department of Visual Studies. As such, it provides a timely and innovative engagement with the field of Digital Humanities on the African continent and South Africa in particular.

The study probes human experience in the network society by flagging two trends within digital self-expression, namely democratisation and datafication. As many scholars have noted, the possibilities for spreading democracy on social media networks are abundant. Of increasing concern, however, is the looming presence of control through datafication (Big Data) and the threats to human freedom this may pose. *Voices from the South* proposes that human interactions with digital technologies manifest in unpredictable, and yet distinct, ways that may dramatically challenge our notions of what it means to be human.

In this study, Digital Humanities are positioned as an important means of engaging with the pervasive digital culture of the 21st century from an humanities perspective. It argues that the humanities and the arts, in particular, have an essential role to play in unlocking the broader human significance of scientific, technological and data-driven research.

Much of the critical engagement with Digital Humanities undertaken in this study centres on the notion of thinking through images. The image in all its different guises dominates the media and social spheres – and our imaginations. The research question posed throughout the volume is: what do images (or selfies more particularly) want? This indicates that images are imbued with a particular agency. Images address us, not only in the sense of interpellation but also in a radical ontological sense. Something comes forward to meet us when we engage with images.

Continued on page 18



Voices from the South

Continued from page 17

The volume brings together research that reflects on Digital Humanities and selfies from various perspectives as viewed from the Global South. In Part 1 particularly, representations of the self, take centre stage through GIS mapping of selfies and visual activism during the *#FeesMustFall* student campaign. In Part 2, the contributions provide ways of thinking through Digital Humanities and digital tools. The latter chapters of the book discuss innovative ways of implementing Digital Humanities strategies and methodologies for teaching and researching in South Africa.

Ubuntu –

its meaning and value

James Ogude, Centre for the Advancement of Scholarship

The philosophy of Ubuntu rests on the premise that our humanity, and indeed our personhood, is fostered in a network of relationships.

In early 2013, Archbishop Emeritus Desmond Tutu received the Templeton Prize for life-long work in advancing spiritual principles, most notably the African philosophy of Ubuntu. In light of the award, the Templeton World Charity Foundation awarded the University of Pretoria a grant 'to increase the knowledge and awareness of Ubuntu, and in the process contribute to the transformation of African communities and societies'.

At the core of the Ubuntu project is a focus on how this concept of connectedness could instil values of compassion, integration, human dignity and selfless service at the level of the individual, the community and the nation, particularly in contexts of conflict and fragile democracies.

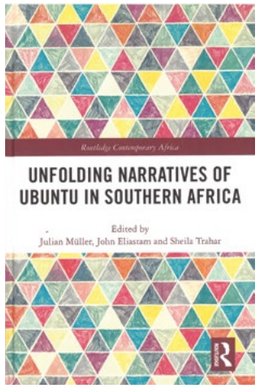
The starting point was to understand Ubuntu in the context of the everyday, especially in post-conflict situations. The project also extended to other parts of the continent, connecting to similar streams of African thought across history and space, and to similar concepts globally. Framing questions included: What does Ubuntu mean in relation to communal ethos? How and why do we use it to reconstitute or restore communities? What lessons can we infer from the African idea of personhood without rendering it a panacea for all our ills? And, in what ways is the idea of Ubuntu mediated by our colonial legacy and the post-colonial moment?

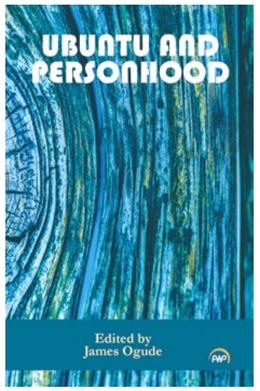
Julian Müller and James Ogude, Director of the Centre for the Advancement of Scholarship.

The result is a total of four edited books, an Ubuntu-themed play, two special journal issues, numerous articles and a series of workshops, seminars, colloquia and public lectures.

The publications show different ways of approaching the concept, while also dealing with the concept critically. In the play, *Mama Mudu's Children* by Masitha Hoeana, the project grappled with complex issues, asking how the concept of Ubuntu could be turned into a mirror for the challenges facing contemporary society and the everyday experiences in Africa.

The first book, *Ubuntu and Personhood* (Africa World Press, 2018), was edited by project leader, **Professor James Ogude**. Different chapters interrogate the idea that the full development of personhood comes with shared identities, and that our humanity depends on a network of human interaction. The book includes contributions from DA Masolo, a leading scholar of African Philosophy, on questions of agency and self-constituency; Mpho Tshivashe on personhood without Ubuntu; and Aloo Majola, on Julius Nyerere and the concept of Ubuntu.





DA Masolo, University of Louisville (US) at the book launch.

The second book, *Unfolding Narratives of Ubuntu in Southern Africa* (Routledge, Taylor & Francis Group, 2018), edited by **Julian Müller**, **John Eliastam** and **Sheila Trahar**, offers novel perspectives on how Ubuntu can be understood through narrative and story-telling with all researchers using some form of narrative inquiry and fictionalised representation as methodological tools.

Both books were launched at the Centre for the Advancement of Scholarship on 4 September 2018.

At the time of going to press in 2019, two further titles, *Ubuntu and the Everyday* edited by James Ogude and Unifier Dyer, and *Ubuntu and the Reconstitution of Community* edited by James Ogude, have been released.

Uniqueness

Mpho Tshivhase, Department of Philosophy

In a world where the focus tends to be more on group identities and group solidarity than individuals, the question regarding the uniqueness of persons seems to have fallen by the wayside.

The work of **Dr Mpho Tshivhase** in the **Department of Philosophy** focuses on both personhood and uniqueness. In 2018, she contributed a chapter to the book, *Ubuntu and Personhood* (Africa World Press) in which she defends the concept of personhood as primarily individual, thus displacing morality as definitive of our understanding of being. Her focus has since homed in on uniqueness in order to capture what is radically distinct about an individual's identity.

She writes that, while most contemporary research on uniqueness tends to compare objects that are different in kind, her own interest is in the uniqueness of persons in relation to other persons, i.e. as instances of the same kind. In short, she is interested in what makes persons unique as beings with the same biological makeup.

Uniqueness of persons refers to the radical difference that captures the distinctiveness of persons that enables us to speak of a person as the only person who can be who s/he is; thus persons could be defined with respect to irreplaceability, incomparability, and rarity. In relation to persons as instances of the same kind, we could speak of a unique person as a person who is one-*within*-her-kind (since nobody within her kind would be exactly like her). This kind of uniqueness, Tshivhase argues, is not given. Uniqueness of persons, or 'processual uniqueness', as she terms it, is a matter of construction wherein the necessary conditions for such construction include, but are not limited to, *autonomy* and *authenticity*.

Comparable views, such as genetic uniqueness, generic uniqueness, and personalism, frame uniqueness of persons as an aspect of humanness that is always already given. Tshivhase's work rejects notions of uniqueness that frame the distinct nature of individuals in this way because such notions do not take into account normative aspects that are relevant in the formation of identities.

There is evidence of the valuing and relevance of uniqueness of persons in society, perhaps best illustrated in the artistic industries and art world where contracts are based on an individual's uniqueness. Other instances that illustrate an implicit valuing of uniqueness include *love*, *death*, and *cloning*. Love makes it possible to perceive a person's incomparable value, while death is an instance of recognising an individual's irreplaceability. The notion of rarity is also notable in the discomfort that persons display towards cloning.

Holding the past to account

Siona O'Connell, Department of Historical and Heritage Studies

The documentary film-maker and writer, Siona O'Connell, is clear in her understanding of South Africa's violent history: that it is far from over and that the past needs to be held to account.

Pivoting on apartheid traumas and restorative justice, **Siona O'Connell's** work in 2018 focused on the long reach of slavery in South Africa by looking at the traces that remain: first, through the question of land restitution and, second, by looking at apartheid-era street photography and the forms of self-representation and freedom that are invoked.

Uitgesmyt is a 26-minute documentary directed and produced by O'Connell. The film premiered in Cape Town and Pretoria in 2018 and also screened on local and international television stations, and at a number of universities in the USA and Europe. The documentary looks at Elandskloof in the Cederberg, the site of the first successful land restitution case in South Africa.

Although the film considers the complexities of land in South Africa, *Uitgesmyt* draws together the attendant threads of slavery, religion, 'colouredness', poverty and inequality. In so doing, it highlights the urgency of memory work related to race-based evictions. In the film, O'Connell makes the point that the issue of land and restorative justice cannot simply be settled in financial ways, or through a return to land. She contends that it is necessary to address and attend to the ongoing legacies of the trauma of apartheid evictions; in post-apartheid South Africa, this trauma continues in projects of social gentrification, and an inability to 'move on' from a past that holds the present to ransom.

The film is largely in Afrikaans – a first for O'Connell – who comments that as soon as one of the interviewees used the term 'Ons was uitgesmyt' (We were thrown out), she knew she had the title of the documentary.

An ongoing project of O'Connell's is *Movie Snaps*, a documentary that she directed and produced in 2015, and which is now theorised in her published work. *Movie Snaps* captures street photography taken in Cape Town between the mid-1930s to the early 1980s, portraying ordinary people of all races living in extraordinary times. O'Connell's work shows that the self-representations of racially oppressed people – evident in dress, posture and gesture, among other markers – are key to understanding South Africa today, providing ways of imagining what freedom could look like and to what extent it is yet to be realised in contemporary South Africa.

Siona O'Connell's Ma and Mama (*Movie Snaps*)

Siona O'Connell is Professor in History and Heritage Studies at UP. In 2018 she was appointed as Distinguished National Endowment for the Humanities (NEH) Professor at Colgate University in Hamilton, USA.

Judging a book by its cover

Corinne Sandwith, Department of English

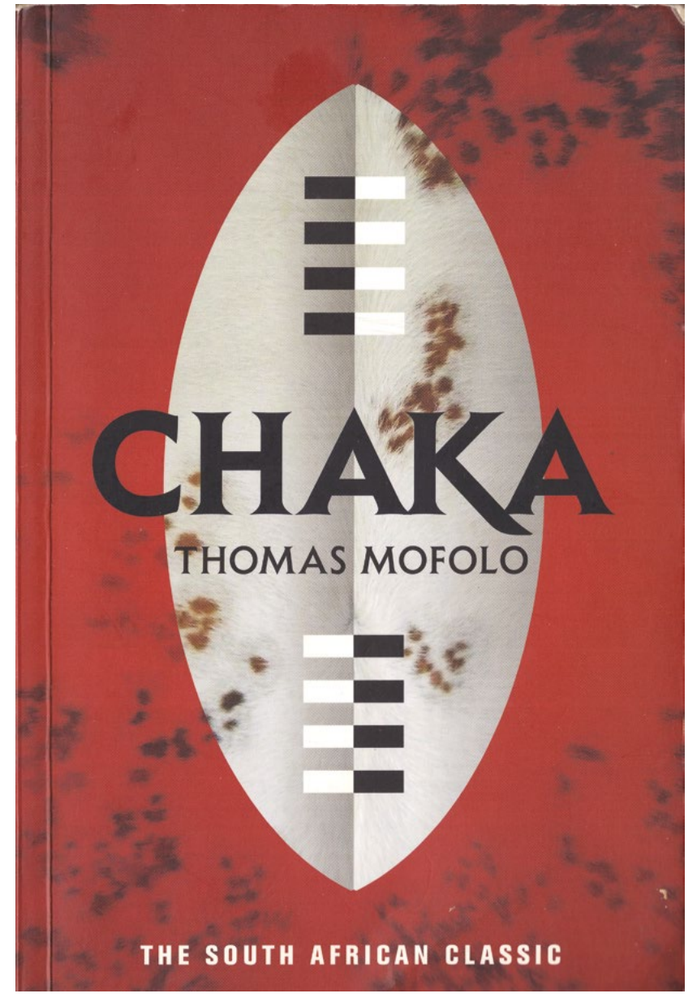
What does it mean to pause at the threshold of the book, to read the 'outside' rather than the 'inside'? What insights can be gained by shifting attention to the book as object – its size, cover design, wrapping and presentation?

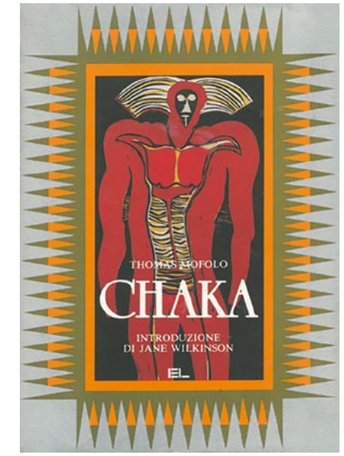
Scholars have coined the term 'paratext' to describe the many elements that make up the packaging of books such as prefaces, dedications and cover images. This zone of transaction, vestibule or threshold introduces the book to the reader in particular ways, establishes expectations and invites particular classifications – as fiction, history or biography. Literary scholars have tended to focus on the 'inside' of the book – on narrative strategies, preoccupations, plot lines and characterisation. But there is increasing awareness of the interpretive potential of the paratext itself. By pausing on the threshold, the literary critic is able to shed light on the long history of textual production and reception – on the different roles the text has been assigned, and the particular ideological interests it has been invited to serve.

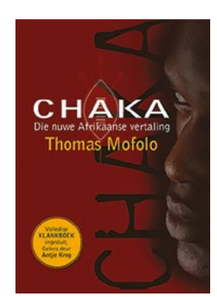
The recent work of Corinne Sandwith, Associate Professor in the Department of English, has turned to the analysis of changing paratextual presentation of works of African literature. In an article published in the *Journal of Southern African Studies* in 2018, she focuses on Thomas Mofolo's Sesotho novel, *Chaka*, first published by the Morija Book Depot in Lesotho in 1925. Her research traces the fortunes of Mofolo's *Chaka* as it moved from Morija mission station in the 1920s to its re-publication as an English novel in London in 1931, and to its later entry into the Parisian literary scene and occupied France. Also important have been subsequent translations into German, Afrikaans, Kiswahili and Italian as well as the novel's re-publication in the period of decolonisation as part of the 'African Writers Series' alongside other 'African greats' such as Chinua Achebe.

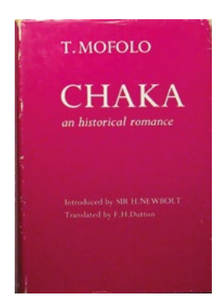
Each new version of the book entails a different paratextual staging, encoding a different understanding of the meaning and value of the text. Sandwith's research homes in on the details of these changes in order to explore more general questions about the ways in which African literary texts have been categorised and framed in successive historical and geographical contexts. In the case of Chaka, the text has undergone a fascinating journey from the categories of 'missionalia', and anthropology to the work of a 'black author', an example of 'African Literature' and novel of postcolonial resistance.

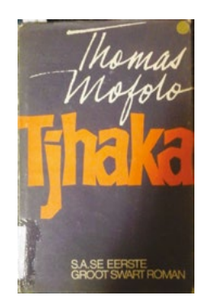
Also compelling about these longitudinal studies is the insight they provide into the textures and preoccupations of particular historical moments. A reading of the paratext thus has important historical value as a means of elucidating the complex, contradictory movements and tensions that give each historical moment its distinctive shape.

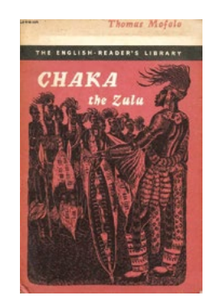












An unfinished reformation

Tanya van Wyk, Department of Systematic and Historical Theology

One of the world's greatest moral struggles relates to the ways in which the relationship between identity and diversity are understood and practised, which invariably lead either to further polarisation or to transformation.

Dr Tanya van Wyk in the Department of Systematic and Historical Theology, has focused her research on political theology; in particular, the relationship between

the State and religious citizens, and between the church and society. Her research aims to develop a political theology for the South African context, with special emphasis on the democratic ideal.

Van Wyk has studied the relationship between identity and diversity – or sameness and difference – and the way in which this relationship has an impact on socio-political contexts. In her earlier research, she examined the socio-political space of the church in South Africa through the lens of reconciling diversity as represented in the Christian confession of God as a Trinity. She is one of a handful of theologians in the country to have specialised in Trinitarian theology. Her current research is undertaken from a feminist theological perspective with a strong focus on gender justice.

In an article published in 2018 in the journal *Verbum et Ecclesia*, she presents an analysis of the ways in which linguistic invisibility and non-recognition play a role in perpetuating unjust social arrangements and, indeed, institutional practices. She examines in detail the harmful effects of gender-exclusive language, specifically on the institutional practices of the church. Gender injustice is the oldest and most entrenched injustice in the world. The persistent use of gender-exclusive language normalises and further entrenches patriarchy, with disastrous effects on the lives of millions of women. This 'reformation' in the church needs to be completed.

Van Wyk maintains that sustainable methods to approach and reconcile diversity need to be developed and strengthened on a continuous basis. Because of the religiosity of the African continent, religious communities like the church can play a major role in developing methods for reconciling diversity. Over the past decades, feminist and womanist theologians from across the globe have made significant contributions to this project, specifically in relation to the theory of intersectionality. This has become an important tool in approaching transformation, because it offers a way to analyse and understand the complexity of social inequality, which is shaped by many intersecting axes of people's identities, and social and political lives.

In her current research, Van Wyk uses this theory to focus on the complexity of women's experiences at the intersection of the UN's sustainable development goals of gender equality and climate action, and the role of religion.

A commitment to socially-just education

Universities across the world need simultaneously to navigate transformation and increased participation in a resource-constrained landscape. In South Africa, these intersecting challenges are intensified by increasing numbers of first-generation students from poor and working-class families.

Dr Talita Calitz's book, *Enhancing the Freedom to Flourish in Higher Education* (Routledge, 2018) explores the complexities of increased participation, while shifting attention to student capabilities, resilience and agency. Based on her doctoral and a postdoctoral research undertaken at the University of the Free State, the focus of her book is on the experiences of students and ways in which university staff and management structures can enable resilience, activate capabilities, and seek collaboration with students, despite academic and resource constraints.

Using South Africa as a case study, the book tracks the experiences of first-generation undergraduate students whose narratives illuminate the structural inequalities affecting their participation in higher education. Calitz outlines the political, economic and academic factors that lead to diminished participation while also foregrounding the many resources that students use to negotiate some of the obstacles. Her analysis shows that student experiences can offer insight into the complex reasons why some students flourish at university while others are marginalised socially and academically.

Proposing a model of equal participation embedded in the experiences of students, the book offers practical suggestions on how to enhance opportunities for students' well-being and freedom to flourish. While grounded in individual student narratives, her analysis brings critical social theory to the problem of unequal participation, showing the invisible and implicit forms of inequality that speaks to broader global debates around justice, widening participation and equality in higher education.

A theory and pedagogy of memory

The troubling euphemising of death and dying becomes an ambiguous project during times of great physical and psychological upheaval.

During the First World War, the war poets attempted to gloss over death by summoning the dead in beautiful word-bouquets of lyrical language and Romantic nature-inspired figures of speech and imagery. Except for the bitter trench poets, the war poets set about creating communal primordial images or archetypes of becoming: these were the forever-young-beyond-the-grave soldiers embraced by verdant nature.

Poetic Bodies and Corpses of War: South African Great War Poetry (Unisa Press) by Dr Gerhard Genis in the Department of Humanities Education is a bold attempt to bring the fields of South African Great War poetry and indigenous oral poetry or *izibongo* into closer dialogue. He makes the argument that *izibongo* are conduits of inter-generational and trans-generational trauma which is revealed through figurative and imaginative word-traces. What these poetic traditions have in common is the major theme of coming to terms with loss, suggesting a common South African consciousness marked by the wounds of conflict.

His work opens up conceptual paths to the study of trauma and literature through an epigenetic lens. Genis explores the close link between language and trauma through epi-poetics, which is a theory and pedagogy of memory. Epi-poetics refers to the implicit collective literary unconscious of a people which is mirrored in poetic language traces that represent culturally embodied marks. These metaphorical and metonymic word-traces find expression both in Great War poetry and in the tradition of *izibongo*.

Towards a jurisprudence of liberation

Joel Modiri, Department of Jurisprudence

The failure of South Africa's legal and political order to dismantle the material and symbolic vestiges of colonialism and apartheid brings to light the deep disjuncture between the constitutional ideals of equality and freedom, and the lived reality of the Black majority.

The research of Dr Joel Modiri in the Department of Jurisprudence draws on the Pan-Africanist philosophical and political archive, settler-colonial studies and associated theoretical approaches to interrogate and rework concepts of justice, power, constitutionalism, memory, transition, and freedom. Working from the disciplinary position of law and jurisprudence, his focus is on the experiences and struggles of indigenous and oppressed communities.

A key assumption of his research is that a jurisprudence or legal philosophy emanating from the imaginations and experiences of historically colonised communities would pose very different questions and enact a different orientation towards South African law, society and politics than is presently the case in the legal academy. The ultimate aim of the research is the development of an alternative critical jurisprudence which challenges eurocentrism and envisions a post-conquest world.

Modiri is specifically interested in tracing how colonial conquest remains an ongoing material and symbolic dynamic in the making and unfolding history of South Africa.

In March 2018, Modiri delivered the keynote lecture at the University of South Africa's flagship *Africa Talks* series; and in November, he presented his research at the Institute of Research in African-American Studies at Columbia University, New York.

He was the editor of a special issue of the *South African Journal on Human Rights* in 2018, entitled 'Conquest, Constitutionalism and Democratic Contestations'. Two decades since the enactment of South Africa's present constitution, the durability and endurance of 'past' inequalities and injustices illustrate that the 'new South Africa' – lauded as a miracle nation with the best constitution in the world – can no longer be regarded as an unqualified success. The legal and constitutional foundations of post-1994 South Africa are in a process of renegotiation that invites new and alternative perspectives and approaches.

Modiri's paper published in the special issue, 'Conquest and Constitutionalism: First Thoughts on an Alternative Jurisprudence' offers a critique and an interpretation of post-1994 constitutionalism from the perspective of its relationship to the *longue durée* of colonial conquest, settler-colonialism and white supremacy. In the paper, he draws on critical theoretical perspectives that challenge optimistic and triumphalist accounts of the constitution, and exposes the fragility of its emancipatory horizon. Modiri describes these accounts as 'constitutional worship' and argues instead for an alternative jurisprudence – a 'jurisprudence from below' or a 'jurisprudence of liberation'.

In 2018, Joel Modiri was selected as an Inaugural Leadership Fellow in the Atlantic Fellowship for Race Equity, a programme housed at Columbia University, New York.

Developing global standards

on peaceful assemblies, demonstrations and protests

Christof Heyns, Institute for International and Comparative Law (ICLA)

Mass demonstrations have played a role in shaping some of the most decisive political and ideological transitions of the last century – in ending colonialism; in the civil rights movement in the USA; and in the fall of communism. They also made a significant contribution towards the transition of power in Burkina Faso, Tunisia, Algeria, and Sudan.

The roots of demonstrations as a form of political intervention can be traced to South Africa, where Gandhi developed it as a tool to pursue the interests of the Indian population. It played a significant role in ending apartheid, and continues to be widely used.

Now a global phenomenon, the question is what are the international law standards on demonstrations? What corresponding obligation does the right of peaceful assembly place on the State? Can protestors be required to ask for authorisation, or is notification enough? When may the police use force?

The nature of mass demonstrations has changed fundamentally with the widespread use of technology. Can one 'assemble' online? Are the police permitted or required to use body-worn cameras? Can drones be used to manage assemblies?

Professor Christof Heyns, working with a team of researchers at the Institute for International and Comparative Law in Africa, has been closely involved with efforts by the United Nations (UN) and the African Union to set international standards on matters such as how protest should be managed and how potential violations should be investigated.

In 2018, the UN Human Rights Committee appointed Heyns as the 'rapporteur' or main drafter of General Comment 37 on peaceful assembly. This is the Committee's authoritative and comprehensive restatement of the standards under international law. Heyns has been a member of the Committee since 2017. Drafting international standards is a singular opportunity. Heyns completed his doctoral degree on civil disobedience many years ago and has, in the meantime, continued to work in this area. The area raises a number of technical questions, but none of them can be answered without an understanding of the role of dissent and protest in society.

Legal restraints on the use of force

Stuart Maslen, Centre for Human Rights

A key component in UP's Freedom from Violence in Africa programme within the Faculty of Law is clarification of how international law restricts the use of force. This is particularly so when an agent of the State is pulling the trigger.

