FROM **HOPE** TO **ACTION** THROUGH **KNOWLEDGE**

The Renaissance of the
University of the Western Cape

2001 – 2014

Editors

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Passing the Baton: Establishing a Niche Area in Microbial Biotechnology and Developing Research Leadership

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Introduction

The Institute for Microbial Biotechnology and Metagenomics (IMBM) was established in September 2007, but its origins date back to 2001, with the arrival of Prof Don Cowan, and coincidentally also Prof Brian O’Connell as Rector and Vice-Chancellor. Prof Cowan, a New Zealander who had been working at the University College London (UK) for the previous 16 years, joined UWC as Professor of Microbiology. His arrival coincided with structural changes in several departments in the Faculty of Natural Sciences and he promptly assumed the role of head of the newly formed Department of Biotechnology that included the staff of two relatively small departments, Biochemistry and Microbiology.

Within two years of his arrival, Prof Cowan established the ARCAM (Advanced Research Centre for Applied Microbiology) ‘research centre’, and with it a potential niche area of research, which was elevated to Institute status in 2007 as a new formally approved institutional research entity. I joined the ARCAM group as a postdoctoral fellow in 2006, and in this chapter I describe how I came to take over the leadership of the IMBM after Prof Cowan’s departure in 2012, which I attribute to a real leap of faith on the part of the University Executive Management, exemplifying UWC’s commitment to “retain, promote and develop talent and effectively empower the next generation of leaders”.

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The IMBM, with a mandate centred on postgraduate training and research, has contributed to UWC's growing national and international reputation as a research-led university. I have attempted to capture a 'before' and an 'after' perspective on the Institute's rise as one of the fruits UWC has reaped as a result of the major strategic realignment led by Prof O'Connell. Despite still being considered a young institute, IMBM's journey to this point has been highly successful but not without challenges; by far the biggest one to overcome was the loss of its founder and leader at a very critical time in the Institute's existence. Difficult decisions were made and crucial turnaround strategies implemented to ensure the ship would stay afloat and continue to warrant its status. The ability to rapidly adapt research projects to respond to internal, national and international challenges has been key to IMBM's success. How this was achieved, and the various role players involved will be revealed throughout the chapter. However, since this success centres on the research conducted, it is therefore necessary to contextualise the legacy left by Brian O'Connell by first describing what microbial biotechnology is and the many facets it encompasses.

Microbial Biotechnology – what it is, and why it's such an important field of study

Microorganisms (minute, simple life forms that include bacteria, archaea, algae, fungi, protozoa and viruses) constitute 60% of the Earth's biomass (Singh et al., 2009). Despite their size, microbes are the engines of the biosphere due to their innumerable associations and key roles in all biogeochemical processes. Simply put, they run the world, or as described by Louis Pasteur over 150 years ago "life would not long remain possible in the absence of microbes". The existence of microbes was discussed for many centuries, but their scientific study only really began in the 1670s with their observation under the microscope (Willey, Sherwood & Woolverton, 2013). This discovery was a significant milestone in the history of science, because for centuries it had been postulated that 'invisible' entities were responsible for decay and disease. Microbiology as a field of study is therefore not only defined by the study of microorganisms, but also by the tools used to study them.

Microbes are found almost everywhere on the planet. All plants and animals have closely associated microbial communities that perform specific functions to enable their hosts to survive. Even in the most extreme environments, at temperatures, pressures and pH levels in which no other

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organisms can survive, microbes are found performing key functions that make life on this planet sustainable. They exist as communities containing thousands of interdependent species, which have developed countless strategies for survival, adapting over generations in response to billions of years of environmental change. As key players in important ecological processes an understanding of microbial dynamics and their interactions with biotic and abiotic factors forms the basis of research conducted under the banner of microbial ecology. Three fundamental questions are typically asked: (i) How many and what type of microbes are present? (ii) What do these microbes do? (iii) How do the activities of these microbes relate to ecosystem functions? Much of the earlier research in IMBM centered on addressing these questions for diverse environmental contexts (Figure 21.1). The tools employed in the research were pioneered by IMBM in South Africa and earned IMBM recognition as a leader in microbial ecology research.