Stuart Maslen, an honorary professor of international law at the Centre for Human Rights, teaches on the programme and supervises doctoral students, focusing his research on the law of armed conflict, human rights, disarmament, and counterterrorism.

He writes that the simplest case to analyse – in legal terms – is when a police officer shoots an individual in the line of duty. National rules are subject to international law, particularly human rights law but, in extreme cases, also international criminal law.

In ascertaining whether an officer's actions were lawful, the right to life will be especially important. Whether a violation has occurred turns first on whether the officer's actions were 'arbitrary' and thus unlawful. This concerns compliance with core principles governing law enforcement, notably necessity and proportionality. These dictate that the force used must be the minimum necessary in the circumstances and also proportionate to achieving a legitimate law enforcement aim.

To see how these international rules are translated into domestic practice, Maslen and co-researchers at UP and Oxford University, set out in 2018 to gather and analyse the law in all 197 states in the world. The result is the *Law on Police Use of Force Worldwide* website (policinglaw.info), a global repository for domestic rules governing police use of force. Many rules are the permissive vestiges of colonialism; disappointingly few truly comply with international law. A major reform effort is needed if the police are to be held accountable for their actions and citizens are to be protected.

More complex is the legality of the use of force during armed conflict, particularly when that occurs between the State and an armed opposition group. Protecting civilians demands analysis of several branches of international law – human rights, humanitarian law, disarmament (as certain weapons can never be possessed much less used), and international criminal law.

In a book published in 2018, *Hague Law Interpreted: The Conduct of Hostilities under the Law of Armed Conflict* (Hart, Oxford) Maslen offers a detailed assessment of the laws regulating combat during armed conflict, exploring the gap between interpretation of the rules and their application in practice. Twenty years after the UN Security Council first tackled the issue, research and teaching is now focusing on how better to protect civilians.

Jus cogens – defining the contours

Dire Tladi, Department of Public Law, and ICLA

The concept of peremptory norms of general international law (*jus cogens*) refers to those norms of international law that are so important and fundamental that no derogation from them is permissible. For international law this is revolutionary.

As a general rule, rules of international law are derogable. Any State is free to derogate from rules of international law by agreeing on different rules that deviate from the general rule. However, peremptory norms may not be derogated from and States may not, even by agreement, depart from them. The most frequently cited examples of peremptory norms include the prohibition of genocide, and the prohibition on the use of force.

The UN International Law Commission (ILC), a subsidiary organ of the UN General Assembly responsible for the codification and progressive development of international law, made the decision in 2015 to initiate a study on peremptory norms and to appoint Professor Dire Tladi to be its Special Rapporteur on the topic. Tladi was first elected onto the ILC in 2011 and subsequently re-elected in 2016. He had proposed the topic for study, noting that while it was immensely important for international law, its contours remained ill-defined. The uncertainties surrounding *jus cogens* have had the effect of reducing its potential impact.

Tladi produced three reports in the period 2016-2018, covering various aspects of peremptory norms and proposing a number of conclusions. The third report, presented in 2018, identified the main consequences flowing from the peremptory character of *jus cogens* norms. The first three reports together proposed 22 draft conclusions. The fourth report will be prepared in 2019 during Tladi's time as Global Visiting Professor of Law at the University of Californian Irvine under a Fulbright grant.

In addition to the reports, Tladi has also been working on the commentaries to accompany the draft conclusions. Once adopted by the ILC, the set of draft conclusions together with the commentaries will represent the definitive law on peremptory norms of general international law.

Tladi's work on peremptory norms has had an impact on his research beyond the ILC. In 2018, he worked on a book with American and German scholars, Mary Ellen O'Connell and Christian Tams, on salient aspects of the prohibition on the use of force: *The Trialogues on War and Peace: Vol I Use of Force Against Non-State Actors* (Cambridge, forthcoming). He also authored a chapter in a book on the use of force, 'The Intervention in Côte d'Ivoire – 2011', in Tom Ruys and Olivier Corten (eds), *The Use of Force in International Law: A Case-Based Approach* (Oxford, 2018).

There is much more to the world around us than we can see with the naked eye. The tools of contemporary science give us windows into microscopic and molecular realms, allowing us to make sense of the 'big data' harvested in the process of research, and to understand the importance of the invisible world and the ways in which it shapes our lives, our environments and our futures.

Technologies, tools and big data

Visualising the unseen

Microbiomes as sentinels of global change

Thulani Makhalanyane, Department of Biochemistry, Genetics and Microbiology, and the Centre for Microbial Ecology and Genomics (CMEG)

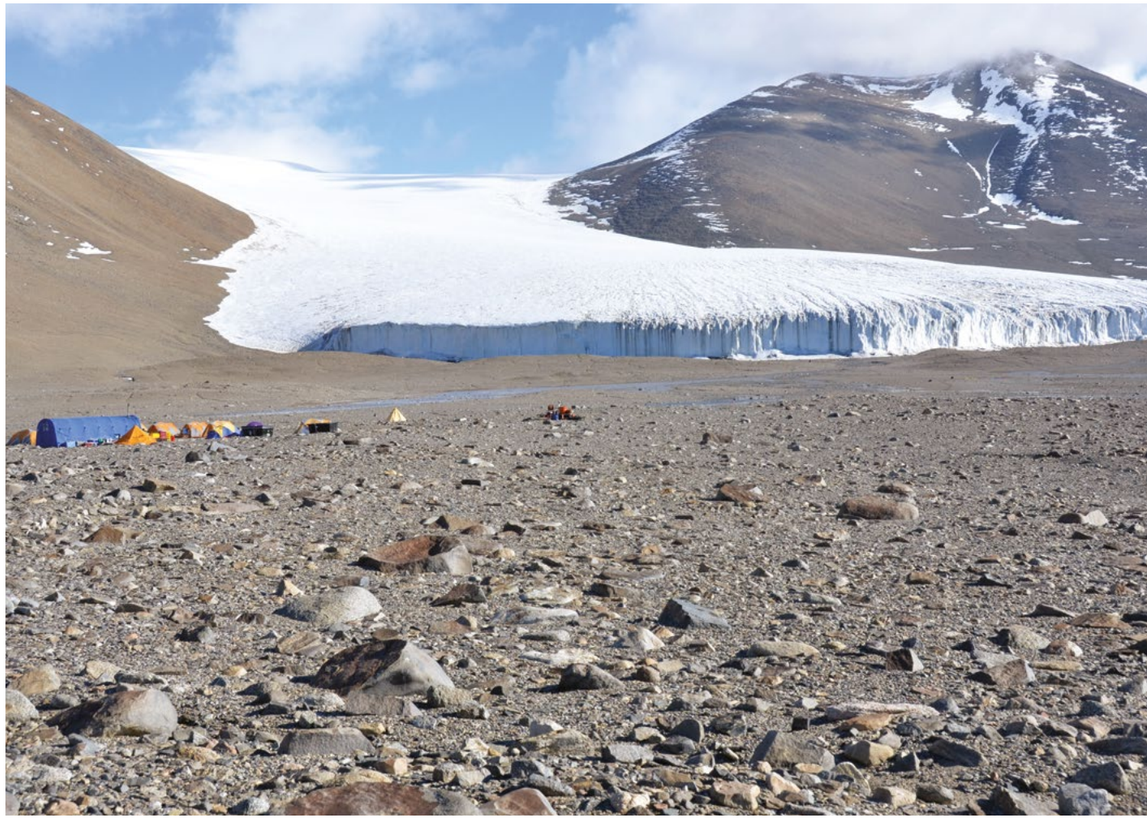
Approximately 4 billion years ago, marine microorganisms shaped and defined the biosphere, facilitating a shift from anoxic to oxic conditions. This transition has allowed multi-cellular life to evolve from ancient unicellular organisms. Despite their centrality in regulating ecosystem processes, our understanding of the microbiome – that is, microorganisms and their genes – remains relatively poorly developed. Due to their rapid metabolisms and response to perturbations, the members of microbiomes serve as crucial sentinels of global change.

Our understanding of the role played by microbiomes has been constrained by several factors. Firstly, microbial communities are numerically abundant across all ecosystems. For instance, current studies suggest that we harbour roughly the same number of microbial cells as human cells, estimated at 37 trillion. Secondly, microbiomes are continuously in a state of flux with widespread gene exchange, gene loss and gene gain, which complicate efforts to clarify the relationship between functional traits and microbial diversity. Lastly, we now know that environmental conditions appear to disproportionately shape microbiomes, leading to substantial variability across local and global scales. Large multidisciplinary teams are required to address these constraints and provide important insights into the ecology of the microbiome.

Dr Thulani Makhalanyane, senior lecturer in the Department Biochemistry, Genetics and Microbiology, and at the Centre for Microbial Ecology and Genomics (CMEG), has recently established several new research themes aimed at illuminating the role of the microbiome in strategically important marine and terrestrial regions. Two publications in 2018, co-authored with CMEG researchers and collaborators, demonstrate the impact and significance of these thematic studies in understanding the effects of microbiomes on global change.

Marine environments occupy over 70% of the Earth's surface and act as a crucial buffer against climate change. Oceans sequester carbon dioxide produced through human activities, and provide food and other essential ecosystem services. Yet knowledge of the role played by the microbiome in key South African regions lags behind our current knowledge of phytoplankton and large marine mammals. In a paper published in *Scientific Reports*, CMEG researchers revealed important insights into the diversity and functional processes of microbiomes in the Agulhas current system. The study showed, for the first time, that ecologically rare taxa disproportionately drive carbon cycling in these marine environments.

Ice-free regions collectively comprise less than 0,40% of continental Antarctica. Over the past two decades, several international teams have provided fundamental insights into the effects of harsh microclimatic conditions on the diversity of microbiomes. Yet, relatively little is known about the functions that these microorganisms perform. In their recent work, CMEG researchers have pioneered studies aimed at understanding antibiotic production and resistance in remote and pristine Antarctic soils. In a paper published in *Microbiome*, the team demonstrated that antibiotic-resistance genes in these remote and uncontaminated soils most likely represent genes with a functional history that may have been inherited over several generations. The researchers relied on contemporary methods where DNA from environmental samples is extracted and sequenced without the requirement for laboratory culturing.



McMurdo Dry Valleys

This approach, called metagenomics, generates several hundred gigabytes of sequence data. Such quantities are analogous to mega-size jigsaw puzzles (with a limited colour palette), that require algorithms to reconstruct the fragmented data representing microbial communities and functional genes.

CMEG researchers are increasingly using computational biology methods to understand the roles played by microbial communities in providing essential ecosystem services.

In 2018, Dr Thulani Makhalanyane was elected to the board of the International Society of Microbial Ecology (ISME) for a four-year term. At 35, he is the youngest and the first African to have joined this esteemed Board of Directors.

Monitoring change

in Arctic tundra microbiomes

Don Cowan, Department of Biochemistry, Genetics and Microbiology, and CMEG

Polar regions are of increasing significance to the world's future: global warming may add huge volumes of fresh water from terrestrial glaciers into the world's oceans, and warming of permafrost could release billions of tonnes of stored carbon, as the greenhouse gasses methane and carbon dioxide.

Professor Don Cowan, Director of the UP Centre of Microbial Ecology and Genomics and NRF A1-rated researcher, moved from one pole to the other in 2018. While his 20-year research programme on Antarctic terrestrial soil microbiology continues, he has recently established a new research collaboration in the Canadian High Arctic.

It was triggered by a move, in late 2017, of long-time collaborator, Professor Ian Hogg, from the University of Waikato (NZ) to the new Canadian High Arctic Research Station (CHARS), sited in Cambridge Bay on Victoria Island and on the northern shoreline on the Northwest Passage.

CHARS, operated by Polar Knowledge Canada, has been designed and built to optimise innovation in Arctic science and technology, to welcome visitors, and to provide researchers with the accommodation and technical services they need. The innovative facility is designed to support a wide range of research needs – from ecosystem monitoring to DNA analysis – where Inuit principles and indigenous knowledge are recognised as fundamentally important to the co-creation of new knowledge.*

Collaborator Eric Bottos (left) and CHARS technical officer, Bryan Vandenbrink recovering permafrost cores.

Professor Cowan first visited CHARS in August 2017, to design a new joint research programme aimed at investigating the manner in which Arctic tundra microbiomes, in surface soils, intermediate active (seasonally thawing and re-freezing) layers, and deeper permafrost, respond to seasonal temperature changes. With Professor Hogg, he established a series of appropriate field sites, designed a comprehensive monthly sampling protocol for the ice-free duration of a full annual cycle, and selected a series of advanced analytical methods designed to address microbial population and gene expression changes, and to investigate carbon exchange and the effect of bacteriophage on microbiome structure and function.

The project will test the hypotheses that seasonal warming (as a proxy for longer-term climate-related warming) triggers fixed-carbon mobilisation, and that there is a net loss of soil carbon through an annual cycle.

After assembly of the necessary equipment and facilities, the full research programme, in collaboration with emerging academic Eric Bottos, from Thompson Rivers University, Canada, will kick off during the next visit to CHARS, planned for July 2019.

Right: Angel Valverde in the Namib Desert.

Investigating antibiotic-resistance genes

Yashini Naidoo, a member of the Centre for Microbial Ecology and Genomics and jointly supervised by Professor Don Cowan and Dr Rian Pierneef, is mid-way through her PhD studies. Her topic is the environmental distribution of Antibiotic Resistance Genes (ARGs), focusing particularly on the ARGs in Namib Desert soils.

ARGs are a hot topic right now: these genes encode proteins that are responsible for resistance to clinically important antibiotics in human and animal pathogenic bacteria. ARGs are often plasmid-encoded, and can be passed from one microorganism to another by a process termed Lateral Gene Transfer.

One of the more important questions relating to ARGs is 'where do they originally come from?' It is an accepted concept that soils represent a reservoir of ARGs which, by processes of Lateral Gene Transfer and mutation, may ultimately end up in clinically important bacteria.

Yashini's project addresses this issue. She is using advanced metagenomic sequence analysis to investigate the diversity of ARGs (there are some 160 different types already catalogued) in desert soils. The choice of desert soils is based on the fact that these soils have relatively little human or domestic animal impact, compared to agricultural soils, so that the ARGs present should better reflect the ancestral genotypes.

She has already made some fascinating discoveries: her desert soil metagenomes contain 75 different classes of ARGs, and she has already discovered one clinically relevant multidrug-resistant plasmid-encoded ARG. She has identified 15 different classes of metal-resistance genes with a few on mobile genetic elements (MGEs). MGEs encoding metal-resistance genes play an important role in the Lateral Gene Transfer of ARGs and the spread of multidrug resistance, increasing the risk to environmental and public health systems.

* https://www.canada.ca/en/polar-knowledge/CHARScampus.html

The evolution of plant species

Yves van de Peer, CMEG and the VIB Centre for Plant Systems Biology, University of Gent

Understanding plant genomes, through genome sequencing and analysis, is critical for many aspects of the agricultural sciences, particularly for plant breeding and crop improvement, and in understanding the evolution of plants and how they respond to environmental stresses.

Yves van de Peer is a part-time professor in the Department of Biochemistry, Genetics and Microbiology, a member of the Centre for Microbial Ecology and Genomics and an NRF A1-rated researcher. He collaborates extensively with UP academic staff, including Professors Don Cowan and Zander Myburg, and emerging researchers Dr Thulani Makhalanyane and Associate Professor Esh Mizrachi.

When not at UP, Professor Van de Peer leads the Bioinformatics and Evolutionary Genomics division at the VIB Centre for Plant Systems Biology, University of Ghent, Belgium.

With his research focussing on the evolution of plants, their adaptation to stress conditions and the the role of genome duplication, Yves and his research team have had a particularly productive year in 2018, with 22 published papers, many in the world's leading Plant Science journals.

Among his collection of high-impact publications in 2018, several stand out. The provocatively titled comment 'Size does matter', published in *Nature Plants*, is a critical analysis of the evolution of Next Generation Sequencing technologies in plant chromosome assemblies, and the latest advances in combining long-read Nanopore Sequence data with Optical Mapping information. His contribution to the genome sequencing of important plant species, including ferns (*Nature Plants*), charophytic algae (*Cell*), the gnetophytes (a small group of exotic plants which includes the enigmatic *Welwitschia mirabilis*) (*Nature Plants*), and members of the tree family Populus (*PNAS*), is evidence of his extensive contribution to science.

One of his recent studies, published in *GigaScience* with a large collaborative team of Chinese researchers from the Beijing Genome Institute, involved the sequencing, assembly and functional interpretation of the genomes of five important African orphan crop species: Bambara groundnut (*Vigna subterranea*), Lablab bean (*Lablab purpureus*), White acacia (*Faidherbia albida*), Marula (*Sclerocarya birrea*), and Drumstick tree (*Moringa oleifera*). These are all economically important food and feed species on the African continent. The genome sequence data will be useful to identify agronomically important genes and to understand their modes of action, and can facilitate future breeding strategies to enhance the performance and resistance of these regional crops.

Yves' interest in gnetophytes led him to join Don Cowan on a short field expedition to the Namib Desert, where he had a chance to see the Welwitschias first-hand, sit on the top of a sand dune to watch the rising sun (which was invisible due to heavy fog), and be photographed at the Tropic of Capricorn.

Genomics of plant pathogenic fungi

Tuan Duong, Department of Biochemistry, Genetics and Microbiology, and Forestry and Agricultural Biotechnology Institute (FABI)

Understanding the genetic basis of virulence in plant pathogenic fungi will undoubtedly have a major impact in controlling diseases and breeding plants for resistance. The recent advances in the field of genomics have presented researchers with opportunities to tackle this challenge on a larger scale and in greater depth than ever before.

Dr Tuan Duong, a senior researcher at FABI, conducts most of his research in the fields of genetics and genomics in collaboration with Professors Brenda Wingfield, Michael Wingfield and Wilhelm de Beer. Dr Duong's research interest is primarily in the genetic basis of pathogenicity and host adaptation of fungal pathogens of plants. He uses comparative genomics, population genomics, and genome-wide association studies as his main methodological tools.

Duong is actively exploring and applying new genomic technologies, such as Chromium and Nanopore sequencing, to generate reference genome sequences for a number of important plant pathogenic fungal species. By using Chromium sequencing, Dr Duong and his colleagues were able to generate the first draft genome sequence of the South African strain of the myrtle rust, *Austropuccinia psidii*. The study, conceptualised by Brenda Wingfield and undertaken in collaboration with researchers in FABI and from Australia and Denmark, was published in *Biotechniques* in 2018.

The sequencing breakthrough would previously have been difficult to accomplish, due to the obligate nature of this fungal species, and the complexity of its genomic content. Few complete genomes are available for rust fungi despite their huge economic importance. The myrtle rust genome is much larger than was expected, and is one of the largest fungal genomes reported to date.

Austropuccinia psidii is an exotic species to South Africa, first reported here in 2013, and is considered a threat to many of the exotic and native *Myrtaceae* species. The availability of the genome sequence thus presents a valuable resource, enabling downstream research better to understand its host range and virulence. This understanding, in turn, will aid better management of the spread of this devastating pathogen, thereby reducing its impact.

Dr Duong is also working on a population genomics project, in which he has generated genome sequences for over 70 *Ceratocystis* isolates belonging to the *Ceratocystis manginecans* complex. This complex consists of the *Ceratocystis* species that causes wilting diseases in *Acacia*, *Eucalyptus*, mango, *Punica* and sweet potato worldwide. Current efforts are focused on exploring genomic data to identify genomic elements that confer adaptation of these pathogens to their respective plant hosts. This information will be useful, especially in tree breeding programmes aimed at strengthening resistance against these destructive pathogens.

Genome-based biotechnology for sustainable forestry

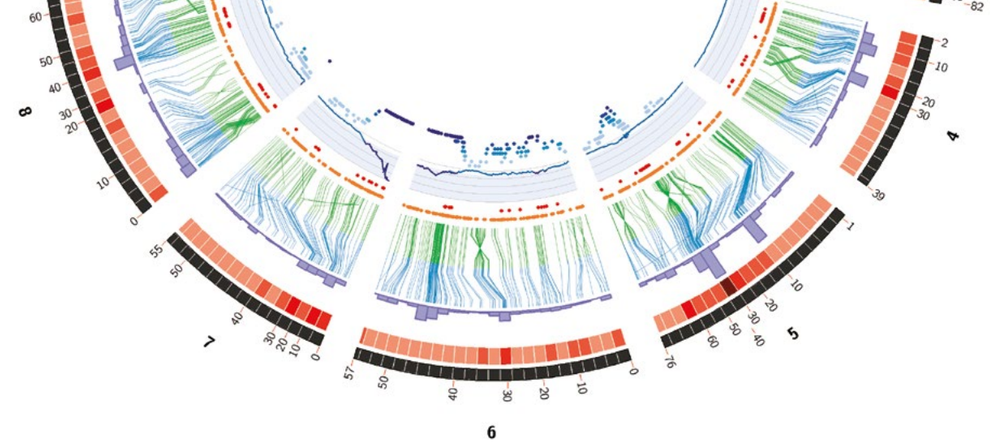
Zander Myburg, Department of Biochemistry, Genetics and Microbiology, and FABI

Natural and planted forests are under threat worldwide due to climate change and associated biotic and abiotic stresses; at the same time, woody biomass from forest trees is gaining importance as a renewable feedstock for a bio-based economy providing alternatives to fossil carbon-derived materials and chemicals. Understanding and mobilising genome diversity in forest trees provides an avenue to develop new sustainable woody biomass crops, while deciphering the genetics of tree growth, development, defence and adaptation.

South Africa produces most of its timber, pulp and paper from only one percent of its land base. This is due in large part to some of the best tree breeding programmes globally and excellent genetic gains achieved by SA tree breeders over the past decades. Professor Zander Myburg is the Director of the Forest Molecular Genetics (FMG) Programme in FABI. Together with colleagues Professors Eshchar Mizrachi and Sanushka Naidoo and Dr Steven Hussey, his research team is developing biotechnology applications further to enhance genetic improvement of South African plantation forests.

Zander Myburg is the 2018 recipient of the Chancellor's Award for Research.

The *FMG DNA Marker Analysis Platform* provides high-throughput DNA research services to the SA forestry industry. In 2018, the platform reached the milestone of having produced DNA profiles for over 50 000 *Eucalyptus* and pine trees, the bulk of the breeding stock for plantation forestry in the country. This technology is now widely accessed by tree breeders for DNA fingerprinting, parentage analysis, species discrimination, genetic resource management and gene conservation.



A major advance in the past year has been the establishment of a Genome Diversity Atlas for *Eucalyptus* and pine tree species grown in South Africa. Another outcome is an international effort in collaboration with North Carolina State University and the University of Connecticut to generate a DNA chip with 50 000 genome-wide markers for tropical pine species grown in southern Africa and South America. This resource will be useful for gene conservation and molecular breeding of pine trees, which has previously been difficult due to the large size of the pine genome (>20 billion bp, seven times larger than the human genome).

Climate change is expected to have major impacts on forestry operations in South Africa, in some cases requiring a complete shift in planted tree species. Genomic technologies can now be combined with spatial technologies such as remote sensing and climate modelling to understand the adaptation of forest trees to changing environments. The FMG team has embarked on this emerging field called landscape genomics to predict tree genotypes that are best adapted to current and future environments. The team initiated a landscape genomics study for *Eucalyptus grandis* trees and mapped novel genomic variation available for this species in its natural range in Australia that can be deployed for sustainable forestry in South Africa.

Most commercially important traits are quantitative in nature and affected by hundreds of genes throughout the genome. Genome-wide DNA marker analysis has proven to be a powerful tool for tracking this genetic variation and developing predictive models of the breeding values of individual trees. Professor Myburg's team has used a single nucleotide polymorphism (SNP) marker chip with 60 000 DNA markers to produce genome profiles for over 4 000 *Eucalyptus* trees in order rapidly to dissect complex traits in these trees. They are collaborating with researchers in Sappi and Mondi to develop and apply Genomic Selection as a novel tree breeding approach.

Adding molecular traits such as gene expression variation in tree populations allow systems genetics modelling to provide further biological insight into the molecular basis of complex trait variation. In collaboration with Eshchar Mizrachi, the FMG team has applied systems genetics approaches to dissect secondary cell wall (wood property) traits in *Eucalyptus*. MSc student Martin Wierzbicki has used this approach to perform the most comprehensive systems analysis of the genetic control of hemi-cellulose (xylan) biosynthesis in a forest tree to date.

Synthetic biology for re-engineering forest biomass

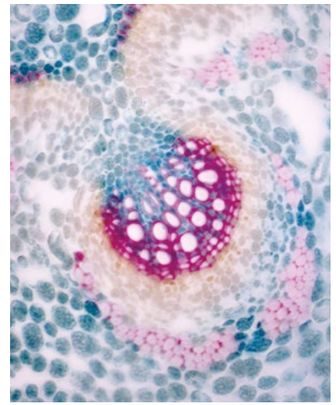
Steven Hussey, Department of Biochemistry, Genetics and Microbiology, and FABI

The ability to synthesise long strands of DNA, including whole genes, has fuelled the emergence of synthetic biology as a new bioengineering approach. Already widely applied in microbial systems, synthetic biology is still being adopted in plants. UP has taken a leading role in the application of this technology in plantation trees.

Aside from increasing the productivity of commercial forestry, custom-engineering woody biomass for the production of sustainable biomaterials may become an essential avenue to the rise of renewables in a circular economy. Synthetic biology approaches have the potential to allow for the re-engineering of regulatory pathways that determine wood properties, and could also allow for the production of metabolites and structures in wood not possible through breeding.

Dr Steven Hussey, working with Professor Zander Myburg in the Forest Molecular Genetics Programme, leads a team investigating the transcriptional regulation, epigenetics and synthetic biology of wood formation in *Eucalyptus* trees. They are applying the latest high-throughput techniques to map the transcriptional networks governing secondary cell wall (wood) formation in *Eucalyptus* and incorporating synthetic biology design principles into the development of a molecular 'toolbox' of DNA parts for woody biomass improvement.

One of the strengths of synthetic biology is the ability to chemically synthesise custom DNA sequences, such as genes, in a laboratory and merge them with the genomes of recipient living organisms. In 2018, Dr Hussey in collaboration with the US Department of Energy Joint Genome Institute completed the design, construction and fabrication of some 286 synthetic DNA sequences for application in tree bioengineering. Published in the journal *ACS Synthetic Biology*, their work represents the largest open resource of its kind for forest biotechnology.



Cross-section through a young poplar stem genetically modified to reveal a gene's expression pattern (blue).

The molecular mechanisms of photosynthesis

Tjaart Krüger, Department of Physics

A vast number of organisms perform photosynthesis, each using unique pigment-protein complexes to capture the light from the sun and to transfer it to a photochemical reaction centre, first to convert the photoenergy into protons and electrons, and later into energy-rich molecules. These light-harvesting complexes do their job extremely efficiently.

The main interest of Tjaart Krüger, Associate Professor in the Department of Physics, and his Biophysics research team, is in the molecular mechanisms of natural photosynthetic complexes. These are a rich source of inspiration for solar cell technologies and extremely useful for biotechnologies aimed at optimising photosynthesis for agriculture.

Krüger's team have discovered that the light-harvesting complexes of diatoms use a different strategy from plants to ensure robust energy transfer by using the laws of quantum mechanics to create a new, favourable energy state and exploiting disorder to populate this state. The results were published in the *Proceedings of the National Academy of Sciences* in December 2017. This was followed by a particularly fruitful year in 2018, with the publication of nine peer-reviewed papers, one textbook and four popular science articles.

In an invited Headline Review published by the *Journal of the Royal Society Interface*, Professor Krüger provided a perspective on the future of the emerging field of quantum biology, which is expected to have a huge impact on numerous technologies. His team's involvement with this work has been the result of collaboration with international leaders in the field.

The research team has been able to unravel many molecular details behind the very first steps in the photosynthetic process by developing novel equipment to push the analytical resolution to the technological limits. Their main experimental tool is single molecule spectroscopy, which allows them to investigate one molecule or protein at a time. As pioneers in the application of this technique to photosynthetic light-harvesting complexes, they published an Invited Review in the journal *Nanophotonics* with colleagues in the Netherlands.

Postgraduate students in the team have built the first single molecule spectroscopy unit on the African continent to investigate light-harvesting complexes. They have demonstrated, in real time, how a small protein is activated by light and binds to phycobilisome to switch off its photosynthetic activity. This was the first time that the interaction between these two physiological partners had been investigated at the level of a single molecule. The results of this study were published in the *Journal of Physical Chemistry Letters* in 2018.

Bringing the invisible into focus

Roger Deane, Department of Physics

At the heart of every galaxy lies a supermassive black hole with a mass ranging from around a million to over a billion times that of the sun. This is true of the largest galaxies in the universe to more medium-sized examples such as the Milky Way which has over 10 billion stars. These objects are regions of space so dense that not even light can escape their gravitational pull, resulting in Nature self-cloaking, using the laws of physics.

Studying and understanding black holes is the primary motivation of the global Event Horizon Telescope (EHT) collaboration: how matter is accreted onto black holes, how black holes accelerate particles along jets at velocities near that of light and, most ambitiously, to test whether Einstein was right about the fundamental force of gravity.

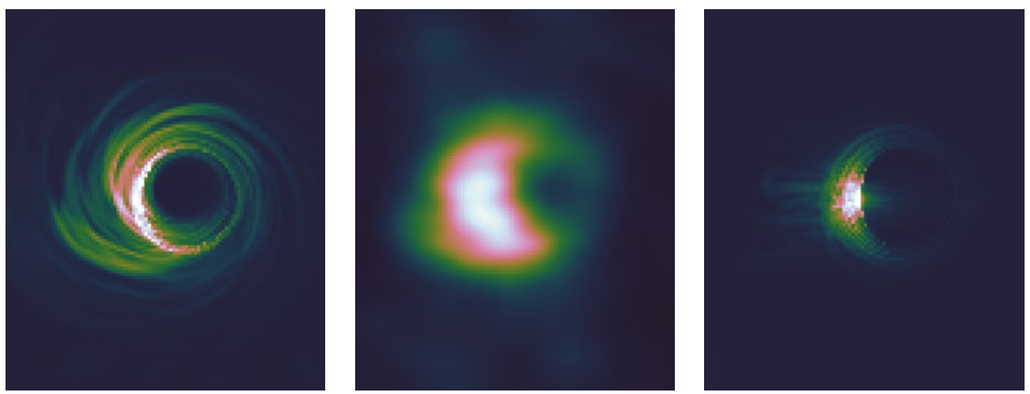
Capturing an image of the extremes of nature required that the EHT assemble a telescope that used the extremities of the Earth. This is exactly what the EHT did: individual antennas had to be at planet-scale distances apart, and on top of mountains and volcanoes, to try to peek above the atmosphere, specifically above the water vapour that can so easily remove any signature of a black hole shadow.

Roger Deane, Associate Professor in the Department of Physics, understood as far back as 2012 when the EHT was still a loose grouping of scientists, that he wanted in, and that he had something to offer – to build highly realistic simulations of the Earth-sized telescope.

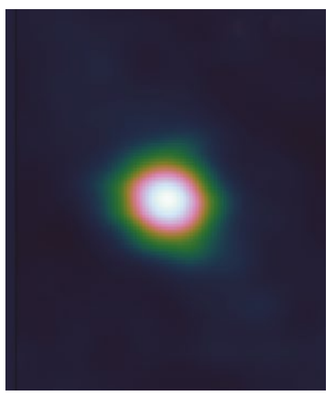
It was in this area – testing the capabilities and limits of this Earth-sized telescope – that Roger Deane and research groups at UP and Rhodes University developed a world-first simulation of the global network of antennas and the atmosphere above. Their work was focused on understanding the performance of this Earth-sized telescope, and to generate confidence in the calibration and imaging results that the EHT released in 2019.

Even in the absence of adverse weather effects and imperfect engineering, the technique that the EHT uses, aperture synthesis, is a complex process. Its inventor, Sir Martin Ryle, was awarded the Nobel Prize in 1974 for his efforts, which have made next-generation telescopes like the MeerKAT and the Square Kilometre Array (SKA) possible. In the case of the EHT, it has required GPS receivers and atomic clocks at each station to time-stamp data to nanosecond accuracy before being recorded to disk and transported to a supercomputer via an aircraft as global internet networks are simply not fast enough to transfer the 4 Petabytes of data produced, particularly from the South Pole.

Simulations of this global instrument consumed all the research efforts of Professor Deane and his research group in 2018. Looking ahead, it is anticipated that the contributions of Deane and his group would be used as a predictive engine to optimise the placement of future EHT sites, including potential African stations.



On 10 April 2019, the Event Horizon Telescope Collaboration made science history by revealing the first image of a black hole to the world, a ring of fire that one could say marks an exit point from our universe. It was a historic achievement for science: the first direct visual confirmation of the existence of these gravitational behemoths predicted by Einstein's general theory of relativity a century earlier.



Simulations of the black hole produced by Roger Deane: Goddi, C., et al. 2018, *International Journal of Modern Physics*, 26, 2.

MeerKAT: a world-leading big data radio telescope

In contrast to the Event Horizon Telescope's detailed study of just a handful of carefully selected supermassive black holes, South Africa's MeerKAT telescope will study millions upon millions of them. If the EHT were to be likened to an electron microscope, the MeerKAT would be a wide-field camera.

Built and operated by the South African Radio Astronomy Observatory, and launched in July 2018, the MeerKAT telescope is a precursor to the SKA, which will be the largest scientific facility on Earth.

The MeerKAT is already a world-beating telescope in its own right. By combining light from 64 antennas in the Karoo, it is able to produce far deeper and higher quality images of the radio sky than have been produced before at these observing frequencies. This presents both an opportunity and a challenge to radio astronomers: it provides unprecedented views of the universe, but at the cost of a staggering data set size and richness. To tackle this, Roger Deane's astrophysics research group has partnered with the well-established Computational Intelligence Research Group (CIRG), led by Dr Christopher Cleghorn in the Department of Computer Science, to use machine learning techniques in the analysis of radio interferometric data.

The two groups have a joint research grant and postgraduate students from the Inter-university Institute for Data Intensive Astronomy, which helps to build cross-disciplinary capacity to address the challenges that these next-generation telescopes present.

Harnessing vast data and scientific discovery

Christopher Cleghorn, Department of Computer Science

The MeerKAT telescope is a great opportunity for South Africa to demonstrate its scientific prowess. However, given the immense data generated by the telescope, the most rapid and scalable way to capitalise on this opportunity is via machine learning.

The use of Artificial Intelligence (AI) techniques will be of paramount importance to ensure scientists are able quickly to detect potentially subtle, astronomical phenomena.

Led by Dr Christopher Cleghorn in the Department of Computer Science has historically focused on fundamental research in the area of stochastic optimisation and neural network-based machine learning. In light of the massive potential of the MeerKAT telescope, Dr Cleghorn has pivoted CIRG's research to ensure the group is able to harness expertise in machine learning to facilitate scientific discovery in astrophysics.

There are currently two primary research focus areas in the field of AI: the theoretical analysis of population-based optimisation algorithms, and the application of machine learning techniques to radio astronomy. In terms of the former, Cleghorn's focus has been on the mathematical derivation of stability criteria for optimisation algorithms. Stability is a facet of algorithm dynamics that is crucial for algorithmic effectiveness in the real world. In 2018, he published an overarching stability theorem for a broad class of particle swarm optimisation algorithm variants. The result obtained relied on provably minimal modelling assumptions and the theorem marks a unification of previous work on stability in the field.

The more recent radio astronomy research focus has been borne out of a CIRG collaboration with UP's astronomy group in the Department of Physics. The ASTRO-CIRG group aims to harness the full power of AI to accelerate the advancement of fundamental astrophysics. To make this collaboration truly effective, ASTRO-CIRG has physicists and computer scientist working in an integrated lab environment.

The initial focus of the ASTRO-CIRG group is two-fold: first, to build and train optimal goal-orientated image stacking controllers, a method already used to detect previously unknown physical phenomena. The second focus is on constructing machine learning approaches to perform rapid morphological classification, in the hope of not only cataloguing, but also making possible the detection of previously unseen morphological structures.

Christopher Cleghorn and Roger Deane.

Reshaping optimality

Daniel Nico Wilke, Department of Mechanical and Aeronautical Engineering

Finding optimal process and design engineering solutions requires models that are computationally efficient, and exploit the right information.

Increasingly, in global and local economic contexts where the 4th Industrial Revolution (4IR), artificial intelligence and the 'internet of things' have become pervasive, the efficient management of large production volumes necessitates precise engineering solutions. This dynamic and fast-changing context places significant pressure on design and process engineers to find the best solutions, to propose competitive approaches to production and service, and to deliver new products timeously. To achieve these increased demands, engineers need responsive and accurate computational models.

In real-world business and engineering contexts, time is of the essence. Weeks, even months, are often required to obtain an approximate answer to assess the quality of a single design or process. Enabling design and process engineers to formulate questions accurately, and to obtain answers within short turnaround timeframes, used to be unthinkable where dilatory systems are pervasive.

Nico Wilke, Associate Professor in the Department of Mechanical and Aeronautical Engineering, has worked on enhancing the efficiency of design and process engineers by developing a mathematical framework that can handle estimates of vastly different accuracies and consequently computational costs. He has also worked with researchers in moving, with ease, from smooth and continuous classical optimisation, to difficult and discontinuous functions, by using gradient-only optimisation and gradient-only surrogates. This work has had application in contexts ranging from finding optimal shapes of structures, to automating the training of deep learning models on graphical processing units.

Wilke's co-authored book, *Practical Mathematical Optimization* (2018, Springer, 2nd edition), was the first on the international market to cover this particular mathematical framework and computational model, supported by unique optimisation algorithms. The focus on application is intended to save valuable computational time for engineers and researchers in solving specific engineering problems. These ideas have also been presented on the international stage through invited talks and PhD courses.

In a number of international collaborations, significant progress has also been made to simulate processes that involve granular materials. Although the second most manipulated substance after water, they remain one of the least modelled by engineers. Significant contributions have included: i) accelerating simulations, ii) improving particle shape representations, and iii) interactive simulations, being enabled by computing on graphical processing units. Over the last three years, commercial codes have followed suit in the use of graphical processing units.

Nico Wilke received the 2018 Vice-Chancellor's book award for his book on mathematical optimisation, co-authored with the late Jan Snyman.

Clean energy –

transitional flow regime and heat exchangers

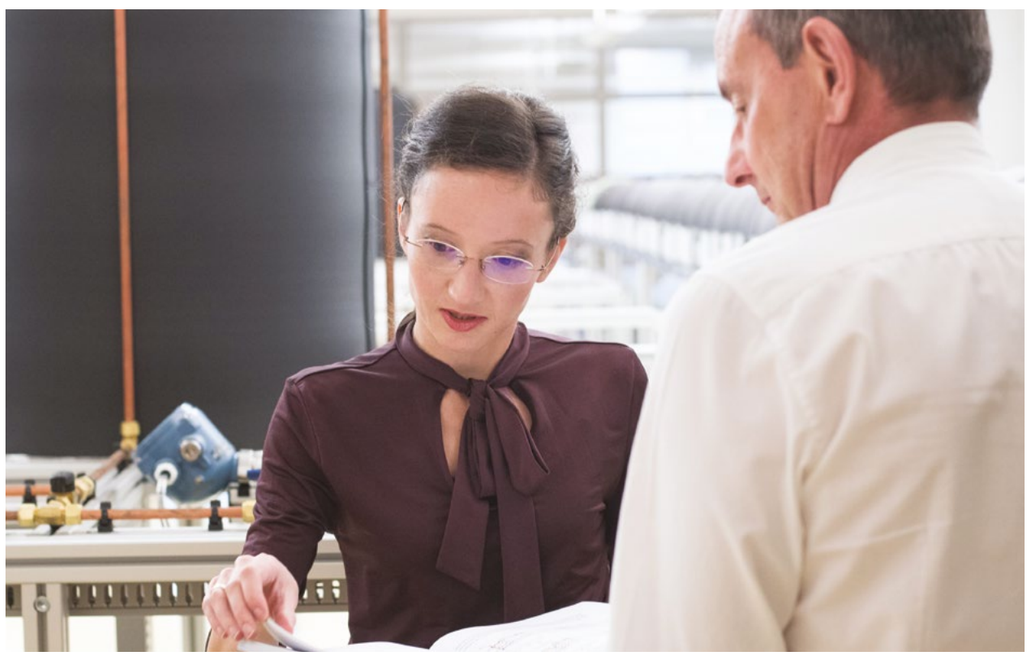
Josua Meyer and **Marilize Everts**, Department of Mechanical and Aeronautical Engineering

South Africa aims to generate 42% of the country's electricity from renewable energy sources by 2030. Having some of the highest solar radiation levels in the world, the Department of Energy has prioritised renewable energy technologies, such as concentrating solar power (CSP). As there are already seven CSP plants in South Africa, it is important that sufficient design information is made available in order to increase the efficiency of these and future CSP plants.

The Clean Energy Research Group (CERG), established and led by Professor Josua Meyer in the Department of Aeronautical Engineering, has two research areas: a broad focus on thermal sciences and fluid flow, and a narrower focus on heat exchangers.

The team's heat exchanger work, at the level of fundamental science, is on flow in the transitional flow regime, nanofluids, boiling, and condensation. At the level of applications, the focus is on thermal, solar, wind and nuclear energy. CERG conducts joint research and publishes with scholars at Ecole Polytechnique Fédérale de Lausanne (EPFL), Massachusetts Institute of Technology (MIT), the Universities of Ghent, Duke and Edinburgh, and the Institut National des Sciences Appliquées (INSA) of Toulouse.

CERG is at present involved in three international collaboration projects. The need continually to increase the processing speed and durability of modern microprocessors in smart-phones, high-performance computing clusters or advanced electronic equipment leads to increased power dissipation and heating. To sustain high speeds and reliable operation, this heat must be dissipated ideally at the same rate as it is generated, but the current state-of-the-art conventional air-cooling is ineffective with 40% of air not playing a role in dissipating heat. The ThermaSMART RISE project is a joint research programme between 18 universities and three industry partners and investigates the use of phase-change cooling of high-power electronic devices.



Marilize Everts and Josua Meyer

Together with Imperial College London and the universities of Lagos and Mauritius, CERG is also involved in a Royal Society Capacity Building Initiative that investigates unsteady boiling that typically occurs in CSP plants when the sun is suddenly blocked by clouds. The third project is the International Science and Technology Initiatives, a collaboration between MIT, Imperial College London and the University of Pretoria. The purpose of the project is to study augmented boiling with nano-engineered surfaces as this can significantly increase the heat transfer performance of CSP heat exchangers.

In the transitional flow regime, Professor Meyer is working with Dr Marilize Everts, a postdoctoral research fellow in the Department. Their research focuses on the fundamentals of mixed convection flow which potentially has a wide range of applications, but is specifically applicable to solar energy.

Heat exchangers make it possible to use solar energy for heating, cooling, lighting, electrical power and transportation. A major environmental benefit is that solar energy has no associated air pollution emissions, and therefore plays a critical role in the reduction of future carbon emissions and thereby ensuring a sustainable energy future. The annual global average solar radiation per square meter can produce the same amount of energy as a barrel of oil, 200 kg of coal, or 140 m^3 of natural gas. Solar energy is an inexhaustible source of energy that contributes to healthier people and a cleaner environment. This is especially important for South Africa, as the air in Mpumalanga and the eastern parts of Gauteng is currently the greatest source of nitrogen dioxide pollution in the world.

Up to now, design engineers have been advised to avoid designing heat exchangers that operate in the transitional flow regime, due to uncertainty and a lack of design information. However, the correlations that were developed by Meyer and Everts now enable them to design heat exchangers that operate in the transitional flow regime. By implementing the state-of-the-art correlations and research, CSP systems are optimised and their efficiency improves. This will make CSP plants more competitive, compared to other power plants and contribute to lower and stable electricity prices.

Professor Josua Meyer is Head of the Department of Mechanical and Aeronautical Engineering and Chair of the School of Engineering. He received the 2018 UP Chancellor's Award for Research, in recognition of outstanding research and international stature over an extended period.

Dr Marilize Everts received the 2018 L'Oréal-UNESCO For Women in Science in Sub-Saharan Africa Postdoctoral Award, in recognition of her talent as a young female scientist in the field of Life and Physical Sciences.

Rock engineering research

makes underground mining safer

Francois Malan, Department of Mining Engineering

Innovative methods of layout design and improvements to the support of deep tabular stopes are required to exploit South Africa's vast remaining gold resource.

The gold mines of South Africa are the deepest in the world and more than 50 000 tons of gold have been extracted since 1886. Even after a sustained production period of mining over this period, the Witwatersrand Basin is still the world's largest resource of gold.

Recent rockburst accidents have drawn attention to the need for research into methods to mitigate the risks associated with mine seismicity, and for the development of updated design criteria for the very deep mines. Remnants and pillars (small, isolated blocks of reef) are mined in many of the older operations. There is currently a great need to improve the criteria used to select which remnants can be mined safely. Work also needs to be done to improve the support design methodology for rockburst conditions.

In 2018, Professor Francois Malan extended the rock engineering research programme in the Department of Mining Engineering to focus on improved methods for layout design and the support of tabular hard rock stopes. This work has also formed part of the Harmony Chair in Rock Engineering.

A key breakthrough by the research team was the development of a numerical modelling method to determine the time-dependent stability of the fracture zone near the edges of tabular excavation layouts when different mining rates and face advance increment lengths are scheduled. The model specifically accommodates energy dissipation computations in the developing fracture zone near the edges of these excavations. This allows the released energy to be used as a surrogate measure of ongoing seismic activity and addresses a number of the weaknesses in the traditional usage of released energy as a criterion for the design of seismically active layouts.

Stope supports in a South African gold mine.

The effectiveness of stope support in deep gold mines was also assessed. The design of rockburst-resistant support for shallow-dipping tabular excavations is particularly problematic when the stoping width is very small. The need for area support to give improved protection to stope workers was highlighted in the research. The work resulted in a number of publications in 2018, of which two were published in the prestigious *International Journal of Rock Mechanics and Mining Science*.

John Napier, Extraordinary Professor in the Department of Mining Engineering, is a key collaborator in this research programme. Collaboration with the rock engineering groups of Northam Platinum, Impala Platinum, Lonmin Platinum and Harmony Gold were also established in 2018.

Geotechnical centrifuge engineering

SW Jacobsz, Department of Civil Engineering

Everything that civil engineers build ultimately stands on soil or rock. While rock normally provides excellent foundations, many types of problem soils occur posing challenges to engineers.

The research interests of Professor SW Jacobsz and his laboratory cover a range of projects in the field of geotechnical engineering, focusing on unsaturated soil mechanics. The research facility at their disposal is the University's 150 g-ton geotechnical centrifuge which enables physical models of geotechnical problems to be studied at full-scale stresses. The centrifuge can accelerate models weighing as much as 1 ton to 150 times the Earth's gravity.

The modelling capabilities offered by the centrifuge has attracted international collaboration with the Universities of Durham, Cambridge, Khartoum and Dar es Salaam to develop guidelines for the design of wind turbine foundations on expansive soils.

The *WindAfrica* project is funded by the Engineering and Physical Sciences Research Council of the United Kingdom Global Challenges Fund. Due to high average wind-speeds large parts of Africa are suitable for wind energy generation, but many such areas (e.g. in Sudan and Tanzania) are underlain by deep expansive soils. The large ground movements associated with seasonal moisture fluctuations in such soils pose particular challenges for the construction of sturdy wind-turbine foundations with very strict permissible movement tolerances. The collaboration includes the construction of a series of heavily instrumented large-scale prototype foundations, which will be load-tested in an expansive clay profile near Steelpoort, Limpopo Province.

The behaviour of these foundations under various loading and wetting scenarios are currently being modelled using small-scale physical models in the geotechnical centrifuge at UP to determine critical load cases to be simulated on the large-scale foundations in the field. This work is complemented by numerical modelling at Durham University, supported by soil testing at the University of Cambridge to quantify the input parameters required by the numerical models.

Another major research interest of Professor Jacobsz and his laboratory involves subsoil cavity propagation leading to sinkhole formation. This is of particular significance in the Gauteng province where approximately 25% of its area is underlain by sinkhole-prone dolomite bedrock. Related to the sinkhole studies is a project to model cave mining in collaboration with the University of Western Australia.

In 2018, co-authored publications that addressed some of the findings of the research group were published in *Geotextiles and Geomembranes*, *Granular Matter* and in *Computers and Geotechnics*.