In addition to their essential activities throughout the biosphere, microbes have been the source of numerous technologies that humans have adopted for improving lifestyle or towards addressing sustainable development goals. The use of microbial technologies for cereal grain fermentation to produce an alcoholic beverage dates as far back as 7 000 BC (McGovern et al., 2004). Modern microbiology reaches into many fields of human endeavour and is therefore a discipline that offers incredible benefits to society. The use of microbes to solve problems and make useful products is what defines microbial biotechnology as a sub-field of biotechnology. With the end goal being to deliver a product or service, the research tends to take a more directed approach to attract the interest of an entity willing to adopt the technology. Biotechnological processes often rely on microorganisms contained within an engineered environment designed to allow some level of operator control (McMahon et al., 2007). However, because the development of the microbial-derived product or service most often ignores or overlooks the microbe's natural context, designing stable and resilient high-performing systems in a cost-effective manner tends to eventually require a great deal of fundamental research to be conducted before it can be adopted by the target industry. Essentially, without effectively bridging the gap between microbial ecology and biotechnology disciplines, truly innovative solutions will not be fully realised.

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Figure 21.1 Applied genomics research has taken IMBM researchers to all corners of the world to acquire environmental samples, for the study of microbial diversity and their adaptation in extreme environments. Through these sampling expeditions IMBM has accumulated an extensive collection of microbial isolates, metagenomic libraries, and environmental DNA preparations, constituting a highly valuable and largely unexplored resource for the discovery of novel, high-valued natural compounds for product development.

What should be apparent by now is the interdisciplinary nature of microbial biotechnology. The integration of microbial ecology and biotechnology disciplines has underpinned the research conducted in IMBM for the greater part of its existence, most notably in the earlier years. However, setting a research agenda is not an easy process in developing countries as many factors, whether internal (interests of the researchers to the ideology of the organisation) or external (historical, political and cultural

context, characteristics of the demand and unanticipated opportunities) have influenced and steered the direction that IMBM has taken. IMBM's navigation through these inputs is what I document in the following sections, highlighting the research that was conducted following a chronological perspective.

Setting Down Roots – Establishing the Advanced Research Centre for Applied Microbiology (ARCAM)

ARCAM was housed in the refurbished ground floor of the Old Chemistry building (which has now been redesigned as the state-of-the-art Computational and Mathematical Sciences building, opened in December 2018). The origins of the University funding of the ARCAM laboratory are not clear; however, a significant amount of funding, in comparison to the annual equipment budget, was allocated for the refurbishment. The fact that this approach was possible alludes to the strategic repositioning of the University under the leadership of Rector Brian O'Connell and the steadily maturing financial management structures at the University. Nevertheless, the ARCAM laboratory was one of the most modern and well-equipped science laboratory suites in the entire University at the time (Figure 21.2A).

Figure 21.2 The world-class research laboratories which housed the ARCAM (2001–2009) (A) and IMBM (2010–current) (B) research teams.

The laboratory rapidly rose in prominence within the University, recognised for both the quality and quantity of its research outputs. Funding was almost exclusively raised from external sources; the Department of Science and Technology (DST), the National Research Foundation (NRF), Water Research Commission (WRC) and a long-term collaborative relationship with UK bioenergy company TMO Renewables. By 2007 the group had grown to a cohort of over 45 researchers (including postdoctoral fellows, PhD and MSc students). Keeping on top of a rapidly growing

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group while maintaining a high quality of research is not always easily managed and carries a certain risk (Smith & Trieu-Cuot, 2018). Scientific leadership is not enough to sustain a group of this size, while single-handedly also managing all the associated resources (laboratory and equipment, and multiple grants). Recognising this, Prof Cowan engaged UCT microbiology PhD graduate Dr Heidi Goodman as the ARCAM Senior Administrator as early as 2002. Dr Goodman was to retain this critical and supportive role, encompassing more than just an administrative portfolio, for 16 years, all through short-term contracts. For some time, the ARCAM laboratory hosted over 30% of the University's entire cohort of postdoctoral fellows. Maintaining a sizeable team of postdoctoral fellows, who played an enormously important role in the success of the Centre, was necessitated to maintain hands-on supervision of the postgraduate students and to ensure the large group size did not become counter-productive. Although an anomaly the world over, it is perplexing how little consideration is given to the risks of growing research groups where the critical supporting roles are played by short-term staff. In South Africa this is exacerbated further by the NRF's policy to fund postdoctoral fellows for a maximum of 2 years, with very few opportunities available for them to be absorbed by the institution into an academic position. Prof Cowan held the only permanent position in the group and a high turnover rate of critical support remained the state of affairs for over 10 years. The success achieved despite the rickety support structure attests to excellent management, creative ways to retain staff for as long as possible, highly committed team members and a substantial operational budget from non-NRF sources. UWC's financial constraints as it was on a path of recovery from a state of bankruptcy in 2001 necessitated a search for alternate external funding.