A recent spin-off from the work on unsaturated soil mechanics was the development of low-cost, high-capacity tensiometers capable of measuring pore water suctions exceeding a Mega-Pascal. One of the highlights in 2018 was the filing of a provisional patent on work related to pipeline leak detection using fibre optic ground strain measurement.

Biodiversity and biotechnology

Identifying the patterns

IDENTIFYING THE PATTERNS

Biological communities, large and small, are structured by ordered interactions between organisms, and between organisms and their environments. These interactions take many forms: physical, chemical, social and behavioural. The consequences of such interactions may be beneficial to the partners, or deleterious, but all are part of the extraordinarily complex arrangement that we refer to as 'life'.

A focus on conservation genetics

Paulette Bloomer, Department of Biochemistry, Genetics and Microbiology

South Africa is one of the mega-diverse countries in the world in terms of species diversity. In addition to the sheer numbers of unique species, the country is also recognised for high levels of endemicity, i.e. species that uniquely occur here and nowhere else.

Three South African biodiversity hotspots have been extensively documented, primarily based on plant species diversity, endemicity and threats to these habitats: the Cape Floristic, Succulent Karoo, and the Maputaland-Pondoland-Albany ecoregions. Molecular phylogenetics and ecology research at UP is revealing that South Africa is also rich in animal diversity and endemism.

'Biodiversity' includes diversity of ecosystems, species and genetic diversity. Genetic diversity has been overlooked in many international policies, but is increasingly recognised as an important factor in conservation, especially in the context of species' resilience to global change.

Professor Paulette Bloomer and Dr Michael Cunningham, members of the Molecular Ecology and Evolution Programme (MEEP) team, with their local and international collaborators have, over the past 20 years, demonstrated that South Africa has hidden terrestrial and aquatic vertebrate biodiversity, and areas of high evolutionary potential (high species and genetic diversity). Their work has shown that genetics research can contribute to the conservation and sustainable use of species, aligned with the South African government's bio-economy and biodiversity strategies.

One of their main focus areas has been on conservation genetics. In a co-authored publication in *Conservation Genetics Resources* in 2018, Dr Isa-Rita Russo, a former MEEP PhD student and current Cardiff postdoctoral fellow, and a team of conservation geneticists and scientists, including Paulette Bloomer, highlighted the potential threats of intentional breeding for specific phenotypic traits and unregulated movement of species.

A member of the iconic African 'Big 5' and prominent species in the wildlife ranching industry is the African buffalo. Dr Deon de Jager, one of the 2018 MEEP PhD graduates and current postdoctoral fellow, developed a software tool, *Friends and Family*, published in *Molecular Ecology Resources* in late 2017. The tool uses genotypic data to identify unrelated individuals in a herd which could assist both wildlife ranchers and conservation managers in developing breeding or translocation plans for any species.

Dr de Jager, Dr Cindy Harper (Onderstepoort Veterinary Genetics Laboratory) and Professor Bloomer also collaborate with researchers at Stellenbosch University who have sequenced the African buffalo genome for the first time. With this resource in hand, and the steadily reducing cost of next-generation DNA sequencing, the team sequenced 40 additional buffalo genomes from four national parks in South Africa, comprising the first population genomics study of African buffalo. The genome-wide data revealed substantially higher inbreeding in Addo buffalo than expected, a result which has increased the urgent need for conservation authorities to intervene to prevent the negative effects of inbreeding depression from manifesting in the population.

The study is a good example of how genomic data can provide novel and valuable information to assist conservation authorities in managing populations and species that are important contributors to South Africa's biodiversity economy.

Members of the MEEP team.

Coastline showing marine and terrestrial ecosystems.

Conserving endemic species

and ecosystem processes

Cora Stobie, Department of Biochemistry, Genetics and Microbiology

Despite being a water-scarce country, South Africa's extensive freshwater ecosystems harbour rich aquatic biodiversity.

Molecular Ecology and Evolution Programme graduate, Dr Cora Stobie, focussed her PhD research primarily on an iconic group of endemic freshwater fish known as yellowfish (genus *Labeobarbus*).

Yellowfishes are highly popular in South Africa, both for subsistence and recreational purposes. They are also used as indicators of river health – their presence indicating low water pollution and few alien fish species. For these reasons, conservation management of yellowfish in freshwater systems is needed.

The genus is particularly interesting from a genetics perspective as all the species are hexaploid; i.e., they have six sets of genetic material, unlike diploid animals (including humans) that have two. This greatly complicates many forms of genetic analysis, and necessitated forays into next-generation sequencing, and restriction-site associated DNA sequencing, to bypass some of these difficulties.

Cora has subsequently shown that *L. natalensis*, the KwaZulu-Natal yellowfish, is divided in two major genetic lineages and five distinct populations across a broad regional habitat separated by drainage systems. These findings, published in *Ecology and Evolution* in 2018, have important conservation implications. She also mined the genome sequencing data to reconstruct partial mitochondrial genomes for three species – *L. natalensis* and the Orange-Vaal yellowfishes, *L. aeneus* and the threatened *L. kimberleyensis*. The genetic analyses uncovered signals of divergence, hybridisation, introgression and even a recent translocation event between drainage systems. With her MEEP team co-authors, this work was published online in *Molecular Ecology Resources* in 2018.

Taken together, the two papers indicate that the distribution of genetic diversity can inform water resource management (among others, setting guidelines for inter-basin water transfers), and translocation policies for species. The northern and southern river systems across KwaZulu-Natal are separate hotspots of diversity, and deserving of special protection to maintain evolutionary and ecological processes.

The Conservation Genetics Specialist Group (CGSG), which functions under the umbrella of the Species Survival Commission of the International Union for the Conservation of Nature, launched its Africa chapter in the KwaZulu-Natal midlands in November 2018. The aim of this specialist group is to promote the use of genetics in conservation management and policy, and thereby to assist the Commission in the development and analysis of genetic data in conservation. Four UP academics are members of the Africa group: Professors Paulette Bloomer, Catherine Sole and Brenda Wingfield, and Dr Thierry Hoareau.

Conservation genetics –

in search of marine evolutionary hotspots

Thierry Hoareau, Department of Biochemistry, Genetics and Microbiology

The world's oceans play a central role in our lives as they provide oxygen, water, food and cultural services, regulate the global climate and support economic activities.

With the emerging concept of 'the Blue Economy', first introduced at the Rio +20 United Nations Conference on Sustainable Development in 2012, several African coastal countries and islands have planned to exploit the full potential of the oceans' resources. A major challenge is to preserve the health of ocean ecosystems while unlocking economic growth to improve livelihoods and create jobs.

The reality is that the oceans are already disturbed by overfishing, destruction of habitats, pollution and sedimentation. Such disturbances are exacerbated by dense populations and high levels of growth and urbanisation in coastal areas. We cannot hope to protect what we overlook and do not understand. Preserving ocean ecosystems and marine biodiversity requires a better evaluation of the current biodiversity and the status of important marine species. This is essential if we wish to research the sustainability of the oceans economy.

Dr Thierry Hoareau and his collaborators published an earlier seminal study in the *Journal of Biogeography*. They had designed a framework to identify marine evolutionary hotspots based on the use of phylogenetics, DNA barcoding and population genetics approaches. Evolutionary hotspots are regions characterised by large species diversity and evolutionary processes important to maintain and generate genetic biodiversity. Identifying such regions is crucial for conservation and management of ecosystems as it guarantees maintenance of the mechanisms at the source of biodiversity.

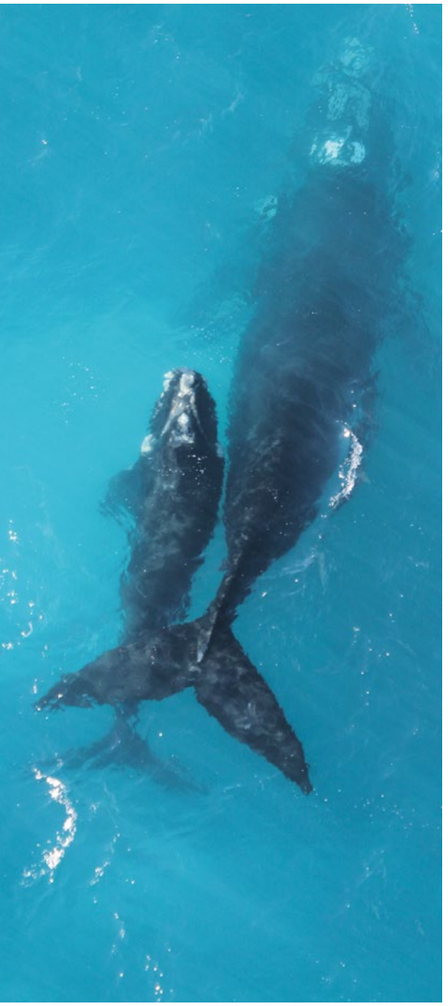
For the past few years, the research team has applied the same methods to other species, including reef brittle-stars and hydrozoans found in coral reefs in the Western Indian Ocean region. Using these new molecular tools has helped them detect an unexpected diversity of species. In 2018, Hoareau and his co-researchers published these results in the *Journal of Biogeography*. A total of 32 new species of brittle-stars and 37 new species of hydroids have been discovered, raising the number of surveyed species by 57% and 318%, respectively. Their studies suggest that the Western Indian Ocean should be considered as a marine evolutionary hotspot.

New applications of the framework will help in the search for evolutionary hotspots along the South African coastline, using linefish and invertebrates as targeted species. Dr Hoareau anticipates that regions that are important for the dynamics of marine biodiversity will be detected, which will provide key information for the management of marine protected areas along the South African coastline, and help towards the goal of the sustainable use of our marine environment.

Whales – sentinels of ocean health

Els Vermeulen, Mammal Research Institute (MRI)

The South African right whale population is estimated to be just over 6 000 individuals, or 30% of its pre-exploitation levels. In the last few years, there has been a slow yet continuous decline in their population growth, most likely a consequence of reproductive failure.



The survey UP's Mammal Research Institute Whale Unit undertakes of the South African right whales (*Eubalaena australis*) is one of the longest running research projects on any marine mammal in the world. Annual aerial surveys are conducted along the southern Cape coast which, since 1979, have included the photo identification of all females with calves. These photographic surveys make possible the tracking of individual females over time, from which population parameters are derived.

Dr Els Vermeulen, lead researcher and manager of the Whale Unit, has collaborated in an international comparative study on right whales, published in *Royal Society Open Science* in 2018, and on the movement patterns of humpback dolphins in South Africa, published in *Aquatic Conservation: Marine and Freshwater Ecosystems*.

Her research team's analyses of the latest data on South African right whales show that the numbers of whales along the southern Cape shore have fluctuated enormously in the last few years. The number of males and non-calving females migrating to the southern Cape coast plummeted from over 400 in 2013 to a mere nine individuals in 2016, and remain extremely low. Similarly, the number of females calving have varied from over 300 in 2014, to 55 in 2016, with an all-time record of over 500 in 2018. From the analyses undertaken, these fluctuations seem to be related to an increase in the calving intervals, which is indicative of calving failure.

The reproductive success of many species is known to be affected by foraging success and body condition. This is no different for whales. Indeed, the first results of a new project, initiated in 2018, have shown a strong correlation between the number of right whale calves, and climate conditions and productivity in their Southern Ocean feeding grounds. The next step will be to collect skin samples for stable isotopes analysis, in order to gain insight into where exactly the whales are feeding, and information on their diet in the different locations.

Due to its annual migration to the coast of South Africa, and the availability of a unique 40-year long dataset, these whales seem to be the 'right sentinel' to assess, from mainland Africa, the health condition of a wide region in the Southern Ocean, while monitoring the population dynamics of these recovering baleen whales.

Improving genetic diversity – endangered species

Isabel Callealta, Department of Anatomy and Physiology, and MRI

Habitat loss and fragmentation, illegal wildlife trade and human-wildlife conflict affect all cat species with 25 of the 36 listed as vulnerable or endangered on the International Union for the Conservation of Nature red list. The African lion (*Panthera leo*) population is estimated to have decreased by more than 60% over the past two decades, with only about 18 000 remaining in the wild in 2018.

In South Africa this big cat is classified as 'least concern', as there is an increasing number of captive animals living on private and national reserves that breed quite well. While this makes the African lion an accessible model species to study, most populations have limited genetic variation and a tendency for inbreeding, which leads to reproductive anomalies and an increased risk of extinction.

Dr Isabel Callealta, a veterinarian, has focused her doctoral studies at UP on the fundamental reproduction physiology of the African lioness. Working under the supervision of Professor André Ganswindt and Dr Imke Lüders at the Mammal Research Institute (MRI), her research also feeds into the development of a protocol for ovulation induction and non-surgical artificial insemination. Assisted reproduction techniques (ART) may help to improve the genetic diversity by introducing new genes into isolated populations, and thereby increase their breeding success.

Information regarding physiological parameters, such as normal ranges for haematology and blood chemistry, or endocrine mechanisms, is currently scarce for large felids, mainly because diagnostic or therapeutic procedures are quite challenging to perform in both wild and captive individuals.

Dr Callealta closely observed, over a period of two years, five female African lionesses hosted at Ukutula Conservation Center in the North West province. The lions were trained through positive reinforcement conditioning to voluntarily allow frequent collection of vaginal smears and blood. Faecal and blood hormones were monitored and the analysis undertaken at UP's Endocrine Research Laboratory. All this information has helped to build an in-depth understanding of the lioness' oestrous cycle, and to identify the right timing for artificial insemination.

The team of UP scientists made world headline news in September 2018 when a lioness at the Ukutula Centre gave birth to the first cubs conceived by artificial insemination.

Research is ongoing as to the feasibility of implementing ARTs in lion *ex-situ* breeding programmes, and the possibility of adapting this method to other felid species. The team anticipates that the programme will open new opportunities to improve breeding of captive and wild lion populations, and thereby assist conservation efforts.

The Dark Side of the Hive

Robin Crewe, Centre for the Advancement of Scholarship

Honey bees have been described as exceptionally clever, well-organised, mutualistic, collaborative, busy, efficient – in short, a perfect society that can act as an exemplar for human societies.

The perfection that is perceived to exist in honey bee societies is a function of a particular experimental focus on the colony as a whole, rather than exploring the idiosyncrasies of its individual members. While the colony is indeed a marvel of harmonious, efficient organisation, it also has a considerable dark side.

Authors Robin Moritz and Robin Crewe write about the life history of the honey bee, *Apis mellifera*, highlighting conflict rather than harmony, failure rather than success, from the perspective of the individual worker in the colony. When one looks carefully, the honey bee colony is far from being perfect. As with any complex social system, honey bee societies are prone to error, robbery, cheating, and social parasitism. Nevertheless, the hive gets by remarkably well in spite of many seemingly odd biological features that are often dismissed as aberrations, requiring us to focus attention on these 'aberrations' since they are central to understanding aspects of social organisation.

Their book dissects the various careers that individual male and female honey bees have and their roles in colony organisation. Competition between individuals using both physical force and chemical signalling drives colonial organisation, and the authors show how this competition deals with handicaps that limit the use of physical force and the chemical arms races that drive competition in relation to worker reproduction. Sex determination

allows for male bees to be produced on demand, and no energy therefore needs to be wasted on their continuous production!

Published in 2018, *The Dark Side of the Hive: The Evolution of the Imperfect Honey Bee* (OUP) deals with individual mistakes, maladaptations and evolutionary dead-ends that are also part of the bees' life. The story told about these non-cooperative elements (the dark side of being a member of a society) within the colony spans the full range of biological disciplines, ranging from genomics to systems biology. By moving beyond an experimental study of bee colonies, the book provides a more complete insight into the nature of complex insect societies by focussing on individual contributions to this society of females.

Authors Robin Moritz and Robin Crewe, with Vice-Chancellor Cheryl de la Rey.

Robin Moritz is an extraordinary professor at UP and an emeritus professor of Molecular Ecology at Martin-Luther-University of Halle-Wittenberg. Robin Crewe is a professor and senior research fellow in the Centre for the Advancement of Scholarship and a member of the Social Insects Research Group.

Turning worker bees into false queens

Abdullahi A Yusuf, Department of Zoology and Entomology

Division of labour and task allocations are key features of organisation in social insects societies such as those of honey bees, ants and termites. Roles performed in reproduction, defence, cleaning or taking care of the young, and other roles in ecosystem services like pollination, make studying and understanding eusocial insects and their behaviour both important and fascinating.

In honey bees, there is clear morphological and physiological differentiation between the workers and the queen, who uses chemical signals to control reproduction in worker bees. However, in circumstances where there is a sudden loss of the queen, this hierarchy is lost and workers have to restore reproductive hegemony through the emergency rearing of a queen. During this process, several changes occur in the hive, which include the ability of workers to lay eggs and the appearance of false queens.

Dr Abdullahi Yusuf and researchers of the Social Insects Research Group (SIRG) have explored the possibility of transforming workers into false queens by the use of exogenous pheromone supplementation. Their study involved two native sub-species of honey bees, *Apis mellifera scutellata* (savannah honey bee), a sub-species in which laying workers are rarely produced, and *A. m. capensis* clones of the Cape honey bee that readily transform into laying workers and false queens.

They succeeded in transforming both sub-species of adult honey bee workers into false queens through the use of mobile honey bee pheromone carriers (bees carrying pheromones on their thoraces), and showed that these bees exhibit the behaviours and the physiology of queens. Another interesting finding was that workers can be manipulated into becoming false queens, irrespective of their genetic origin. They are now exploring the possibility of using pheromone supplementation in the management of social parasitism at its onset. The study, co-authored with Professors Robin Crewe and Christian Pirk, was published in 2018 in the *Journal of Experimental Biology*. The study also shows that the development of a mobile pheromone delivery system can be applied in other models in laboratory and field studies.

There are a number of concurrent research projects in SIRG, with published findings in 2018 including work on the molecular basis of pheromone production and regulation in honey bees, genes responsible for pheromone production, and the enzymes involved in downstream regulation of worker reproduction in social insects.

Nature's own contraceptive

Nigel Bennett, Department of Zoology and Entomology, and MRI

Naked mole-rats live in colonies ranging in size from 70 to up to 300 individuals. The ruler of such a colony is a despotic queen who pushes members around to get them to work, but also to let them know who is boss!

The naked mole-rat occurs in the eastern horn of Africa in Kenya, Ethiopia, Somalia, and Djibouti. They use an extensive burrow system in hard clays and live in so-called 'castles of clay' where nonbreeders act as helpers. The queen usually has between two and three male consorts who breed with her.

For many years, Professor Nigel Bennett had been puzzled as to why the nonbreeders of both sexes had swollen teats despite the fact that nonbreeding females, and of course males, were not pregnant. The presence of swollen teats in males was especially bizarre, and he suspected that elevated levels of hormone prolactin might be important. At the time, there was no specific assay for mole-rat prolactin (PRL) available. He approached Professor André Ganswindt (MRI) to see if a guinea pig assay (the guinea pig being a close relative to the naked mole-rat) could be used to measure PRL. After some trouble-shooting at the Endocrine Research Laboratory, and validations by Stefanie Ganswindt, the team was ready to measure the PRL concentrations in the naked mole-rat!

The PRL levels measured in the nonbreeders of both sexes showed that although there is some variability, many values are clinically hyperprolactinaemic. This suggests that the high levels of PRL act on the GnRH neurons and bring about suppression of reproduction. Indeed, elevated PRL is known to suppress fertility in many birds and mammals and it has been found to be an important factor in mediating both alloparental and parental care.

Vanessa Wanja Kamgang, a PhD student, with Nigel Bennett.

As would be expected for a reproductively active breeding female mammal, the circulating PRL concentrations detected in naked mole-rat queens were around pregnancy and lactation. These results suggest that elevated PRL in nonbreeders may be an important component of reproductive suppression in nonbreeding males and females, but in promoting helping behaviour in these cooperatively breeding animals. However, how the queen orchestrates this socially induced infertility still remains unknown.

Recent transcriptome profiling of the naked mole-rat brain has shown the breeding animals have increased expression of the genes involved in dopamine metabolism (dopamine inhibits prolactin secretion) compared with nonbreeders. This is wholly consistent with the concept of high levels of PRL in nonbreeding naked mole-rats and strongly suggests a role for hyperprolactinaemia as a component in socially induced reproductive suppression in the naked mole-rat.

The paper was published in 2018 in the highly prestigious Royal Society journal, *Biology Letters*.

Forests at risk –

coming to grips with a tiny beetle

Wilhelm de Beer, Department of Biochemistry, Genetics and Microbiology, and Forestry and Agricultural Biotechnology Institute (FABI)

In the space of just over a year, between the discovery of the invasive Polyphagous Shot Hole Borer (PSHB) beetle in 2017, and its destructive path throughout 2018, it has been confirmed present on 80 host tree species, 35 of which are native to South Africa.

Wilhelm de Beer at a coral tree killed by PSHB.

The PSHB is an aggressive, 2 mm long ambrosia beetle that can attack many different species of trees. It bores through the bark to construct breeding tunnels (called galleries) in the sapwood. Each little beetle carries a specific fungus that is cultivated as a food source in these galleries. In the case of the PSHB, this fungus is a species of *Fusarium* that can kill the infected trees.

Dr Trudy Paap, a postdoctoral fellow in FABI and the South African National Biodiversity Institute (SANBI), discovered the beetle in Pietermaritzburg in early 2017 as part of a routine survey of pests and diseases in the Botanical Gardens. A team of researchers at FABI, led by Professor Wilhelm de Beer, assisted in establishing a countrywide research network to resolve unanswered questions about the invasive beetle and its fungal symbiont.

For 15 years, Wilhelm de Beer's research has been on fungal associates of bark and ambrosia beetles, linked to the work of FABI's Tree Protection Co-operative Programme, and involving collaborators from five continents. Thus, when the PSHB was detected in South Africa, FABI had the knowledge base and experience immediately to confirm the beetle and fungus identities, using DNA sequencing technology.

What distinguishes the PSHB invasion from other tree pests is that it affects so many different trees, in the agricultural sector, in urban forests and in natural forests. In an article published in *Australasian Plant Pathology* in 2018, some of the detail of this new invasion in South Africa was described.

Under the leadership of Professor de Beer, FABI has embarked on a number of research projects in collaboration with seven universities in South Africa. The aim is to provide science-based advice on the management of this destructive beetle to a broad range of stakeholders – government and the forestry industry, green industries, agriculture, and the general public.

Identifying fungal pathogens and pathways

Irene Barnes, Department of Biochemistry, Genetics and Microbiology, and FABI

Tree diseases are growing in importance globally. Characterising and describing the biodiversity, host ranges and geographic distributions of the different fungal pathogens that cause these diseases are critical in stemming this tide.

Dr Irene Barnes, a senior lecturer at FABI and one of the research leaders in the Tree Protection Co-operative Programme, focuses her research on fungal pathogens that cause diseases on native and non-native forest tree species. Over the past few years, together with her students and colleagues in FABI, she has developed molecular diagnostic tools that can be used accurately and effectively to identify species of fungi that cause tree diseases. They have also generated markers that can be used to study the population genetics of these important pathogens so as to understand how they spread.

Red Band Needle Blight disease.

Recently, Hawaii has been experiencing a devastating disease epidemic called rapid `ōhi`a death (ROD) where hundreds of thousands of their native tree species, *Metrosideros polymorpha*, have been dying. Dr Barnes, together with colleagues in various parts of the world, discovered that the disease is caused by two fungal species. These *Ceratocystis* species, both new to science, were described and given Hawaiian names. The findings were published in *Persoonia* in 2018. Population genetic analyses showed these species were most likely newly introduced onto the Island although their origin remains a mystery. Knowledge of the pathogens and their biology is contributing to efforts to manage this serious disease. This work is also contributing to the growing knowledge of other *Ceratocystis* diseases important to trees such as *Eucalyptus*, which are important to forestry in South Africa.

The spread of pine needle diseases globally is of special interest to Dr Barnes and her collaborators. One of the objectives of their research is to understand the threat pathogens causing these diseases pose to the South African pine industry. Following this area of interest, Dr Barnes has made extensive collections in Central America – the source of some of our pine species planted in South Africa – to determine the biodiversity of these pine fungi. This work has led to the discovery and description of several new fungal species.

Dr Barnes has also been involved in or led the production of the most comprehensive current reviews on important pathogens of pines, including *Lecanosticta acicola* and two *Dothistroma* sp. Studies are being conducted with scientists from over 40 countries, on all continents where the pathogens occur, to produce detailed distribution maps, and to characterise the global population genetic structure and diversity of these pathogens.

Dr Irene Barnes received the internationally acclaimed 2018 Ethel Mary Doidge Medal for outstanding early career research in mycology by the International Mycological Association. This Africa-wide award is named after the famous plant pathologist Ethel Doidge (1887-1965), who was the first female to receive a doctorate in South Africa. Barnes was also named the first runner-up in the Distinguished Young Women Researchers category of the Department of Science and Technology's Women in Science Awards.

The influence of farming practices

on genetic diversity of fungal pathogens

Dave Berger, Department of Plant and Soil Sciences, and FABI

Capital intensive maize farming is the backbone of food security in South Africa, accounting for more than 95% of production. There are, however, an estimated 2,5 million small-holder maize farmers. Understanding the constraints they experience is important for household food security.

Professor Dave Berger and the Molecular Plant-Microbe Interactions Group have addressed the issue of how different farming practices influence the genetic diversity of fungal pathogens of maize. Their research has focused on the fungus *Cercospora zeina* that causes the economically important grey leaf spot disease of maize.

David Nsibo, Dennis Omondi and Irene Barnes doing field work in Kenya.

In August 2018, the UP team presented a workshop on maize foliar fungal pathogens and molecular diagnostics at Maseno University, Kenya. This was part of a joint South Africa-Kenya collaboration funded by the respective National Research Foundation of each country. As part of this bi-lateral collaboration, MSc student Dennis Omondi has spent two sessions of laboratory training at UP. Being involved in a bi-lateral project with Kenya has been particularly gratifying for Prof Berger, who was born and grew up in Kenya.

In the South African study, the KwaZulu-Natal province, a hotspot for the disease with commercial and small-holder farms in close proximity, was selected. Several hundred isolates of the fungus were collected from each farming system, and population genetic analysis showed that a significant amount of variation was conferred by farming systems. Most importantly, the results indicate that although the fungus can disperse across the province by wind-blown spores, there is selection for greater diversity in small-holder plots.

The project was carried out by PhD student, David Livingstone Nsibo, recipient of a scholarship from the Intra-ACP Mobility Project for Crop Scientists for Africa Agriculture, funded by the European Union. Mentored by Prof Berger and Dr Irene Barnes, David Nsibo's PhD studies have also covered the population genetics of *C. zeina* in small-holder farms of his home country Uganda, as well as in Kenya, Zambia and Zimbabwe. His findings have challenged the hypothesis that the pathogen spread through Africa after an initial introduction to South Africa, and favour alternative hypotheses of multiple introductions, or even an African origin for *C. zeina*. Based on the findings, a paper co-authored with Irene Barnes, Ncobile Kunene and Dave Berger was published in the journal *Fungal Genetics and Biology* in January 2019.

Fungal pathogens and mating genes

Brenda Wingfield, Department of Biochemistry, Genetics and Microbiology, SARChI Chair in Fungal Genomics, and FABI

Mating-type genes are useful in determining the population structure of pathogens, and in understanding the potential of pathogens to recombine and adapt.

Brenda Wingfield, Professor in Genetics and SARChI Chair in Fungal Genomics, works with a team of young researchers on the mating-type genes in fungal pathogens, among a number of research focus areas.

Working on non-model species means that studies on these fungi have revealed some unexpected observations about mating-type genes. Markus Wilken, a postdoctoral fellow, has discovered that the MAT 112 gene is not limited to the MAT1 mating type, as has previously been reported in model species. This has implications with regards to the functions of this gene, a finding that Wilken and research team collaborators published in *Fungal Genetics and Biology* in 2018. Melissa Simpson in her PhD research has shown that an unexpectedly high rate of recombination is found in the MAT locus in *Ceratocystidaceae*. Published in *Fungal Biology*, these findings are in contrast with those found in model species where this locus has suppressed recombination. Using the MAT locus, Wilma Nel, a Master's student, has shown that *Berkeleyomyces* species are probably heterothallic. While unexpected, this finding does account for the high degree of clonality observed in population studies of these economically important pathogens.

Having access to the genomes of a number of fungal pathogens has enabled the research group and PhD student Mohammad Sayari to investigate the Poly Ketide Synthase genes in the *Ceratocystidaceae*. These genes are thought to be involved in pathogenicity in some fungi. Stephanie van Wyk, also a PhD student, used the genome data available for *Fusarium circinatum*, a pine pathogen, to unpack the QTL linked to growth and showed it to consist of five genes of different origins.

As with Brenda, Mike Wingfield is passionate about capacity building and conscious that African researchers need to play a much larger part in world research. He has had the privilege of working with many young people through their PhD studies and celebrated, in 2018, the completion of the 100th doctoral thesis under his guidance. He also received the UP Vice-Chancellor's Award for Excellent Supervision.

Professor Wingfield has achieved both international and national recognition for his research. He is listed among the most highly cited scientists in the world, and one of only 10 scientists in South Africa to have achieved this recognition.

At the intersections of disciplinary fields

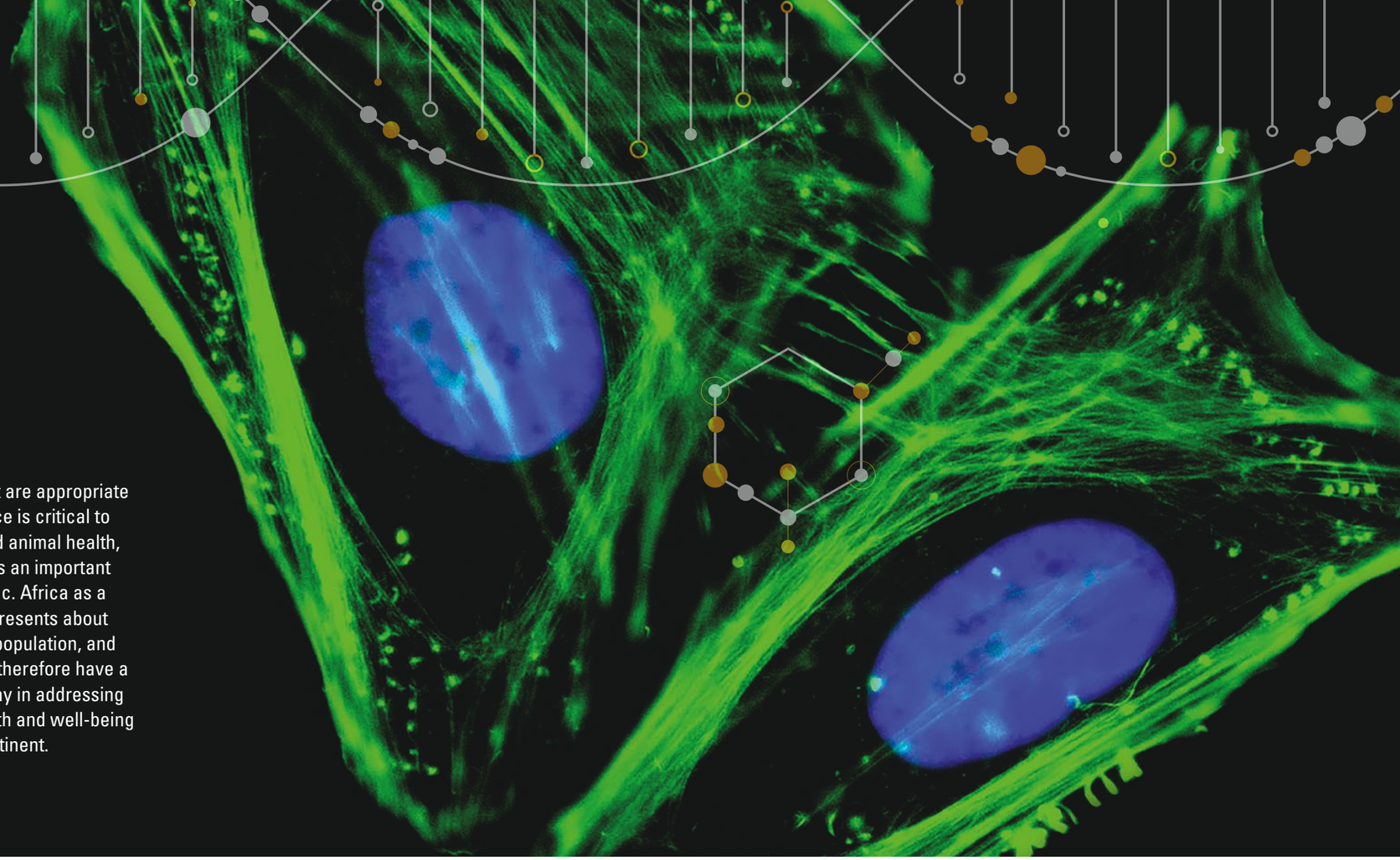
Mike and Brenda Wingfield have spent a lifetime working together and are one of a handful of couples in the country where both partners have National Research Foundation A-ratings. They do not have the same academic background – Mike was trained as a plant pathologist and entomologist; Brenda's primary degrees are in genetics and biochemistry. The fact that they approach research questions from very different perspectives has meant that often their science collaboration has been at the intersection between their respective fields of expertise.

Much has been written about the innovation that is possible at such intersections. The Wingfield's careers perhaps epitomise this. Mike is a skilled morphologist and excellent mycologist with a deep interest in ecology. His strong observational abilities have served him well in spotting tree disease symptoms where others might overlook them. Brenda has focused on gene expression and DNA sequences, seeking to understand life in terms of genetics and chemistry. Thus, while both are passionate biologists, the result of examining research questions from two very different philosophical standpoints has been excellence in research and, indeed, many lively debates.

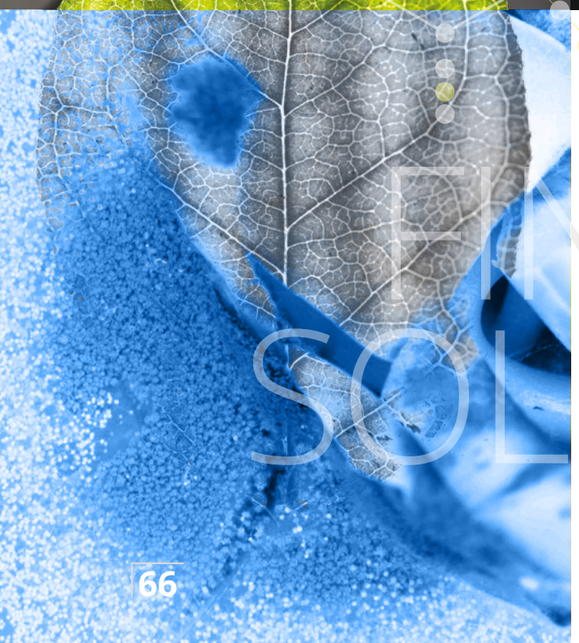
Mike Wingfield is the founding Director of the Forestry and Agricultural Biotechnology Institute (FABI) at UP. FABI celebrated 20 years of research excellence in 2018,* commemorated with a symposium held in January, among other events, that gathered most of the postdoctoral research fellows and PhD students who had graduated from FABI over the past two decades. It is significant that many of these young scientists now hold leadership positions in knowledge institutions here in South Africa, on the continent, and globally. This achievement underscores the very identity of FABI - a truly international research institute where postgraduate students and early career researchers are given opportunities (and have the mentorship) to thrive.

Brenda Wingfield joined UP in 1998 as a professor of genetics, and later served a seven-year term as the deputy dean of research, and for a short period as dean. She now holds the SARChI Chair in Fungal Genomics. She is also the vice-president of the Academy of Science of South Africa (ASSAf), and is serving a second term as the secretary-general of the International Society of Plant Pathology. Brenda has pioneered the use of DNA sequences in fungal taxonomy, and in 2009 sequenced the first fungal genome on the African continent. She is recognised internationally for her research in fungal phylogenetics, population genetics and genomics. This recognition is reflected in her receiving the designation of an APS Fellowship (American Phytopathological Society) at the International Congress of Plant Pathology held in Boston in 2018.

* https://www.fabinet.up.ac.za/webresources/FABI20thAnniversary/FABI20_Programme.pdf



Finding solutions that are appropriate to context and place is critical to issues of human and animal health, and food security is an important part of this dynamic. Africa as a region already represents about 20% of the world's population, and African researchers therefore have a significant role to play in addressing issues related to health and well-being on this continent.



FINDING SOLUTIONS

Health and place

Finding solutions

Genetic and epigenetic variation in non-communicable diseases

Alisa Phulukdaree, Department of Physiology

Genetic and epigenetic variations may explain the alterations in biochemical pathways that lead to pathology of diseases with persistent chronic oxidative stress, inflammation and hypercoagulation. These changes vary between continents, races, ethnicities and individuals and therefore identifying such differences is a key step toward precision medicine.

Alisa Phulukdaree, an associate professor in the Department of Physiology, is using her knowledge of medical biochemistry to understand ways in which genetic and epigenetic differences influence the pathology in heart disease, type 2 diabetes mellitus, asthma and other non-communicable diseases. Published in *Current Diabetes Reviews* and *Biomedicine and Pharmacotherapy* in 2018, her group demonstrated the relationship between genetic differences (single nucleotide variations) and enzyme activity, which affects drug metabolism and effective blood clotting.

The altered breakdown of the commonly used immunosuppressant, Azathioprine, causes side-effects when a gene variation in the thiopurine methyltransferase (TPMT) gene is present. Professor Phulukdaree and her research group strongly support 'early warning' SNP testing to ensure that patients are able to tolerate the medicine. The risk of heart disease and strokes is higher in type 2 diabetes mellitus patients and this may be due to the gene variation of key molecules that determine how efficiently a blood clot can be removed from circulation.

In 2018, Alisa Phulukdaree became the third Next Einstein Forum (NEF) fellow from the University of Pretoria. Sanushka Naidoo and Vinet Coetzee, both in the Department of Biochemistry, Genetics and Microbiology, were the first two researchers selected from UP to become NEF fellows. This unique pan-African forum connects science, society and policy in Africa, with the goal of leveraging science for global human development. Alisa is one of the research leaders at the Future Africa Institute, and a mentor on the Africa Science Leadership Programme.

Phulukdaree has also collaborated with researchers at the University of KwaZulu-Natal, Professors Anil A Chuturgoon and Rajen N Naidoo, to compare the response of pregnant women to nitrogen oxide pollution. They found that women living in industrialised areas, or those living in areas with higher levels of nitrogen oxide pollution, had higher serum concentrations of 8-oxo-7, 8-dihydro-2'-deoxyguanosine (8-OHdG), an indicator of oxidative stress. Their research, published in 2018, in the *Archives of Environmental Contamination and Toxicology* and *International Journal of Immunogenetics*, suggests that women who are exposed to nitrogen oxide pollution may have shortened pregnancies, and have also linked increased levels of 8-OHdG to carcinogenesis.

Further collaborative work with Chuturgoon and Dr Rene Khan is focused on understanding how various types of cancer cells respond to oxidative stress. Published in 2018, in *Human and Experimental Toxicology* and in *Toxicon*, they tested the relationship between Fumonisin B_1, a toxin produced by fungi that grow in stored grain products such as maize, and oxidative stress in oesophageal cancer cells. Fumonisin B_1 also has epidemiological links with increased prevalence of oesophageal cancer. Their findings demonstrate that when exposed to Fumonisin B_1, oesophageal cancer cells displayed signs of oxidative stress.

Advancing the use of nuclear imaging in a clinical setting

Mariza Vorster, Department of Nuclear Medicine

Nuclear medicine imaging provides unique information, which offers the potential to identify disease in its earliest stages. Using small amounts of radioactive material called 'radiotracers' which are typically injected into the bloodstream, inhaled or swallowed, nuclear imaging uses the gamma rays emitted to create diagnostic images. This can then be taken a step further by targeting the disease with therapeutic radionuclides, also known as a 'theranostic approach'.

Researchers in the **Department of Nuclear Medicine** are at the forefront of developing new strategies to improve targeted molecular imaging and therapy in TB, HIV and cancer. **Professor Mariza Vorster** is one of the core team members, working closely with **Professor Mike Sathekge** to improve the clinical application of nuclear imaging. The Molecular Imaging Research Centre uses positron emission tomography/computed tomography (PET/CT) units that are able to generate a range of diagnostic images.

In research published in *Clinical Genitourinary Cancer*, Lengana, Sathekge and Vorster have shown that PET/CT scans were able to identify lytic and bone marrow metastases in patients who had prostate cancer. Importantly, they have found that PET/CT scans were diagnostically superior to standard bone scans. The nuclear medicine team has also been testing the suitability of certain radiotracers for prospective imaging of prostate cancer. Published in the *Journal of Nuclear Medicine*, their study showed that both ^{18}F-DCFPyL and ^{18}F-PSMA-1007 had identical clinical findings.

In addition to cancer, nuclear imaging has much value in the diagnostic monitoring of tuberculosis (TB). Working with an international team, Professor Voster has published a review article in *Seminars in Nuclear Medicine*, detailing the value of nuclear imaging in the treatment of TB. Using nuclear medicine, clinicians can now detect latent TB infections, and assess the spread of the disease to other tissues. Importantly, nuclear imaging also allows clinicians accurately to assess if patients are responding to treatment.

Researchers at the Department of Nuclear Medicine have extended their research using nuclear imaging to assess whether different population groups have different responses to disease. Using non-invasive imaging biomarkers, researchers can assess how different individuals present with certain diseases at different time points, allowing for targeted analysis and treatment.

Mariza Vorster is one of the research leaders at the University's Future Africa Institute.

Theranostics: See it, treat it!

Nuclear medicine is rapidly shifting from 'trial and error' medicine to personalised medicine, which holds great promise for improved patient outcomes.

Mike Sathekge, Professor and Head of the **Department of Nuclear Medicine** at the Faculty of Health Sciences and the Steve Biko Academic Hospital presented the 22nd UP Expert Lecture, titled, *Theranostics: See it, treat it!*

The Expert Lecture Series provides a public platform for UP researchers to engage with a general audience on significant developments in their field of expertise.

Theranostics is a revolutionary approach that promises improved treatment by focusing on specific molecular features of disease, greater predictive power of adverse effects, and new ways to objectively monitor response to therapy. Professor Sathekge explained that cancer patients have to deal with escalating medical costs, in part due to the gap between diagnostics and therapy. Using nuclear imaging and theranostics, clinicians can adopt a 'see it, treat it' approach, which will allow clinicians to identify the right therapy, for the right patient, at the right time.

Vice-Chancellor Cheryl de la Rey, Panyaza Lesufi, Gauteng MEC for Education, and Mike Sathekge.

Targeted drugs for fighting cancer

Annie Joubert, Department of Physiology

Globally, cancer is one of the leading causes of mortality. The incidence of cancer is expected to increase as populations age, and as people become more sedentary and adopt lifestyle behaviours that pose as risk factors in cancer development.

In high-income countries, common cancers are managed by improved screening, early detection and the transfer of knowledge concerning healthy lifestyles. The fight against cancer is also progressing with the design of drugs that specifically target cancer cells. Conventional chemotherapy and radiation cancer treatments have an impact on both malignant, as well as healthy cells, leading to severe side effects.

Professor Annie Joubert, Head of the Department of Physiology, is taking a different approach in the fight against cancer by investigating novel compounds that prevent cancer cells from multiplying and spreading, while leaving healthy cells unharmed. Currently, Annie Joubert's team is focussing on *in vitro* cellular and molecular studies to assess the potential anti-cancer activity of these agents against cervical and breast cancer cells.

The research team has been working on modifying 2-methoxyestradiol (2ME) to increase oral bioavailability. Increased oral bioavailability limits the rapid hepatic first pass metabolism of the steroid analogue. Working with Professor Fourie Joubert from the Centre for Bioinformatics and Computational Biology, Annie Joubert's laboratory used *in silico* modelling to design novel sulphamoylated estrogen analogues (ESE-16, ESE-15-one, ESE-15-ol) which have also been synthesised by a pharmaceutical company. In particular, ESE-16 has been shown to limit proliferation by disrupting the formation of microtubules during cellular replication, eventually causing cell death. This novel compound disrupts the proliferation of breast cancer and cervical cancer cell lines *in vitro*. Working with colleagues from the Department of Pharmacology at UP and the Biomedical Research Centre at Onderstepoort, the team has tested the oral bioavailability of these compounds in mice and found that three ESE derivatives were still present in serum up to two hours after dosing.

Their research focusses on the premise that tumourigenic cells are physiologically different to healthy cells, and use modified metabolic signalling pathways to support hyperproliferation and survival. By focussing on molecular systems, Joubert's group targets the modified metabolic signalling pathways of tumourigenic cells, thereby providing exciting new avenues for the treatment of cancer.

Professor Joubert's further research, involving both national and international collaborators, focusses on molecular 'cross-talk mechanisms' between induced cell destruction and cell death, and the *in vivo* efficacy of anti-cancer drugs to target cancerous cells at low dosages and at less frequent treatment intervals.

From left: Annie Joubert, Sandra Tatchum and Michelle Visagie. Front: Thandi Mqoco and Elize Wolmarans.

Linking children's health outcomes

to insecticide exposure – a cohort study

Riana Bornman, UP Institute for Sustainable Malaria Control (UP ISMC)

It is estimated that more than 120 million people globally are exposed to insecticides that are used to control malaria mosquitoes. While indoor residual spraying may be effective in controlling mosquitoes, little is known of the potential side effects in humans.

The Venda Health Examination of Mothers, Babies and their Environment (VHEMBE) is a birth cohort of 752 mother-child pairs in the Limpopo province, South Africa, that has tracked the health outcomes of babies as they develop, and related these health outcomes to *in utero* insecticide exposure. Professor Riana Bornman in the Faculty of Health Sciences and the UP ISMC, is the local principal investigator, and works with Dr Jonathan Chevier (McGill University, Canada), and Brenda Eskanazi (University of California, Berkeley, US).

The study is undertaken in an area close to the Mozambique and Zimbabwe borders, which has the highest malaria burden in South Africa, and where homesteads are routinely sprayed to control mosquitoes. The study measures associations between insecticide exposure and a number of perinatal outcomes, aspects of child growth and maternal health. This intensive research project relies on the efforts of a local team from surrounding communities. The field office is based at the Tshilidzini Hospital in Thohoyandou, Limpopo.

In 2018, the group described the environmental predictors of pyrethroid metabolites in maternal urine, published in *Environmental Health Perspectives*. Pyrethroid metabolites are associated with the use of insecticides in and around the home, especially the spraying of yards and food stocks. Pyrethroid metabolite levels are also associated with a high fat diet. Interestingly, pyrethroid levels seemed to influence children's growth. After 3,5 years, mothers who had higher levels of pyrethroid metabolites when their babies were delivered had thinner children who were more prone to infection. These associations were stronger for children who lived in poorer households, and whose mothers had inadequate calorie intake during pregnancy.

Cohort studies are incredibly rare in Africa and require long-term investment, with respect to finance, human resources and sustained effort. The VHEMBE cohort study has produced valuable insights into the effects of insecticides on human health, and highlights the healthcare challenges experienced by mothers and children living in rural communities with significant environmental pressure.

Supported by the Canadian Institute of Health Research, the VHEMBE cohort study will continue to investigate the impact of postnatal exposure to insecticides used to control malaria, and of air pollution on immune function and allergic airway disease. The excellent news is that child follow-up in the VHEMBE cohort has been extended from age 5 to 8 years.

Changing community perceptions of malaria

Researchers at the UP Institute for Sustainable Malaria Control (UP ISMC) – **Professor Tiaan de Jager**, **Dr Taneshka Kruger** and **Dr Cheryl Tosh** – have contributed to a book, *Quality of Life in African Societies* (Springer, 2018), where they present their analysis of how malaria competes with the pressures of poverty, lack of education and food security.

To overcome some of these barriers, the UP ISMC has focussed on education and technology to change the perceptions of local communities towards malaria, to accept malaria as a serious threat to health and livelihoods, and to be informed about prevention and treatment. **Professor Riana Bornman** from the UP ISMC, and a group of co-workers described the educational outcomes of a community education programme in the Vhembe District, Limpopo, South Africa (*International Quarterly of Community Health Education*, 2018). In a five-year programme, 1 330 community members participated in an interactive malaria education initiative led by home-based care workers that significantly improved participants' knowledge of how malaria is transmitted and how the disease can be prevented.