Setting the stage: Initiating a niche area of Research at UWC in Applied Microbiology

The research focus of the first decade of ARCAM and later IMBM research was, inevitably, dictated by the skills and interests of Prof Cowan. He was a microbial enzymologist by training, but by the time he joined UWC in 2001 he was broadening his research interests into microbial ecology and had already established something of a reputation in the new field of metagenomics. The term 'metagenomics' first appeared in publications in 1998 (Handelsman et al., 1998), and was defined as a genomics technique that enables the study of individual (microbial) species without the need

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for isolation and laboratory cultivation (Chen & Pachter, 2005). The initial studies in the field shocked the scientific community by revealing a completely new (micro) universe. It became apparent that less than 1% of microorganisms in most habitats can be grown and studied in the laboratory, and therefore much of what was understood and taught in the field of microbiology represented only a very small proportion of what actually exists. This powerful technique was expected to revolutionise our understanding of the entire living world (Marco, 2011) and to have profound impacts on many aspects of society. Prof Cowan's laboratory was the first to introduce this revolutionary technique and field of study to South Africa and is now a technology that has been widely accepted across the South African academic community. At about the same time other researchers in the Biotechnology department (Prof Jasper Rees) and in UWC's South African National Bioinformatics Institute (SANBI) (Prof Vladimir Bajic) were also developing genomic programmes and collectively contributed to UWC building a reputation as a leader in genomics.

One of three major projects Prof Cowan brought with him from London was the Antarctic soil microbiology programme, initiated in 1999 with New Zealand collaborators. This attracted many a student, nationally and internationally, with the aspiration of being offered an opportunity to collect their own samples towards their research projects. Although Prof Cowan conducted a yearly sampling expedition in the summer months, much to every students' disappointment it was only possible for three PhD students to accompany an expedition over the 12-year period. Prof Cowan's interest in microbial ecology continued to expand into other extreme environments, leading to the development of several new research programmes. However, the Antarctic programme was the only project that spanned the pre- and post-IMBM years through which IMBM gained iconic status (it remains active to this day, although the programme is now based at the University of Pretoria). The benefits of establishing and maintaining long-term research programmes are far-reaching (Kuebbing et al., 2018) both in terms of the scientific knowledge that can bring material benefit to society (Romanowski, 1988), but also with respect to productive outputs (student training, publications, collaborations). The benefits, however, stand in notable contrast to most research funding decisions, where usually only short-term (1-3 year) grants are awarded. The continuity of this research was mostly possible as a result of collaborations with international partners leading major Antarctic programmes, and funding through the long-standing South

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African National Antarctic Programme (SANAP), which is firmly rooted in the South African National R&D Strategy.

The second programme that moved with Prof Cowan to UWC was the use of functional metagenomics to identify enzymes of biotechnological interest. The development of the technologies involved in preparing environmental DNA libraries to recover novel genes was a major achievement that set the foundation on which many of the current research projects in IMBM still rely. The technologies employed have continuously evolved and been adapted as more complementary tools (for example, sequencing technologies, bioinformatics capacity and proteomics) became available and are discussed later in the chapter.

For more than a decade before Prof Cowan's arrival in South Africa, he had enjoyed the support and mentorship of prominent UK biotechnology entrepreneur, Dr Tony Atkinson, founder of the company TMO Renewables Ltd. With the company's focus in the bioenergy sector, it was for many years considered a leader in next-generation biofuels for developing a breakthrough technology projected to offer several competitive advantages to the conventional bioethanol technologies used worldwide (Taylor et al., 2009). Consequently, the third major programme in ARCAM involved a role in assisting TMO's research team to develop the thermophilic bacterial strain on which the technology was based. Partnering with industry brings a different dynamic to a research group due to a divergence of motives, but also provides much needed funding to support a higher level of productivity which is not reliant on postgraduate training, crucial for retaining the support of an industry partner.