The UP ISMC is involved in a number of initiatives that focus on education and health promotion of especially young children. These include the development of a song about malaria and the *Sibo Fights Malaria* book that was published in 2017, and projects by students investigating the possibility of including malaria education in the South African school curriculum. The UP ISMC approached the Department of Drama at UP to develop an informative play on malaria aimed at young children. Social media and digital apps are two contemporary tools that the Institute is using to communicate malaria information to the public. The 'Malaria Buddy' app helps travellers in malaria endemic areas understand malaria, as well as how to prevent, recognise symptoms and seek treatment.

In 2018, in recognition of its education innovation and outreach, the UP ISMC received the National Science and Technology Foundation award for Communication.

Tiaan de Jager, Director: UP ISMC

Postgraduate students at the UP ISMC, with some of the researchers.

Finding new ways to fight malaria

Lyn-Marie Birkholtz, Department of Biochemistry, Genetics and Microbiology, SARChI Chair in Sustainable Malaria Control, and UP ISMC

Malaria is a global public health problem. In a report released by the World Health Organization in November 2018, it was stated that 219 million cases of malaria were reported in 2017, with an estimated 435 000 deaths, mostly occurring in children younger than five years old.

Malaria is preventable and treatable, but control, management and the prospect of eliminating the disease is impeded by the complexity of host-vector-parasite-environmental interactions. Over the past 70 years, controlling and eliminating malaria has been based on two strategies; namely, controlling the *Plasmodium* parasite, and controlling *Anopheles* mosquitoes.

Professor Lyn-Marie Birkholtz, the incumbent of the **SARChI Chair in Sustainable Malaria Control** and key member of the **UP ISMC**, is focussing her research on understanding the complex biology of malaria parasites to discover the 'Achilles heels' that can be targeted by novel antimalarials. Published in *Scientific Reports* in 2018, Birkholtz and her team showed that asexually proliferating malaria parasites use unique mechanisms for cell cycle control. Her research team has developed a novel system to halt malaria parasites at a specific point in their cell cycle in a controlled fashion. This provides a valuable framework for investigating drugs targeting cell cycle regulation in malaria parasites, similar to anticancer drugs.

Beyond targeting proliferating malaria parasites, the team identifies drugs that can block transmission of malaria parasites between humans and mosquitoes. Potential novel therapeutics, including a next-generation *Plasmodium* PI4K inhibitor, UCT943, were shown to have the potential to form part of a single-exposure radical cure and prophylaxis (SERCaP) to treat, prevent and block the transmission of malaria (published in *Antimicrobial Agents and Chemotherapy*). Other drug discovery studies, published in *Bioorganic and Medicinal Chemistry Letters*, include testing 10 artemisinin derivatives. Currently, malaria is treated with artemisinin-based combination therapies (ACT), but resistance to ACT has recently been reported. Of the 10 derivatives, artemisone and artemiside inhibited asexual and gametocyte stages of the *Plasmodium falciparum* parasite, showing potential for malaria treatment.

This ability to block malaria transmission prompted a study to determine the prevalence of human genotypes that are susceptible to haemolysis as a potential side effect of transmission-blocking drug treatment. Based on the findings, published in the *Malaria Journal* in 2018, such deficiencies are rare in South African human populations, supporting the use of particularly primaquine as an adjunct tool to support malaria elimination strategies in South Africa.

The newly established Community of Practice (CoP) on Malaria Elimination, led by Professor Birkholtz, is an NRF initiative that came into effect in 2018 as a vehicle to implement integrated trans- and multidisciplinary solutions to the disease. The CoP incorporates the current expertise of five SARChI Chairs to focus on intervention strategies for malaria elimination, including the discovery of novel drug leads used with optimised delivery systems against both the malaria parasite and mosquito vectors.

Linking the environment and health

Natalie Aneck-Hahn, Department of Urology, and Environmental Chemical Pollution, and Health Research Unit (ECPH)

Africa faces a number of unique environmental challenges and there is, in general across the continent, a lack of institutional capacity to support comprehensive environmental studies. Many industrial processes and consumer products are sources of potential endocrine-disrupting chemicals (EDCs), with proven negative health effects, including cancer and reduced fertility.

Postgraduate student Mandy Naude collecting post-treatment water from the Rietvlei Water Treatment Plant.

Researchers at the Environmental Chemical Pollution and Health Research Unit (ECPH) have been busy identifying and quantifying the levels of EDCs in South Africa. In 2018, a team of researchers investigated the levels of DDT metabolites in men of reproductive age in rural villages in the Vhembe District of the Limpopo province. Men living in villages where dwellings are routinely sprayed had significantly higher concentrations of DDT and DDE isomers, as well as significantly higher levels of free testosterone, and lower concentrations of follicle stimulating hormone. The research findings, published in *Environment International*, support previous studies that have revealed links between congenital birth defects in male babies, and epigenetic theories that these defects may negatively influence long-term male fertility.

Dr Natalie Aneck-Hahn and Professor Tiaan de Jager, and their research team and collaborators, also measured the endocrine activity of selected cling film brands, and of plastic bottles used for commercially available bottled water. Of eight common cling film brands used in South Africa, one brand had a very high concentration of DEHA, which is associated with adverse health effects and carcinogenic risks. Cancer risks resulting from exposure to DEHA are equal to about five in 1 000 people, which is 50 times higher than the acceptable cancer risk. The findings, published in *Human and Ecological Risk Assessment* in 2018, show that only two of the eight cling film brands were below the detection limit for all target chemicals, and also had the CANSA-smart choice seal of approval. In a similar study, published in *Journal of Water and Health*, testing the levels of plasticisers in plastic water bottles, Dr Aneck-Hahn and co-workers found negligible levels of plasticisers and estrogenic equivalent compounds in the water stored in the bottles, confirming that bottled water brands in South Africa were safe for human consumption.

Given the international importance of the health effects of EDCs on humans, Dr Natalie Aneck-Hahn, Director of the ECPH, contributed to a study, published in the *Water Research Journal*, evaluating the endocrine activity in water samples from six countries – Germany, Australia, France, South Africa, the Netherlands and Spain. Samples of drinking water did not have any bioassay activity and low concentrations of chemicals, indicating that in these six countries, drinking water was safe for human consumption.

Fighting sexually transmitted diseases

in resource-constrained settings

Remco Peters, Department of Medical Microbiology, and Anova Health Institute

The World Health Organization estimates that more than a million sexually transmitted infections (STIs) are acquired every day. While some STIs, such as HIV and Human Papillomavirus (HPV), are incurable, other bacterial STIs can be detected and treated, provided there is ongoing surveillance and screening. Since many patients have asymptomatic infections, screening as a first step is vital.

Remco Peters from the Anova Health Institute, and an extra-ordinary professor at the Department of Medical Microbiology at UP, has highlighted the importance of screening and treating STIs at the primary healthcare level. Working in the Mopani district in Limpopo, Peters and his research team, which includes Nireshni Naidoo (University of the Witwatersrand) and Kate Rees (University of Cape Town), have found that almost half of women visiting mobile clinics have an STI, a much higher prevalence than previously observed at primary healthcare facilities. By deploying mobile clinics in remote areas that have few primary healthcare facilities, and by working closely with community health workers, the team was able to find many more women who needed treatment.

Their findings, published in *PLOS One* and the *Southern African Journal of HIV Medicine*, highlight the challenges regarding access to care in remote areas, which contribute to the sustained high burden of STIs in deep-rural areas. Moreover, molecular analysis of some bacterial infections, specifically *Chlamydia trachomatis* (CT) and *Mycoplasma genitalium* (MG) infections, showed a well-established genetically diverse epidemic indicating ongoing transmission. Drug resistance, however, was uncommon.

In a similar study in the Tshwane municipality, conducted in partnership with the Foundation for Professional Development, Peters and his team assessed the prevalence of STIs among pregnant women who were infected with HIV, using the GeneXpert platform for STI testing performed at a primary healthcare facility. Their research, published in the journal *Sexually Transmitted Diseases*, showed that nurses were reliable users of this platform to test for STIs, and to provide patients with a same-day result. Pregnant women were reportedly satisfied to wait for their test results, and subsequently to receive appropriate and targeted treatment. In Tshwane, approximately 40% of pregnant women tested positive for an STI, received their results in the same day, and were treated within seven days.

Professor Peters maintains that as the high burden of STIs contributes to negative pregnancy outcomes, screening and testing for STIs should be routine for women, and form part of holistic community-based health care.

Diabetes –

addressing the growing burden of non-communicable diseases

Paul Rheeder, Department of Internal Medicine, and Steve Biko Academic Hospital

Diabetes is a growing epidemic and the second biggest killer in South Africa, second only to TB. In Africa, diabetes is responsible for more deaths than malaria, HIV/AIDS and TB together.

One of South Africa's greatest challenges in controlling this epidemic at primary healthcare level is in the initial provision of insulin and then its up-titration; i.e., increasing the concentration of the drug to have the optimum effect. Legally, only a doctor can prescribe insulin, yet many clinics are primarily managed by nurses. So, for many South Africans with diabetes, accessing quality care close to home is almost impossible. Professor Paul Rheeder leads the Tshwane Insulin Project (TIP), a five-year collaborative project between a number of departments, including Internal Medicine, Family Medicine, Human Nutrition and the School of Health Systems and Public Health. The project focusses on investigating the use of remote prescription to help primary care physicians and nurses better serve the needs of people living with diabetes in underserved areas.

Sumaiya Adam and Paul Rheeder

Professor Sumaiya Adam in the Department of Obstetrics and Gynaecology has been working with Rheeder and colleagues to identify potential biomarkers for gestational diabetes. Gestational diabetes develops during pregnancy, and is characterised by relative insulin resistance and high blood sugar. This type of diabetes is associated with the baby growing too large for natural birth, with premature birth, or with too much amniotic fluid which may complicate the birth.

Although high-risk groups have been identified for gestational diabetes, there is a need for routine screening of all pregnant women. In this context and at the primary healthcare level, biomarkers are a promising screening tool. The research findings from these studies have been published in the *South African Medical Journal*, the *Journal of Diabetes Research*, and in the *International Journal of Molecular Sciences* in 2018.

Adam and Rheeder also tested the performance of the Roche Accuchek Active glucometer in diagnosing gestational diabetes mellitus, comparing their results with those of the gold-standard laboratory test. From the same sample of women, the standard laboratory test identified twice as many women with gestational diabetes compared to the glucometer, suggesting that the glucometer is not an accurate measure of gestational diabetes. These important findings were published in *Biomarkers*.

The team has also demonstrated that women with gestational diabetes have lower circulating levels of microRNAs (very short sequences of RNA which are involved in the regulation of gene expression), suggesting that there may be value in adding these biomarkers to a screening toolkit for gestational diabetes. Published in *Molecular Diagnosis and Therapy*, the findings point to insulin-sensitivity markers as good predictors of gestational diabetes.

The Tshwane Insulin Project is in collaboration with and funded by the Lilly Global Health Partnership, a global pharmaceutical research company that introduced human insulin to the market in the 1980s.

Exploring the secrets of an age-old disease, anthrax

Henriette van Heerden, Department of Veterinary Tropical Diseases

Anthrax, linked to the biblical fifth and sixth plagues, is one of the oldest infectious diseases. Best known as the white powder bioweapon, anthrax is a complex zoonotic disease that affects livestock, wildlife (especially herbivores), and to a lesser extent humans. It is caused by the endospore-forming bacterium *Bacillus anthracis*, which enables the bacterium to survive for decades.

In South Africa, anthrax is endemic to the northern region of Kruger National Park and the Ghaap area in the Northern Cape province. The Kruger National Park has offered UP researchers an ideal opportunity to investigate the *B. anthracis* life cycle in susceptible wildlife hosts.

Henriette van Heerden, Associate Professor in Veterinary Tropical Diseases, and researchers in the anthrax group at UP are at the forefront of anthrax studies. They have contributed to the diagnostics of *B. anthracis*, molecular characterisation using whole genome sequencing, rendering methods, and the microbiology of anthrax and vaccine development.

Research published in 2018 included an ecological prediction model of the survival of *B. anthracis* spores in the Kruger National Park (*PLOS One*); rendering methods during outbreaks (*Onderstepoort Journal of Veterinary Research*); and the characterisation of a rare strain (*BMC Research Notes*). With respect to vaccine development, the group has continued in the tradition of Max Sterne who developed the first anthrax vaccine at Onderstepoort in 1937, derivatives of which are still widely used globally. The research group has optimised a passive protection model to test protection of anthrax vaccines in mice (*Journal of Veterinary Research*) and is optimising non-living vaccine with a vaccine company.

Recent research conducted by the anthrax group, in collaboration with Skukuza State Veterinary Services and South African National Parks (SANParks), forms part of an international grant funded by the US National Science Foundation, in partnership with ecologist Wendy Turner at the University at Albany. The focus is on investigating the roles of hosts, and persistent pathogen and environmental factors in the transmission and evolution of anthrax. The project has already started tracking the movements of impala, kudu, zebra and wildebeest using telemetry collars.

Anthrax is a disease that continues to have an impact on agriculture and the livelihoods as well as health of communities across the African continent. The research group at UP has established the African Infectious Diseases Network to assist in advocating the importance of diagnostics, and to render support to other SADC countries with respect to disease identification and control.

One Health – viral zoonoses

The **UP Centre for Viral Zoonoses** (UP-CVZ)

The Centre for Viral Zoonoses is an interfaculty initiative including the Faculties of Health Sciences, Natural and Agricultural Sciences, and Veterinary Science.

In 2018, the UP-CVZ produced a volume of research in viral zoonotic diseases of global public health concern. Professor Marietjie Venter wrote an invited review in *Current Opinion in Virology*, assessing the zoonotic potential of arboviruses of African origin. Using a One Health approach, her group has described several neglected viruses that may cause epidemics in Africa with the potential to emerge elsewhere. To complement this work, the group published a study in *Acta Tropica* in 2018 where they identified four mosquito species belonging to the *Aedes* genus that took blood meals mainly from rock hyraxes in Kacheliba, West Pokot County, Kenya. Venter and co-workers also demonstrated that most febrile patients, in a public health facility in Madagascar, had viral infections (26,5%), followed by malaria (17%) and bacterial infections (1%). Interestingly, their study, published in *PLOS Neglected Tropical Diseases* (2018), detected pathogens of public health interest such as Rift Valley Fever Virus and the first case of laboratory-confirmed leptospirosis infection in Madagascar.

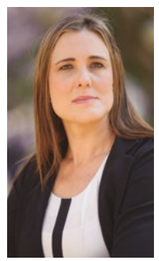
Professor Wanda Markotter, also from the CVZ and recipient of the SARChI Chair in Animal Infectious Diseases, used a metagenomics viral discovery approach to identify Middle East Respiratory syndrome related coronavirus in *Neoromicia* bats, which are insectivorous and often occur close to human settlements. Published in *PLOS One*, their results also described multiple potential zoonotic viral families in this abundant species. Working with colleagues, Markotter also published the first account of the filovirus, Marburg, in South African fruit bat species (*Emerging Infectious Diseases*, 2018). Published in *Viruses*, Markotter described the antibody response in Egyptian Rousette bats, which correlated with the reproductive season of the bats, identifying high-risk periods for transmission to other animals and humans.

Professor Louis Nel from the Department of Biochemistry, Genetics and Microbiology works on the control and elimination of rabies, in South Africa and abroad. With several journal articles published in 2018, including in the *Lancet Global Health* and the *Bulletin of the World Health Organization*, Nel's research focusses on the characteristics and management of domestic dogs. His research is used to help state veterinary services plan mass vaccination drives for domestic dogs. Nel is also working with the Global Alliance in Rabies Control to formalise the Asian Rabies Control Network. Published in *Antiviral Research* (2018), Nel and co-authors described the progress of member countries towards rabies elimination and identified gaps for future interventions.

Professor Armanda Bastos, Head of the Department of Zoology, is using genetic techniques to identify pathogens in various animal taxa from around the world. Using a multi-gene PCR screening approach, Bastos and co-workers recorded that almost 70% of Baluchistan gerbils trapped over a year, in Saudi Arabia, tested positive for *Bartonella*, the bacteria responsible for cat scratch or trench fever (*Infection, Genetics and Evolution*, 2018). Published in *Virus Genes* (2018), Bastos and co-authors described the rapid evolution of the African swine fever virus. Genetic profiling linked African swine fever outbreaks in Kenya to isolates from southern Africa, but with unique changes in the B602L gene.

The Centre for Viral Zoonoses hosted a One Health symposium in November 2018 that brought together students and staff of UP, partners in the Department of Health, Agriculture Forestry and Fisheries, and research institutes in Gauteng, including the National Institute for Communicable Diseases, Onderstepoort Veterinary Research and the Council for Scientific and Industrial Research. The day was supported by the European Union LEAP-Agri: Long-term Europe-Africa Research Network on neglected arboviral zoonotic diseases.

Marietjie Venter



Wanda Markotter

Louis Nel

Armanda Bastos

The epidemiology and control of FMD in goats

Geoffrey Fosgate, Department of Production Animal Studies

What would be the consequence of a foot-and-mouth disease (FMD) outbreak occurring in the free zone of South Africa, say every 5 to 10 years? Should the current dogma concerning the risk factors associated with FMD occurrence and spread within South Africa be challenged?

The 2011 FMD outbreak in KwaZulu-Natal province prevented South Africa from regaining FMD-free status until 2014, and cost an estimated R4 billion due to export bans on livestock and wildlife products. In 2018, an outbreak in the Limpopo province threatened to cross over into the free zone of KwaZulu-Natal, only four years since the FMD-free status was regained. The prevailing belief is that these FMD outbreaks are primarily caused by direct contact between wildlife and cattle.

FMD is a highly contagious transboundary viral disease that poses a risk at the wildlife interfaces of southern Africa. In South Africa, three wildlife parks are classified as FMD-infected zones due to the presence of the African buffalo (*Syncerus caffer*), which are a wildlife reservoir host: the Kruger National Park, and two parks in the KwaZulu-Natal province – the Ndumo Nature Reserve and the Tembe Elephant Park.

FMD is caused by infection with the FMD virus (FMDV), a small, positive-sense RNA virus in the genus *Aphthovirus* that derives its name from Greek *aphtha* meaning vesicle. The disease affects domestic and wild cloven-hoofed species causing fever, loss of appetite and lameness, in addition to vesicular lesions primarily in the mouth and on the hoofs. Control measures include restricting animal movement and vaccination. To date, the role that susceptible animal species, other than cattle and the African buffalo, play in the epidemiology of FMD at the wildlife interface has largely been neglected. Goats, for example, are not included in prophylactic FMD vaccination programmes.

Professor Geoffrey Fosgate in the Department of Production Animal Studies, in collaboration with postgraduate students and researchers at the Transboundary Animal Diseases of the Onderstepoort Veterinary Research campus, has been studying the epidemiology of FMD at the wildlife interface for the past decade. In 2018, two articles were published in *Preventive Veterinary Medicine*, and the team completed the first-ever experimental infection study in goats to determine the vaccine dose to protect this livestock from a South African-origin FMDV.

The experimental study also included new collaborations with Dr Tanja Wolf, a postdoctoral researcher at the Mammal Research Institute, who studied the behavioural and stress responses in research animals, in addition to Dr Didi Claassen and Dr Lieza Odendaal in the Department of Paraclinical Studies who are investigating pathogenesis and tissue tropism of FMDV using immunohistochemistry. The collected data are expected to yield new insights into the epidemiology and control of FMD in goats.

Geoffrey Fosgate and David Lazarus

Efficacy of vaccination and exploring goat movement patterns

Dr David Lazarus has focused his doctoral studies in the Department of Production Animal Studies on understanding the immune responses of goats to viral infections and the efficacy of FMD vaccination. He has also explored livestock movement patterns among smallholder farmers.

The priority in animal disease control programmes has been large ruminants and commercial livestock production. Small ruminants, including goats, are affected by FMD but the clinical signs of the disease are often mild and inapparent, with consequences for the 'silent' transmission through the uncontrolled movement of infected animals. Goats contribute to the livelihoods of smallholder farmers and the local economy. Lazarus's study has confirmed that goats are typically moved great distances within a communal farming system, which increases the potential spread of FMDV.

His project has also involved the study of the immunology of the disease and vaccine in goats in a controlled environment. Preliminary findings suggest that indigenous goats experimentally infected with FMDV can transmit infection to in-contacts. Results from the vaccination study suggest that one-sixth of the FMD vaccine dose used for cattle will be sufficient for the reduction of viral shedding in goats.

Plant poisonings

of veterinary and economic importance

Christo Botha, Department of Paraclinical Sciences

Livestock mortalities as a result of ingesting poisonous plants are a major concern for farmers in South Africa, and of direct economic importance to the farming community.

South Africa is inherently rich in flora and the native plant life is the richest temperate flora in the world. There are more than 24 500 taxa of flowering plants indigenous to South Africa. With such diversity in plant life, there are invariably numerous potentially poisonous plants as well. The problem is exacerbated by many exotic and invasive plant species that have become naturalised in South Africa.

Christo Botha, Professor and Head of Department of Paraclinical Sciences at UP, has focused his research on plant poisonings and mycotoxicoses affecting livestock. With his

Zehtu Mathe, Christo Botha and Michael Famuyide.

postgraduate students and research collaborators, he has also investigated new or lesser-known plant poisonings in livestock and companion animals. In 2018, he co-authored articles published in *Mycotoxin Research*, and in the *Journal of the South African Veterinary Association*.

Although there are over 600 indigenous and exotic poisonous plants known, not all are equally important. While the scientific documentation of new and lesser known plant poisonings is still a key objective, Professor Botha's research efforts have recently focussed on the prevention of poisoning caused by cardiac glycoside-containing plants, and the mechanisms of action of the poisonous chemical compounds.

In collaboration with doctoral student, Hamza Isa, the immunisation of livestock to prevent yellow tulp poisoning was evaluated. These findings were accepted for publication in *Toxicon and Toxins*. While vaccination as a means of preventing cardiac glycoside-induced poisoning seems to be quite feasible, improved methods that would induce the generation of antibodies able to bind and inactivate the plant toxin deserves further investigation.

To reduce the use of sentient animals in experimentation, Master's students, Danielle Henn and Zehtu Mathe, used established cell lines as *in vitro* models to investigate cytotoxicity and subcellular mechanisms of toxicity of compounds isolated from poisonous plants. Their projects focussed on 'krimpsiekte' (shrinking disease), a chronic form of cardiac glycoside poisoning, and on 'vermeersiekte' or Geigeria poisoning.

From farm to fork –

contributing to food security

Neriman Yilmaz, Department of Biochemistry, Genetics and Microbiology, and FABI

Fungi are important for health and well-being at many levels. In the food supply chain, fungi are the cause of much food spoilage and are thus a challenge for producers, suppliers, retailers and consumers alike.

Fungi not only contaminate food and animal feed but also produce toxins that are dangerous to people and animals. These so-called mycotoxins are secondary metabolites produced by various genera of fungi, the most important being *Aspergillus*, *Penicillium* and *Fusarium*. Although more than 300 fungal toxins have been identified globally, only five are classified as being of public health or agricultural importance: aflatoxin, deoxynivalenol, zearalenone, fumonisin and ochratoxin A – the last two were discovered by South African researchers. Walter Marasas, for many years an honorary professor at UP, led the team on fumonisin work.

The identification of food and feed spoilage fungi using both traditional and molecular methods are important in food safety, and to maintain the quality of food and feed products from farm to fork. It is estimated that approximately 25% of global food and feed output is contaminated by mycotoxins. This figure is higher for the African continent, in large part due to the lack of regulations, or where regulations exist, the lax or irregular enforcement thereof.

Dr Neriman Yilmaz, a senior postdoctoral fellow at the Department of Biochemistry, Genetics and Microbiology and FABI, studies the taxonomy of the mycotoxigenic genus *Fusarium*. She works in the newly establishment Applied Food and Feed Mycology Programme at FABI with Professors Pedro Crous, Bernard Slippers and Cobus Visagie, exploring the biodiversity and phylogeny of fungi related to food and animal feed and the raw materials used in production.

In collaboration with GrainSA, the research team screens maize, soybean seeds, sunflowers seeds and animal feed for the presence of *Fusarium*, *Aspergillus* and *Penicillium*. The data are then combined with mycotoxin levels detected in samples to determine the relationship between the presence of these species and the mycotoxin levels. The team isolates and identifies fungi, describes novel species, and develops rapid identification techniques for the monitoring of the most important species.