When I joined ARCAM in March 2006 as a postdoctoral fellow, I took an interest in all three programmes described above. I was principally charged with initiating a completely new area of research for the group: assessing the virus diversity to complement the ongoing microbial ecology analyses that focused only on the bacterial counterpart. Despite viruses being the most abundant biological entities on Earth, most microbial surveys completely ignore the virome due to several technical challenges (Paez-Epsino et al., 2016) and therefore this represented a really exciting new area of research for an aspiring researcher and for the group. I had trained as a molecular microbiologist but had not yet been exposed to the metagenomic and molecular ecology tools that were being developed in ARCAM. Keen to use the opportunity to the fullest, I involved myself in all the projects described to build as much experience as I could. This

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proved to be an important decision in my preparation to later take over the leadership of the Institute. However, since Prof Cowan could initially fund my position only for a 5-month period, and I was at that time 6 months pregnant with my first child, my future involvement in this kind of capacity was not on anyone's radar. The next section details how both I and ARCAM transformed into new entities at UWC.

An Institute is Born: The Institute for Microbial Biotechnology and Metagenomics (IMBM)

The achievements and impact of the research conducted through the ARCAM years played a significant role in the evolution of UWC from a historically disadvantage institution with low levels of scientific research activity (prior to 2000) to one of the leading research-led institutions in the country and on the continent. Because of this success, ARCAM was formally elevated to Institute status at a launch in 2007 with presentations by Rector Prof Brian O'Connell, Dean of the Faculty of Natural Sciences Prof Jan van Bever Donker and Prof Cowan, followed by an informal cocktail function (Figure 21.3). At the end of his presentation Prof O'Connell paused, looked down at Prof Cowan sitting in the front row, and with deep emphasis said, "Don't let me down, Don". Amusingly, Prof O'Connell, one of the most accomplished of orators, always struggled with his pronunciation of the word '*metagenomics*', as have many a journalist and media representative.

Figure 21.3 The launch of the IMBM in 2007 was celebrated by addresses from Prof O'Connell (A) "Don't let me down Don", Prof van Bever Donker (B) and Prof Cowan (C) "I'll do my best Prof O'Connell" followed by a celebratory cocktail function.

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As an Institute, IMBM had a formal constitution, requiring two key components to be introduced: the appointment of a Management Board to oversee the activities of the Institute within a framework of excellence, impact and accountability; and the creation of a Deputy Director post as a succession strategy. A criterion for institute status at UWC is for it to be self-funded and demonstrate financial sustainability. The Deputy Director post could therefore initially only be established as a 3-year contract position, fully financed by donor funds. I had managed to secure Claude Leon Foundation funding for my postdoctoral fellowship between 2007 and 2008, and therefore the opportunity to apply for the Deputy Director position came at a very timely point in my career. Through the formal University process, I was appointed as the Deputy Director in IMBM and Senior Lecturer in the Department of Biotechnology in 2009. This position represented a very important development for the IMBM; it not only provided a mechanism to nurture and prepare a younger staff member for key roles later on, but it also enabled the scope of the Institute's academic pursuits to be expanded. IMBM continued to excel and in recognition of the achievements, one of the innovative activities of the DVC Academic, Prof Ramesh Bharuthram, was to award two 1-year postdoctoral positions to the Institute, and a three-year early career researcher position, a first for the University of the Western Cape. Another accolade to recognise the achievements of IMBM was for Prof Cowan to be the first recipient of the Vice-Chancellor's Annual Award for Research Excellence for Established Researchers in 2008, which together with an award for Emerging Researchers, was launched to promote research excellence.

The IMBM was growing and beginning to burst at the (laboratory) seams. Therefore, the opening of the new Life Sciences building in March 2010 brought much anticipated relief and an opportunity for bigger ambitions. The origins of the donor funding that initiated this substantial evolutionary step in UWC's advancement are told elsewhere, but the building and its impact remain one of Prof O'Connell's greatest legacies to the University. Following the building's official opening, IMBM was rehoused in a 1 200 m² laboratory on the second floor, the first laboratory in the building to be occupied. This thoughtfully designed laboratory space, which includes office spaces for staff and postdoctoral fellows, open-plan desk space for postgraduate students, wet-laboratory benches and special-use technical rooms in an integrated layout, has a capacity for some 50+ researchers and has been, and still is, a totally world-class facility (Figure 21.2B). Although the laboratories throughout the building are generally uniform and modular in design, the assiduous involvement in the planning stages

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ensured that a number of crucial adjustments were incorporated to suit the needs of the IMBM researchers. As an example, the inclusion of a cold room, necessary for most biological research, was overlooked by other departments and as a result is frequently accessed, and coveted, by other departments.

The new laboratory space provided a further stimulus for IMBM research activities, particularly as a 'visual aid' for postgraduate student recruitment, but also in making the laboratory an attractive destination for visiting researchers and in further enhancing the status of the Institute within and outside the University. It was particularly noticeable that, from day 1, the University Executive took every available opportunity to show-case their leading science research group. IMBM staff and students became very comfortable with the sight of visitors (including international visitors, sponsors and government Ministers, led by Prof O'Connell, the DVC Academic or the Dean) touring the laboratory and admiring the vitality of the research team in a magnificent physical research environment. I have witnessed visitors' perceptions of UWC change for the positive when they tour the IMBM and the new Life Sciences building. The most notable was the reaction of the research manager from a prominent petro-chemical company in South Africa, who indicated that their policy not to employ UWC graduates would have to be reconsidered, following a visit to the IMBM facility in 2013. As the current Dean, Prof Mike Davies-Coleman, likes to remind his Faculty management team, "It's not a new building, but the quality and impact of the research conducted in the building ... that should wow". The impressively equipped laboratory equally matched with cutting- and leading-edge research, seems to have made a noticeable impact in transforming the public's view of UWC.

n=2: A second group leader to diversify the research portfolio

The IMBM provided a very supportive environment for me to easily make the switch from operating as a postdoctoral fellow to now establishing research independence. I was quickly able to secure two NRF research grants to distinguish my research direction under the IMBM umbrella, but one of the most instrumental influences on my academic track was the opportunity to continue my involvement in most of Prof Cowan's projects as a co-investigator. The transition was seamless. Not every young academic has this experience. In fact, it is rather rare and emphasises the benefits of joining an active research team with well-developed systems, processes and a well-equipped laboratory. It was a symbiotic relationship

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that benefited us both, and I recognise the value of a good mentor who helped open up pathways for me to advance quickly to the next stage of my career.

Two new collaborative projects were initiated which resulted in rapid postgraduate growth in IMBM. Through the early 2000s, there was growing government interest in biotechnology through the DST, leading to the formation of the BRICs (Biotechnology Regional Innovation Centres). With a footprint in biofuel research through the collaboration with TMO Renewables, Prof Cowan and I successfully leveraged a four-year grant of R4 million from PlantBio for a project focused on finding new enzymes suitable for the commercial digestion of plant biomass for biofuel production, using functional metagenomics. The end of the project in 2013 coincided with the dissolution of the BRICs and the formation of the new national Technology Innovation Agency (TIA) with an expanded mandate, which resulted in the termination of the next phase of the BRICs project. However, the development of new enzymes for various industrial applications is still a central theme in IMBM, serving as an excellent platform for training postgraduate students in core biotechnology techniques. The second project was triggered by an invitation in 2008 from the famous NASA astrobiologist, Dr Chris McKay, to join the *Spaceward Bound* outreach programme. A long-term desert soil microbiomics research programme, which in many regards paralleled the Antarctic research programme, was established. The Namib Desert microbial ecology programme celebrated its 10th Anniversary in April 2019 at the Gobabeb Research and Training Centre, commemorating the many collaborations initiated, many students and researchers trained, and over 35 published research articles. My involvement in this programme, together with the bacteriophage expertise I had established during my postdoctoral years in ARCAM, and a very important piece of work conducted by Dr Lonnie van Zyl towards our collaboration with TMO renewables, came to cement bacteriophage/metaviromics as another core research theme in the IMBM.

Stepping up: A new era for IMBM

Prof Cowan's retirement from UWC in early 2012 represented both the end of one era and the start of a new one. His farewell party was a very memorable and celebratory event, where Prof O'Connell and others praised Prof Cowan's achievements and contribution to UWC (Figure 21.4).

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His departure came as a rather unexpected shock to all, not least to me, who as the Deputy Director of the Institute, was the logical successor. However, the decision to keep the IMBM doors open was not unanimously supported. Considering Prof Cowan's influence and stature, some feared that he would continue to direct the IMBM from the University of Pretoria, which posed a risk to the investment UWC had made in establishing the Institute as a proudly UWC niche area. Considering my fledgling research career at that point, having only started as an academic three years earlier in 2009, the doubts as to whether I had the necessary experience, and most importantly sufficient grant funding to satisfy the criteria of Institute status, were understandable. The establishment of IMBM occurred 20 years into Prof Cowan's research career, and so it may have been considered a hope too high for such an early-stage career academic, on a contract appointment with two small grants to her name, to sustain and grow the Institute. Fast forward seven years later, IMBM celebrates its existence under my leadership for a longer period than that of its founder. This highlights the significance of mentorship of young researchers to accelerate their development into leadership positions and the importance of a succession plan, which is a key component of the staff research capacity development strategy of the University. The IMBM was well resourced and a very enabling and supportive scientific environment, key components to grooming and fast tracking the academic career of young researchers. The fact that I as the Director of a second Institute in the Faculty of Natural Sciences and Prof Alan Christoffels, Director of SANBI, have followed similar paths and succeeded, speaks to the determination to prosper in the face of challenges within a well-defined strategic framework, and wholly embodies Prof Connell's vision to "overturn accepted beliefs about what is possible and probable".