Dr Yilmaz has described many new fungal species. Her latest research was published in *MycoKeys* where she described a new synnematous *Talaromyces* from India. This study was undertaken in collaboration with the National Fungal Culture Collection of India and Agriculture and Agri-Food Canada. In another international partnership with the Westerdijk Fungal Biodiversity Institute (WI) in the Netherlands, she has characterised almost 300 strains belonging to the *Fusarium fujikuroi* species complex (FFSC) using multigene sequencing, and discovered six novel species.

Soybean seed with *Aspergillus flavus*, which produces aflatoxin.

Using technology to create SMART foods

Naushad Emmambux, Department of Consumer and Food Sciences, and DST-NRF Centre of Excellence in Food Security

The triple burden of malnutrition in Africa relates to deficiencies in macro and micronutrients, and to overweight and obesity and the associated non-communicable diseases. It is estimated that in South Africa about 25% of children under the age of three are stunted as a result of nutritional deficiencies, and about 60% of women are overweight or obese.

Professor Naushad Emmambux is leading a team of researchers in developing SMART foods and food ingredients to combat child malnutrition – the acronym stands for Safe, Marketable, Affordable, Ready to eat and Tasty. The focus is on indigenous grains and locally available food, such as maize, sorghum, teff, Bambara groundnut, cowpeas and orange flesh sweet potato.

Emmambux and fellow researchers have shown that processing technologies can reduce the viscosity of indigenous grains, making such grains suitable for infant feeding and nutrient dense. They have also tested different processing technologies. The team's experiments have shown that extruded cassava-soy porridge with wheat bran or grape pomace (by-products of the food processing industry) can have a lower glycaemic index and satiety due to the presence of dietary fibre. Other manufactured products which have commercial potential are gluten-free expanded snacks from maize and orange flesh sweet potato, quick cooking high-protein gluten-free pasta from sorghum and cowpeas, maize and orange flesh sweet potato.

The technique to reduce energy density is either by developing novel fat replacers, or by reducing the glycaemic index through starch modification. The team has developed modified starch that contains nanomaterials to mimic fat in emulsion type sauces with an 80% oil reduction. They are also working on lowering the glycaemic index of starch through the production of resistant starch in maize meal.

In 2018, some of their findings were published in *LWT Food Science and Technology*, *Food Hydrocolloids* and *Starch-Stärke*.

Healthy and tasty foods from climate-smart crops

Snack foods such as biscuits are excellent complementary food vehicles because they are widely popular, energy-rich, have a long shelf-life, and need no further preparation.

A team of researchers, led by **Professor** Riëtte de Kock in the Department of Consumer and Food Sciences, has focused their work on optimising the sensory and nutritional properties of food and beverages to contribute to the well-being of people in sub-Saharan Africa. With seed-funding from the Southern African Network for Biosciences, the UP team has commercialised a novel, nutritious sorghum-based biscuit range, launched under the brand name SO-YHUM. Made from sorghum flour, the biscuits are tasty and gluten-free, and also protein-rich. In collaboration with the National University of Lesotho and Botswana University, the consortium has developed and implemented a business model aimed at empowering university graduates to start food businesses that connect science, industry and society.

The team leaders from the neighbouring countries, **Dr Rosemary Kobue-Lekalake** and **Dr Pulane Nkhabutlane**, are both UP doctoral graduates. Keneiloe Kganane, an entrepreneur who has become part of the research team, was selected in 2018 to participate in the *Leaders in Innovation Fellowships Programme* of the Royal Academy of Engineering, London. In the final business pitching, Kganane was awarded first prize on behalf of the UP consortium.

Panel discussion at the launch of the ARUA Centre of Excellence in Food Security, December 2018.

Finding solutions to food security

Food insecurity in Africa and globally presents an immense challenge and finding solutions has been prioritised across nations, regions, institutional types and frameworks.

In January 2018, UP was awarded the African Research Universities Alliance (ARUA) Centre of Excellence in Food Security, in partnership with the Universities of Nairobi and Ghana, and **Professor** Hettie Schönfeldt appointed as Director. The aim of the Centre is to create a critical mass of researchers and a network of research talent who collectively can contribute to a common goal – through research, and the translation of research into policy and practice, to address what appear to be intractable problems.

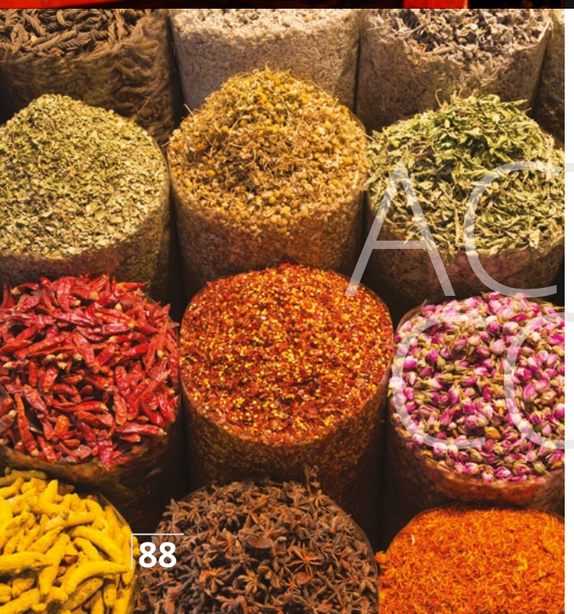
UP has wide-ranging expertise and a number of existing research platforms focussing on food security and nutrition. In addition to the ARUA Centre of Excellence, it is co-host, with the University of the Western Cape, of the DST-NRF Centre of Excellence in Food Security, a virtual Centre that brings together national, regional and international expertise, and also hosts the UNESCO Chair in African Food Systems.

At institutional level, the Institute for Food Security, Nutrition and Well-being at UP has a strong multi-disciplinary focus related to food security and nutrition, and a wide network of collaborating partners.

In more recent years, UP has foregrounded 'research that matters'. There are many examples, including of food security, that illustrate the effectiveness of research as one mode of response in fulfilling the role that universities can play in addressing priority agendas, with food security as a pivotal cross-cutting goal that interlinks several other sustainable development goals.

Importantly too, the ARUA Centre was launched at the Future Africa campus in December 2018, a unique location and hub for the development of young scientists and science leadership in finding solutions to Africa's major development challenges.

Development encompasses a broad spectrum of institutions and activities, some of which are captured in the research profiles presented here: from African markets and networks, to export, intellectual property, and business ethics; and further, to ways in which sustainable development and the well-being of individuals and communities can be built and regenerated.



ACTING IN CONTEXT

Markets and development

Acting in context

African markets –

networks, difference and responsible management

Ian Macleod, GIBS Centre for African Management and Markets (CAMM)

Under the tagline 'Build. Connect. Do.', the GIBS Centre for African Management and Markets, or CAMM, conducts research into the markets and management philosophies of African countries and companies, while fostering dialogue and sharing knowledge on the economies of the continent.

Nicola Kleyn, Dean: GIBS

Adrian Saville, Director: CAMM

The Centre was launched in September 2018 with the inaugural *Business of Africa Conference* at the Illovo campus in Johannesburg. Covering topics ranging from governance and sovereign ratings to the complex commercial relationship between African countries and China, the event set the tone for CAMM's networking and research agenda.

Two pieces of academic work out of CAMM reflect the challenges of unsatisfactory institutional environments in Africa. In one, CAMM fellow and GIBS researcher **Professor Albert Wöcke**, along with GIBS **Kerry Chipp** and **Manoj Chiba**, describe an as-yet unstudied mode of market entry in their paper accepted for publication by the *European Business Review*, 'Overcoming African Institutional Voids: Market entry with networks'.

Noting that the literature on modes of entry into new markets had focused on firm-level strategies, predominantly using institutional theory and the resource-based view, this paper applies a novel lens: network theory. More specifically, the authors argue that a loose network, known as a bridging network, is a mode of cross-border market entry particularly well-suited to emerging markets, such as exist in Africa, where firms very often move into environments where networks and other institutions are lacking or, indeed, are non-existent.

The authors use existing theory and case examples to submit that these alliances of multiple firms entering markets together as an extension of an existing loose network are often preferable to entry as a single firm in an African context.

GIBS postdoctoral researcher and CAMM manager **Tess Onaji-Benson** has looked at African institutions from a second unconventional angle. In a paper she co-authored with two UK-based academics, 'Navigating Institutional Differences in Africa: Moving beyond the institutional voids perspective', Onaji-Benson critiques the institutional void thesis itself. Key to the argument is that while formal, Western-style institutions are widely lacking in Africa, care must be taken not to ignore the informal institutions that nonetheless emerge.

Studying the topic through case studies of multinational entities (MNEs) operating on the continent, Onaji-Benson and her co-authors argue that it is not a case of one or the other. Rather, informal and formal institutions co-exist resulting in a new institutional mix, particularly in emerging markets. They conclude that MNEs need to be responsive to the regionally distinct mixes of institutions, and consider strategies that can be transferred from institutionally different contexts, and new capabilities that are needed to operate successfully in Africa.

Project Orbit is a major research project led by GIBS Dean, **Professor Nicola Kleyn** and CAMM fellow and Head of Research at GIBS, **Professor Helena Barnard**. Having conducted interviews in Zimbabwe, Kenya, Nigeria, Namibia, Botswana and South Africa, the focus is on building better understanding of business and responsible management in Africa through the study of the keystone industries of finance, retail and agribusiness.

One of the early noteworthy findings is the way in which many leaders rely on their faith to provide a moral compass in decision-making and strategy. **Professor Caren Scheepers** and CAMM fellow **Dr Anastacia Mamabolo**, both GIBS researchers, recently had accepted for presentation at the Academy of Management Conference in Boston their paper on the topic titled, 'Exploring faith as antecedent to Servant leadership in a Sub-Saharan African context'.

Sundeep Desai, Ian Macleod, Natalie van der Veen and Tess Onaji-Benson at the launch event of CAMM.

The export premium

Marianne Matthee, Gordon Institute of Business Science (GIBS)

Exports contribute to the generation of employment and economic growth within a country. Indeed, empirical evidence shows that exporting firms pay higher wages and employ more employees than non-exporting firms.

This so-called 'export premium', particularly in the manufacturing sector, has been the focus of Professor Marianne Matthee at GIBS. The basic premise is that the manufacturing sector, and therefore manufacturing exports, have the ability to create economic and employment multipliers across value chains. In South Africa, policymakers have long acknowledged the important link between stronger exports and sustainable job creation and economic growth. Yet, research on the relationship between exporting, employment and wages is still limited, especially at the level of firms.

Matthee and co-researchers have addressed this relationship by using business entity-level data obtained from administrative tax records. Their work has formed part of a research project undertaken by the United Nations Universities World Institute for Development Economics Research (UNU-WIDER), in partnership with National Treasury and the South African Revenue Service (SARS).* The availability of SARS data enabled them to study the population of manufacturing firms, and to make international comparisons.

In line with many global studies, they have found that South African exporters in the manufacturing sector employ more workers and pay higher wages (i.e., they create better-paying jobs) than non-exporters. Their research has also shown that the export and employment premium within exporters depend on the size of the firm, the number of products exported, the number and type of destinations served, as well as the firm's export status. Exporters operate under very different circumstances and enhancing exports in South Africa would require a nuanced approach.

The researchers were also able to track employment growth over a four-year period. They found that overall employment growth is faster in manufacturing exporting firms than in non-exporting manufacturing firms. These exporting firms also tend to employ higher-skilled and more experienced (older) workers. Firms that entered the export market had faster employment growth, and those who continued with exports displayed faster growth in skilled jobs than in unskilled jobs.

The findings, co-authored with Carli Bezuidenhout, a doctoral student at North-West University, and Neil Rankin from Stellenbosch University, were published in *Development Southern Africa*. Their research gives some insight into aspects that require further deliberation, and the need to deepen understanding of the firm-level relationship between skills and jobs.

* In 2017, UNU-WIDER expanded to become what is now called the Southern Africa – Toward Inclusive Economic Development (SA-TIED). National Treasury hosts the administrative data in a newly-developed data-lab, and the ongoing research on a wide range of pertinent topics on the South African economy contributes towards policy debates and formulation.

Property tax –

a much-needed revenue source for African cities

Riël Franzsen, Department of Economics, African Tax Institute, and SARChI Chair in Tax Policy and Governance

Managing urban areas has become one of the most important development challenges of the 21st century. It is estimated that by 2050, urbanisation in Africa will grow to 55%. With the high rates of urbanisation experienced in many African cities, there is an immense and growing demand for infrastructure and services. In this context, the recurrent tax on immovable property is eminently suitable for city governments.

The work of Professor Riël Franzsen and researchers at the African Tax Institute (ATI) on property taxes is therefore both timely and relevant.

Although the ATI's research on property taxes is still largely focused on improving property tax policy on the African continent (and beyond), improving tax administration has also become an integral part of the research agenda. Furthermore, the research focus has shifted from metropolitan and capital cities to smaller, secondary cities – as evidenced by work undertaken in Arusha (Tanzania), Kiambu (Kenya), as well as Kitwe and Ndola (Zambia). This research links up with the property tax research initiated by the International Centre for Tax and Development, Sussex University.

In 2018, Professor Riël Franzsen and Dr William McCluskey, co-editors of *Property Tax in Africa – Status, Challenges, and Prospects* (2017, Lincoln Institute of Land Policy) were invited to present the key findings at the World Bank's annual conference on land and poverty, and also at the Fiscal Affairs Department of the International Monetary Fund. They also co-authored an International Centre for Tax and Development (ICTD) working paper on the role of information and communication technology in enhancing property tax revenue in Africa, with a former ATI research fellow Dr Mundia Kabinga, and MPhil student Chabala Kasese.

The property tax administrative reforms in Kampala, Uganda, are discussed in an ATI working paper (one of seven working papers on property taxation published in 2018) by Mihaly Kopanyi and Riël Franzsen.

The ATI has since 2015 partnered with the Vienna University (WU) of Economics and Business (Austria) and the United Nations Office on Drugs and Crime in a research project on tax and good governance in Africa. This project has explored the vexing problem of illicit financial flows from Africa and how revenue authorities can collaborate to counter this problem, both within countries and across country boundaries. One of the outcomes of this project was a scholarly book titled, *Inter-agency Cooperation and Good Tax Governance in Africa* (PULP, 2018), edited by Jeffrey Owens, Rick McDonell, Riël Franzsen and Jude Amos.

Riël Franzsen and William McCluskey are the recipients of the 2018 UP Vice-Chancellor's book award.

Intellectual property and IP rights –

application and enforcement

Chris Job, Centre for Intellectual Property Law

Intellectual Property (IP) is an essential driver and component of economic growth and IP rights (IPRs) constitute highly valuable properties and exploitable assets, also for foreign investors. This is particularly relevant in the present era of knowledge-based economies and the Fourth Industrial Revolution characterised by the convergence of digital, physical and biological technologies in ways that are changing the world.*

South Africa has a strong tradition of ensuring local statutory compliance with the numerous international conventions and treaties that exist in the field of IP,

and of effective enforcement of IPRs through our judicial system. Significant efforts have also been made towards harmonising our statutory IP regime with the laws of our major trading partners. However, it is in the manner of application of our IP laws and the enforcement of IPRs by the courts that the nub of the problem lies.

Chris Job, an honorary professor at the Centre for Intellectual Property Law, has pursued research related to the interpretation and enforcement of IPRs in South Africa. His research, and that of the Centre for IP Law, have primarily been in relation to the enforcement of trade mark rights. The focus has been on ways in which our senior courts have addressed traditional trade mark infringement situations (involving the likelihood of consumer deception or confusion), and the more recently recognised infringement by trade mark dilution (involving diminution of the reputation and distinctiveness of well-known trade marks).

In an article published in 2018 in the *South African Intellectual Property Law Journal* (IPLJ 92), Job reviews the inconsistent manner in which the Supreme Court of Appeal and other senior South African courts have applied the trade mark infringement requirement that the parties' goods or services be either identical or sufficiently 'similar' to warrant a finding of the likelihood of consumer confusion and, hence, infringement.

This inconsistency has led to a degree of legal uncertainty. Rulings in the senior appeal courts in the UK and the EU show that a far more analytical process is followed, leading to balanced 'global assessment' of whether a likelihood of consumer confusion existed. In the article, Job proposes two possible alternative approaches, which would involve amendments to the Trade Marks Act, namely: to delete the 'similar' goods or services requirement entirely; or to extend trade mark protection to 'similar or related' goods or services.

Other areas of research by Professor Job have included a comparative study of aspects of trade mark dilution law in South Africa, the USA and the EU, published in the *South African Mercantile Law Journal*.

* Chris Job is a former chairman and partner of Adams & Adams Attorneys, South Africa.

Digital forensics –

apprehending cyber criminals

Hein Venter, Department of Computer Science

In an interconnected cyber world, cyber security is used to secure our emails, documents stored in the cloud, social media interactions, internet banking transactions, online shopping, and much more. Unfortunately, cyber criminals seem always to be one step ahead of the cyber security professional.

Hein Venter (far right) and his students who graduated at the April 2019 graduation ceremony: Derek Masvosvere, Albert Antwi-Boasiako, Elsabe Ross, and Dirk Ras.

Cyber security professionals attempt to secure systems from various angles in an attempt not to leave a single aspect of a digital system vulnerable to cyber attack. Cyber criminals, on the other hand, only have to discover one single vulnerability in order to perpetrate a successful attack. Therefore, cyber security inevitably fails at some point, and this is when digital forensic investigations need to be conducted.

Professor Hein Venter, Head of the Digital Forensic Science (DigiForS) research group in the Department of Computer Science, conducts research in this field. His main research efforts are focussed on pioneering intelligent digital forensic investigation principles and techniques across all computing platforms. His research group's focus include, among others, the standardisation of new and intelligent digital forensic investigation techniques (specifically within the public cloud computing domain), digital forensic readiness (in the cloud, internet-of-things and smart cities), and enabling digital forensic policing in Africa.

The group's work is highly relevant in an increasingly digital and digitised world. The sheer volumes of big data increase by the minute in these environments. The volatility of the cloud environment further exacerbates the degree of complexity of digital forensic investigations. What is more, it becomes impossible for digital forensic investigators to sift manually through the sheer volumes of data. In a paper published in the *Journal of Machine Learning and Cybernetics*, co-authored by members of the research group and their collaborators, an intelligent new digital forensic investigation technique is reported on that was developed to use a person's mouse-behavioural statistics to determine whether the real computer user was responsible for suspicious actions on their computing device, or a cyber criminal.

Dr Albert Antwi-Boasiako, a recent PhD graduate supervised by Professor Venter, developed a model for establishing the admissibility and evidential weight of digital evidence as part of his doctoral studies. The United Nations Office on Drugs and Crime has adopted the model as part of its Education for Justice (E4J) Programme on Cybercrime.

Professor Venter's leadership in the field of cyber security is underscored by his close involvement in the writing of international standards for the International Organization for Standardization (ISO), notably the ISO 27043: Incident investigation principles and processes.

Understanding social enterprises

Anastacia Mamabolo and **Kerrin Myres**, GIBS

Across the country, tens of thousands of social enterprises and non-governmental organisations – from a single person to national organisations employing hundreds of people – are working to improve the quality of life for marginalised South Africans.

Anastacia Mamabolo

Kerrin Myres

Social enterprises, defined as organisations that use innovation and entrepreneurial methods to solve social and environmental challenges, are clearly important to South Africa's future. Yet, as analysis has shown, relatively little is known about social enterprises in South Africa, a gap in understanding that would make it difficult to strengthen support for such organisations.

The GIBS Entrepreneurship Development Academy recently conducted the first national study of South Africa's social enterprises. The study, led by Dr Kerrin Myres and Dr Anastacia Mamabolo, was undertaken in collaboration with the Bertha Centre for Social Innovation and Entrepreneurship at the UCT Graduate School of Business.

The team screened over 33 780 organisations to identify 453 social enterprises for inclusion in the survey. Telephonic interviews were conducted with all respondents qualifying as 'social enterprises' on the basis of their social impact, and economic sustainability.

A comprehensive set of data was generated in the process, with several notable findings. To illustrate: social enterprises are typically small, employing fewer than 10 people; over 65% reported levels of growth above inflation; most have been operating for over three years and expected their organisations to grow rapidly in future. Most importantly, the social enterprises in the study reported being able to operate independently of donor funding, making them viable and sustainable, even as they innovate to solve social problems in under-served communities.

Some of the findings were published in the *Journal of Social Entrepreneurship* in 2018. The research group also published a Stakeholder Report that summarises the data collected and includes profiles of successful social enterprises from across South Africa, further enhancing our understanding of their practices. These two outputs, with others in the pipeline, provide an overview and understanding of the state of social entrepreneurship in South Africa, which is a necessary foundation for any strategy and future policy initiatives, entrepreneurship practice, as well as a basis for further research on social enterprises.

Measuring the soft underbelly of business ethics

Gideon Pogrund and **Marius Oosthuizen**, GIBS

Ethical performance is vital for corporate sustainability, and business' social license to operate. However, ethics has a 'soft underbelly' – in the absence of a metric, it's difficult to assess and manage performance.

In response, Rabbi Gideon Pogrund and Marius Oosthuizen at GIBS established the GIBS Ethics Barometer, an innovative instrument that measures expectations and perceptions about business conduct. It is a project of the GIBS Ethics and Governance Think Tank, which in 2018 was recognised by the AACSB (Association to Advance Collegiate Schools of Business) – a network of over 800 business schools – as one of 31 'Innovations that Inspire'.

The Think Tank's research agenda has emerged through its various activities and engagements: a national conversation, featuring prominent leaders, about business ethics; closed door cross-sectoral dialogue sessions between business, government and civil society leaders; collaboration with corporate managers working in areas such as risk, compliance, ethics and sustainability; and links with international institutions including Harvard Business School, the Wharton School of Business, Nottingham Business School and Boston University's Questrom School of Business.

The Barometer is based on the Global Business Standards Codex, a research tool developed by HBS academics to test whether companies adhere to widely endorsed standards around business conduct. It has also been contextualised and localised, ensuring that it addresses South Africa's specific issues and challenges - especially with regard to transformation and the correcting of historical wrongs.

The Barometer examines organisational behaviours across six constructs: treatment of customers; treatment of suppliers; treatment of employees; organisational culture and practices; engagement with broader society; and avoidance of misconduct. Results are analysed in terms of various demographics, including population group; gender; business unit; grade; length of service; and age.

During the initial phase, 15 companies participated and over 8 000 of their employees were surveyed. They are among South Africa's leading corporations in the banking, insurance, mining, retail, property, leisure and legal sectors. Company-specific data is aggregated and anonymised into the general data, and the analysis of these results will be published in 2019.

In parallel with the engagement with companies' employees, focus groups have been conducted with representatives from the media, trade unions, NGOs, churches and youth, seeking to better understand their expectations and perceptions of business and how these compare with business' views of itself. This data will also be published.

The vision is to turn the Barometer into a longitudinal study, and expand the number of participating companies, sectors and markets.

Energy technologies at the centre of economic development

Roula Inglesi-Lotz, Department of Economics

The debates on climate change and its connection to the choice of energy generation mix and optimal energy consumption – and the relationship between emissions, energy and economic growth – have captivated the attention of the world. While the energy-growth nexus has been studied extensively, there still seems to be little consensus as to what would constitute an optimal nexus.

Roula Inglesi-Lotz, Associate Professor in the **Department of Economics**, conducts research towards understanding the dynamics and mechanism of this relationship. In 2018, she contributed a chapter to the book, *The Economics and Econometrics of the Energy-Growth Nexus* (Academic Press), discussing the role of other factors, such as trade and financial development, in influencing the energy-growth nexus. She also co-authored eight papers published in international journals, while being the founding President of the South African Association for Energy Economics (SAAEE).

For many years, the African continent was not the focus of energy research: firstly, the lack of data availability did not allow for advanced quantitative techniques to be used; and secondly, the continent's historically low emissions gave priority to other critical issues on the development agenda. In recent years, this reality has changed, and that is where Professor Inglesi-Lotz aims at contributing.

In a co-authored paper published in *Renewable Energy* in 2018, the results show that income increases will promote the adoption of renewable energies. However, current volatile and uncertain socio-economic, political and financial conditions do not allow for massive investments, even though such decisions have in recent times become increasingly important issues on the political agendas of African countries. Her research has also confirmed the expected negative impact of fossil fuels on environmental degradation. But, she writes, the African region is not yet ready to abandon fossil fuels completely, due to the unexploited reserves that might keep the cost of coal at affordable levels. The critical question then becomes for how long the cost of coal-generated electricity can remain competitive, compared to the cost of renewable energies.

From a demand-side perspective, energy efficiency technologies are considered a significant instrument in reducing the total energy requirements of economies, and hence, lead towards a reduction in emission. In a paper published in *Energy* in 2018, she considers South Africa's CO_2 emissions within the context of BRICS countries. Carbon and energy intensity are found to be the determinants that have the potential to mitigate CO_2 emissions – they can both be improved by technological advancements and R&D investments.

Roula Inglesi-Lotz is a member of the South African Young Academy of Science, and of the Global Young Academy and the co-leader of the Academy's Women in Science workgroup. She was selected as a fellow of the Africa Science Leadership Programme (ASLP), a joint initiative between UP and the Global Young Academy.

Evolving public space – constructing a knowledge of place

Karina Landman, Department of Town and Regional Planning

Cities across the world have experienced unprecedented change. Many people associate public spaces with decay and the fear of crime, yet public spaces evolve over time and are, importantly, also about revitalisation and regeneration.

In recent years, Karina Landman, Associate Professor in the **Department of Town and Regional Planning**, has focused her research on the transformation of cities and city spaces in South Africa. Her book, *Evolving Public Spaces in South Africa: Towards Regenerative Space in the Post-apartheid City* (Routledge, 2018), addresses the outcomes of a six-year project. It is a tale of changing urban conditions and the multiple narratives of 'entangled' public spaces that continue to accommodate and enable everyday life for a wide variety of users, be it in the inner city or the suburbs, townships or informal settlements.

Landman's research is based on over 100 case studies undertaken of different types of public spaces: these include parks, botanical and food gardens, plazas or squares, pseudo-public spaces such as shopping malls, common open spaces in gated communities, and streets. Over a six-year period, Landman and her students spent time in these different types of public spaces to gather information, and to build a knowledge base of public spaces in South Africa. Using the tools of spatial analysis, participant observation and semi-structured interviews – including interviews with the managers and developers of public spaces – she has developed a careful delineation of the nature and use of public spaces in South Africa.

The book combines a narrative of multiple places and temporalities, of key moments of intervention, and of double-sided meanings. Landman writes that the fact that public spaces in post-apartheid South Africa are changing is often exacerbated by the multiple transitions that have characterised urban space in South Africa. She therefore extends her analysis beyond the constant process of transformation and introduces a parallel process – that of evolving public spaces. Building on the theory of regenerative development and design, the understanding she presents of the evolution of public spaces is concerned with constructing a knowledge of place, in order to align place and people and open up leverage points for meaningful socio-material flows and exchanges in public spaces.

Landman's work offers an alternative understanding of public space, and of pathways towards regenerative space and the making of the commons in our cities. She challenges the negative views related to the 'death of public space' and argues that temporary decline can present opportunities for something new to emerge, not only in South Africa, but also on the African continent and in the global South.

The Mamelodi Collaborative –

a community anchor strategy

Nthabiseng Ogude, Dean: Mamelodi campus

UP's Mamelodi campus is a unique environment defined by multiple community-linked interventions and research activities – all dedicated to broadening educational opportunities and strengthening the well-being of the community where it is situated.

A twelve-month planning project between **Rutgers University-Newark** and the **Mamelodi campus**, called the Mamelodi Collaborative, led to the articulation of five research niche areas as the primary focus of the anchor institutions' strategy in their respective communities. These are: i) broadening educational pathways; ii) leveraging arts and culture; iii) contributing to strong, healthy and safe neighbourhoods; iv) encouraging entrepreneurship and economic development; v) and promoting interest in science and the urban environment.

The niche areas provide a framework for the academic activities of the campus through research projects associated with each area. Two of these projects are directly linked to two of the global sustainable development goals: Goal 4 – quality education, and Goal 2 – zero hunger.

Kyle Farmby, RU-Newark

The Mamelodi Collaborative has identified space and place as key factors in enhancing student access and success. Research projects thus build on student success initiatives at the Mamelodi campus and RU-Newark in order to broaden educational opportunities in both contexts. What could be regarded as UP's most profound success story to date is the development of multi-level interventions at the pre-university level for school-going youth through after-school programmes and mentoring. Also central is the flagship extended curriculum programme which provides a structured intervention for those wishing to pursue degree studies in the natural and agricultural sciences, or in economics and management sciences.

The goal of pre-university interventions is to increase the number of first-generation graduates. It is anticipated that this will make an important contribution to ending the cycle of poverty in families. In partnership with the Gauteng Department of Education and Stats SA, UP is able to monitor tangible

change over time. In 2018, the school district from which students were selected for the pre-university programme was placed second in Gauteng in the final school-leaving results. The collected data is also used in comparative studies with the mirrored strategies of RU-Newark to keep a strong analytic focus on the evolution of strategies designed to broaden educational pathways.

A multidisciplinary Food Security project between UP's Unit of Urban Citizenship and the Mamelodi campus has focused on establishing an urban food and play garden on the Mamelodi campus. Also built into the project is a feeding scheme for the learners attending the after-school programmes, students in the extended curriculum programmes, and entrepreneurship opportunities for the residents of Mamelodi. By harnessing UP's research strengths, the projects present endless opportunities for engaged scholarship to all involved.

The University's research strategy over the past decade has been to build on areas of research strengths. An appropriate conclusion to this 2018 Research Review is to consider, briefly, three new platforms that are set to change the shape of research at UP, and some of our research leaders who were recognised for their excellence in 2018.

Looking ahead

Building on our strengths

New research platforms

Future Africa

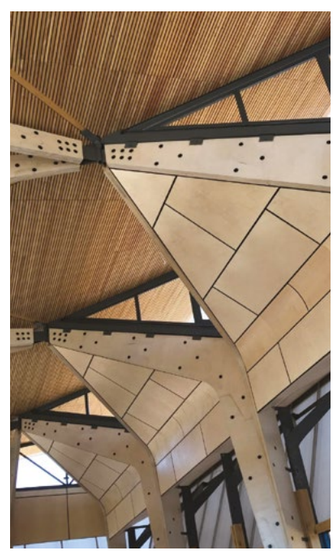
Bernard Slippers, founding Director: Future Africa, and Director: The Forestry and Agricultural Biotechnology Institute

When the Future Africa initiative was launched in November 2013, it signaled the University of Pretoria's deliberate emphasis on its place in Africa and pursuing research that would make a difference.

Future Africa is anchored by the commitment of the UP community to the African continent, to the belief that knowledge generation will be the foundation of the continent's development, and the acknowledgement that this cannot be done in isolation. To have a substantive impact on the pressing issues facing society globally, Africa needs to take its rightful place as an equal partner with other world regions as knowledge generator.

The global conversation on the role of science is increasingly focused on developing a globally connected, interdisciplinary and socially responsive science system. Given the norms of disciplinary training and research, traditional universities often struggle to respond to these objectives. Being early in a phase of rapid development, there are exciting opportunities in Africa to ensure that universities of the future are at the forefront of global trends to align excellence in research and training with social and environmental needs.

This is the reason for the existence of Future Africa; it was developed to serve as an incubator of research initiatives focused on societal issues, a hub for local and global research networks to align behind these priorities and initiatives, and as a point of connection with sectors of society involved or affected by our research that lie outside our academic institutions. It will have to do so with focus, persistence and patience for decades to come to have truly transformative impact. While we must exercise patience in this pursuit, we need at the same time to work with an urgency of people knowing that we are dealing with global challenges that threaten the very fabric of our society and world. And with the enthusiasm of people who know that collectively we have the power and opportunity to address these issues.



The Future Africa initiative set out to develop a centre of excellence to stimulate and support interdisciplinary dialogue and research through innovative ways of connecting excellent and developing researchers around challenging problems, together with broader communities of practice relevant to these issues. Secondly, it would develop advanced science leadership training programmes to equip the next generation of scientists to lead complex interdisciplinary and globally connected research projects. The aim remains to develop a community of scholars with a vision and the skills to use their position as knowledge generators and their global networks to transform the societies in which they are embedded.

The first of these programmes, the Africa Science Leadership Programme, was launched in July 2015, at a conference venue on the outskirts of Pretoria. The impact on the pan-African cohort of young research leaders who were brought together was immediately evident, and initiatives to expand the programme followed soon after. Today these include local university programmes (e.g. Tuks Young Research Leader Programme), regional (e.g. West African Science Leadership Programme, soon to be followed by programmes in East, North and Southern Africa), topic-focused (e.g. the Carnegie Early Career Research Leadership Fellowship), and international (e.g. ASEAN Science Leadership Programme and programmes run by the Global Young Academy).

While these programmes were developing in various spaces on and off the UP campus, a dedicated and dynamic living and learning environment was being created to anchor the vision and activities for Future Africa. A space where the academic life and living space of a community of scholars (including advanced undergraduate, postgraduate, postdoctoral fellows, academic leaders and visiting scholars) would be integrated, advancing excellence in scholarship, dialogue and social responsibility across disciplines, cultures, generations and sectors of society.

The philosophy behind Future Africa permeated all elements of the development, from its design to the sourcing of its materials and the people who were trained as part of the building process. The end-result is a contemporary African design that focuses the attention on the people and place in which the institute is embedded, and the commitment to sustainability from a social, environmental and economic perspective; a space that would be as challenging and transforming to every visitor and resident as the ideas we hope to stimulate, fostering connectedness, ambition and innovation down to the details of its design.

It was with great enthusiasm that Future Africa opened the doors to its unique campus in October 2018, in anticipation of its formal launch in March 2019. The campus features forage gardens that are integrated into its restaurant and research programmes, a Conference Centre that is custom-designed to foster group work and interaction, a Research Commons with offices and meeting rooms ready for its incubator role, and Accommodation for a research community stretching across disciplines and across the world. It speaks of enthusiasm and commitment to people and place in Africa.

The Javett-UP Art Centre –
home of the art of Africa

Vasu Reddy, Dean: Humanities

The Javett-UP Art Centre is one of the largest philanthropic ventures in South Africa aimed at promoting the arts and cultural heritage in the region.

Set to be launched in September 2019, the Javett-UP complex is already a distinctive feature in the capital city's landscape. The galleries and meeting spaces will be a place for the exchange of ideas – for academics and students, the public, and visiting academics and artists-in-residence from Africa and beyond. Straddling academic and public spheres of practice, the deliberate intention is to make the art of Africa accessible, relevant and engaging.

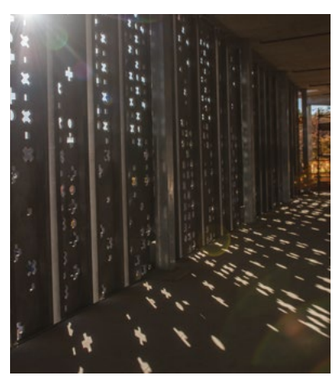
The impressive complex is located on UP's south campus, with a bridge gallery connecting the building to the main campus. There are nine exhibition spaces that will house local and international exhibitions, and permanent collections. The permanent collections will be the Javett Foundation's collection of 20th century South African art, and the Mapungubwe Gold, an archaeological collection with historical and cultural significance. A student gallery and piazza link the complex to the Departments of Architecture and Visual Arts.

Since its inception, the idea has always been of Javett-UP as a collaborative, multidisciplinary space that makes possible engagement with the ideas, methodologies and concerns of the art of Africa, and as a platform and catalyst for research and education.

Javett-UP is also the site for the first Master's degree programme in Tangible Heritage Conservation in South Africa. The programme, developed with funding from the Andrew W Mellon Foundation, and launched in 2018, is set to play a significant role in the conservation of the art of Africa. Drawing on the humanities and the sciences, it is intended to develop new generations of highly skilled heritage conservators, and to strengthen the idea and meaning of science that is best achieved through its societal, creative and humanistic contexts.

Research themes such as historical studies and tourism, capital cities, the human economy, inequalities, decolonisation, and demography are already active or have been identified as key focus areas.

Also in 2018, students Sandisile Gqweta and Olu Yakhe were named the winners of the first annual Javett Music Awards, and Professor Lenora Helm Hammonds from North Carolina Central University (US), as recipient of the first artist-in-residence award.



UP's Engineering 4.0 –
a research platform creating new possibilities

Sunil Maharaj, Dean: Engineering, Built Environment and Information Technology

The fundamental building block for any vibrant economy is efficient and modern infrastructure. For South Africa and Africa to leapfrog into the Fourth Industrial Revolution (4IR), these building blocks must be in place in order to advance the necessary cyberphysical systems through data analytics, smart materials, artificial intelligence (AI) and the internet of things (IoT).

The Engineering 4.0 initiative in which the University of Pretoria has invested, is a unique outward-looking approach to create a research platform of opportunities.

Through the partnership with and investment by the South African National Roads Agency Limited (SANRAL), this unique world-class African facility will be a place where novel ideas, scientific research, global expertise, students, academics, entrepreneurs and industry partners can converge to generate new thought leadership, innovation and training opportunities through collaborative partnerships.

Engineering 4.0 will be developed in phases: The initial facilities through the SANRAL grant will entail a national integrated materials reference laboratory, a research laboratory for pavement (road) engineering and a training laboratory. This will be combined with Africa's first live traffic research facility and an accelerated pavement testing (APT) facility. The combination will allow for the development of an extensive database of material properties for the country and the evaluation of models in the APT and live traffic lanes by monitoring pavement response under both accelerated and live traffic conditions.

Work done in IoT sensor technologies, concrete, smart materials, and at the UP Institute for Big Data and Data Science, will realise this new approach to inter- and transdisciplinary research, innovation and application with industry partners and entrepreneurs.

Intelligent and Smart Transportation will be embodied in the Engineering 4.0 facility, while the investment will be closely aligned to the UN Sustainable Development Goals focussing, among others, on Goal 9: Industry, Innovation and Infrastructure, and Goal 11: Sustainable Cities and Communication. This dual focus, through collaboration, innovation and impact, will seek to address South Africa's job creation, poverty and inequality while implicitly addressing global grand challenges.

UP's science leaders – A-rated scientists

A-rated researchers are unequivocally recognised by their peers as leading international scholars in their respective fields for the high quality and impact of their recent research outputs. In 2018, UP had 14 science leaders with an A-rating.

NIGEL C BENNETT

Prof Bennett is in the Department of Zoology and Entomology, Faculty of Natural and Agricultural Sciences, and the Mammal Research Institute. He holds the UP Austin Roberts Chair of African Mammalogy and the DST-NRF SARChI Chair* of Mammalian Behavioural Ecology and Physiology.

DON A COWAN

Prof Cowan is in the Department of Biochemistry, Genetics and Microbiology. He is the Director of the Centre for Microbial Ecology and Genomics, and of the Genomics Research Institute in the Faculty of Natural and Agricultural Sciences.

PEDRO CROUS

Prof Crous is an Associate Professor in the Forestry and Agricultural Biotechnology Institute (FABI). He is Director of the Westerdijk Fungal Biodiversity Institute in Utrecht, The Netherlands.

ERIKA DE WET

Prof de Wet is Professor of International Law in the Faculty of Law and holds the DST-NRF SARChI Chair in International Constitutional Law.

ANDRIES P ENGELBRECHT

Prof Engelbrecht holds the DST-NRF SARChI Chair in Artificial Intelligence and was the Director of the Institute for Big Data and Data Science in the Faculty of Engineering, Built Environment and Information Technology until end-2018. He has since moved to Stellenbosch University.

JOSUA P MEYER

Prof Meyer is Head of the Department of Mechanical and Aeronautical Engineering and Chair of the School of Engineering, and leads the Clean Energy Research Group in the Faculty of Engineering, Built Environment and Information Technology.

ROBERT P MILLAR

Prof Millar is Director of the Centre for Neuroendocrinology in the Faculty of Health Sciences.

STELLA NKOMO

Prof Nkomo is Strategic Professor in the Department of Human Resource Management, Faculty of Economic and Management Sciences.

YVES VAN DE PEER

Prof Van de Peer is part-time Professor at the Genomics Research Institute at UP, and Professor in Bioinformatics and Genome Biology in the Department of Plant Biotechnology and Bioinformatics, Ghent University, and the Department of Plant Systems Biology, VIB.

CHARLES VAN ONSELEN

Prof Van Onselen is Research Professor in the Centre for the Advancement of Scholarship at UP.

JOHANNES VAN OORT

Prof Van Oort is Extraordinary Professor in the Department of Church History in the Faculty of Theology at UP.

BRENDA WINGFIELD

Prof Wingfield holds the DST-NRF SARChI Chair in Faculty of Natural and Agricultural Sciences. She is a member of the DST-NRF Centre for Excellence in Tree Health Biotechnology and the Tree Protection Cooperative Programme in FABI.

MICHAEL J WINGFIELD

Prof Wingfield is the founding Director of the Forestry and Agricultural Biotechnology Institute (FABI) at UP, a position from which he stepped down in 2018. He is advisor to the UP Executive and has continued as Research Professor at FABI. He also serves as President of the International Union of Forest Research Organisations (IUFRO).

XIAOHUA XIA

Prof Xia is Director of the Centre of New Energy Systems (CNES) and holds the Exxaro Chair in Energy Efficiency in the Faculty of Engineering, Built Environment and Information Technology.

* Department of Science and Technology (DST) and National Research Foundation (NRF) South African Research Chairs Initiative.

Awards and recognition

There are numerous awards and accolades that UP staff and students receive in recognition of their achievements. This brief overview is of the internal UP research awards, and of some of the most prestigious external awards in 2018.

INTERNAL AWARDS

The Chancellor's Award, in recognition of exceptional achievement in research:

- Prof Zander Myburg, Department of Biochemistry, Genetics and Microbiology, Director of the Forest Molecular Genetics Programme in the Forestry and Agricultural Biotechnology Institute, and Chair of Forest Genomics and Biotechnology at UP.
- Prof Josua Meyer, Department of Mechanical and Aeronautical Engineering, and Chair of the School of Engineering.

The Vice-Chancellor's Book Awards, in recognition of excellence in the publishing of scholarly books, monographs and collections:

- Prof Jan Snyman and Prof D Nico Wilke, *Practical Mathematical Optimization* (2nd edition, Springer, 2018)
- Prof Riël Franzsen and Dr William McCluskey, *Property Tax in Africa – Status, Challenges, and Prospects* (Lincoln Institute of Land Policy, 2017).

The Vice-Chancellor's Award for Excellent Supervision, underscoring the critical link between research and postgraduate students: Prof Mike Wingfield, founding Director of the Forestry and Agricultural Biotechnology Institute (FABI), who has been the advisor or co-advisor of 101 doctoral students and 68 master's students over a period of 30 years as an academic.

Exceptional Academic Achievers Awards, made to senior academics who have consistently excelled in their academic fields:

- Prof Teresa Coutinho, Department of Biochemistry, Genetics and Microbiology
- Prof Louis Nel, Department of Biochemistry, Genetics and Microbiology
- Prof Emma Steenkamp, Department of Biochemistry, Genetics and Microbiology
- Prof Lyn-Marie Birkholtz, Department of Biochemistry, Genetics and Microbiology
- Prof Marion Meyer, Department of Plant and Soil Sciences
- Prof Andrew McKechnie, Department of Zoology and Entomology
- Prof Steve Cornelius, Department of Private Law
- Prof Ragan Gupta, Department of Economics
- Prof Walter Föcke, Department of Chemical Engineering.

Exceptional Young Researchers Awards, in recognition of early career achievements in research:

- Prof Regard Brits, Department of Mercantile Law
- Dr Thulani Makhalanyane, Department of Biochemistry, Genetics and Microbiology
- Dr Tung Le, Department of Mathematics and Applied Mathematics
- Dr Paul Razafimandimby, Department of Mathematics and Applied Mathematics
- Dr Hendrik Brink, Department of Chemical Engineering
- Dr Nico Wilke, Department of Mechanical Engineering
- Dr Jeannie van der Linde, Department of Speech-Language Pathology and Audiology.

EXTERNAL AWARDS

- Prof Robert Millar – the African Union Kwame Nkrumah Award for scientific excellence, and for his contribution to advancing the field of science and research on the continent.
- Prof De Wet Swanepoel – the Newton Advanced Fellowship by the Academy of Medical Sciences in the UK.
- Prof Dire Tladi – the Fulbright Visiting Research Scholar Program Grant for his work on the International Law Commission's Peremptory Norms of General International Law.
- Prof Egmont Rohwer – the Georg Forster Award of the Alexander von Humboldt Foundation.
- Prof Alisa Phulukdaree – Fellow of the Next Einstein Forum.
- Dr Irene Barnes – the Ethel Mary Doidge Medal in recognition of outstanding early career research in mycology.
- Dr Taryn Bond-Barnard – the Global Young Researcher Award.
- Danielle Twilley – the L'Oréal-UNESCO Women in Science International Rising Talents Award; and Fiona Mumoki and Andy Wilson, Fellowships for Women in Science Regional Programme.
- UP academics won three National Science and Technology Forum Awards: Prof Tiaan de Jager and the UP Institute for Sustainable Malaria Control team – Communication for Outreach and Creating Awareness of Science Engineering Technology and Innovation; Prof Kevin Ward – the Lifetime Achievement Award; and Prof Mmantsae Diale – the Award for Exceptional Performance in Research Development.
- Prof Brenda Wingfield – the South African Society for Microbiology's Gold Medal for exceptional service over an extended period of time.
- Prof Mike Wingfield – the South African Academy for Arts and Sciences MT Steyn Prize.
- Dr Siona O'Connell – the Humanities and Social Sciences Award for *Hanging on a Wire*.
- Prof Braam van Wyk – the South African Association of Botanists Gold Medal Award for his lifetime contribution to Botany.

All authors in this Review are featured here. For links to their profiles, please visit **https://www.up.ac.za/research-reports-and-news** for an electronic version of this report.

Project coordinator, writer and editor

Hanlie Griesel

Photography

EyeScape, photo libraries (Shutterstock, Unsplash), and as per individual credits: Alet Pretorius **104**; Chamanti Laing **59**; Christo Botha **84**; Cobus M Visagie **Cover**, **85**; Dave Berger **63**; Deon de Jager **53**; Don Cowan **34-36**; Dook **101**; Dook, EarthWorld, Wynand Steyn **102**; Dook, EarthWorld, Wynand Steyn **103**; Els Vermeulen **56**; Francois Malan **48**; Geoffrey Fosgate **82-83**; Goddi et al. **43**; Dr Gustav Paulay, Florida Museum of Natural History **50**; Hannah Jacobs **73**; Henriette van Heerden **79**; Irene Barnes **62**; J Mercier **67**; Justin Bower, Unix Gallery **17**; Karina Landman **99**; Liliesleaf Trust Archive **11**; Liv Oeian (Shutterstock) **27**; Maxine Marx **12**; Movie Snaps **21**; Nanette Christie **39**; Natalie Aneck-Hahn **76**; Neill McNicoll **54**; Neriman Yilmaz **31**, **85**, **101**; Nerman Yilmaz and Cobus M Visagie **1**; Next Einstein Forum **68**; Nicole Kwiatkowski (Shutterstock) **80**; Patrick Mynhardt **52**; Pawel Janiak (Unsplash) **28**; Phillipe Borsa **53**; Robin Crewe **58**; Roger Deane **43**; Siphumeze Khundayi and Tiffany Mugo **13**; Steven Hussey **40**; Therina Groenewald (ProSelect Images) **24**; Thulani Makhalanyane **33**; UKZN Press **14-15**; UP Centre for Viral Zoonoses **81**; Wilhelm de Beer **65**; Willi Jacobs **57**; WITS University Archives **10**; WITS University Press **13**; Wynand Steyn **7**, **8**, **89**, **105**

Design, layout, and publishing

Words'worth

Printing

Montyprint

FSC
www.fsc.org

This report is printed on Munken, a paper that is endorsed by the Forest Stewardship Council (FSC). The FSC aims to support environmentally appropriate, socially beneficial and economically viable management of the world's forests. All forests from which the pulp is sourced are man-made and the mother-tree (which generates seeds for new seedlings) is never cut down.

FSC management brings direct benefits to the forest, such as protecting biodiversity, indigenous peoples' rights, worker's rights, and areas of significant environmental or cultural importance. It further provides a connection between the forest and the end user, ensuring that products with the FSC label uphold principles and criteria which bring the highest social and environmental benefits.

The Research Review 2018 is published in print and e-versions.

Please visit **https://www.up.ac.za/research-reports-and-news** for an electronic copy of this 2018 Research Review and previous Reviews.

ISBN 978-1-77592-192-9

University of Pretoria
Research Review 2018

www.up.ac.za