A new vision and mission for the IMBM was adopted together with a rejuvenated logo to represent the new era. Adopting my own managerial style, I established an internal management team comprised initially of Dr Goodman, Dr Bronwyn Kirby (Senior Lecturer) and Dr Lonnie van Zyl (laboratory manager), who have to this day been faithful and central to the continued development and success of the IMBM. Dr Goodman who was there even before the Institute's inception, seeing it through a management change, *finally* retired in 2018. Her role in ensuring the smooth-running and success of the Institute cannot be overstated.

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Figure 21.4 Celebration of an era, and the start of a new one. Prof Cowan retired in 2012, after 11 years of highly productive research at UWC, celebrated by students, staff, collaborators and esteemed colleagues (From left: HoD Biotechnology, Prof Pieter Gouws; current Science Faculty Dean, Prof Mike Davies-Coleman; Deputy Vice-Chancellor Academic, Prof Ramesh Bharuthram; then Acting Director, Prof Marla Trindade; Prof Don Cowan; Vice-Chancellor, Prof Brian O'Connell; Deputy Dean Research, Prof David Fisher).

Resulting from numerous achievements, and with the notable support from the University Executive Management, several key staff positions have been established to further strengthen the IMBM and foreground its continued growth. The first of these was the awarding of the DST/NRF SARCHI Research Chair to UWC in Microbial Genomics in 2013, to which I was appointed in 2014, the first female academic at UWC to hold a SARCHI Chair. Through the Chair numerous significant opportunities have been leveraged which have raised the profile of the Institute, including attracting significant funding, expansion of international collaborations, opportunities for Dr Kirby and Dr Van Zyl to establish themselves as independent researchers in IMBM and thereby being instrumental in expanding the research agenda for IMBM, and larger numbers of postgraduate students and postdoctoral fellows. Subsequently, with the support of the University a DHET nGap lecturer position was awarded in 2017, which together with the establishment of a Research and Innovation Manager portfolio in the IMBM – that in itself represents a radical departure from the ‘norm’ – indicates the innovative support strategies for the continued development and growth of the Institute.

Professor O'Connell's Legacy: A flourishing institute

The preceding sections reflected on the period during which Prof Brian O'Connell held the position of Rector at UWC. However, his foresight to elevate the University's stature through establishing cutting-edge research areas has had far-reaching impact, beyond the years that he served at UWC. Although IMBM is still a young Institute, it has continued to celebrate achievements that cannot be dissociated from what Prof O'Connell had made possible. The next section describes the trajectory of research and innovation at the IMBM after Prof O'Connell's retirement, to highlight the importance of the foundation that was established during his visionary leadership, as well as a tribute and a celebration of his contributions to advancing UWC's status as a research-led University.

Implementation of an Innovation Strategy

For a number of reasons, it became important for me to establish an independent research direction for the IMBM that would not be in direct competition with the programmes that Prof Cowan had moved to the University of Pretoria upon his retirement from UWC. One of the aspects that was critically assessed was the Institute's prior performance in *delivering* biotechnology, in the form of development of intellectual property (IP) and commercialisable products/technologies/services. This audit happened to coincide with the establishment of the Technology Transfer Office at UWC, promulgated by Act 51 of 2008 on Intellectual Property emanating from publicly funded research and development, which made it mandatory for universities to perform a technology transfer function. It therefore seemed opportune to strategically align research initiatives with enterprise and industry needs from a 'technology push' to a 'market pull' focus, to accelerate the translation of the research into commercial opportunities. To drive this agenda, Dr Anita Burger was brought on board as a Research and Innovation Manager in 2016, to focus on matching the most promising technologies from the IMBM with a suitable industry partner. This interface is particularly challenging in an academic environment where the readiness level of the technologies generated by postgraduate students is generally very early stage and considered too risky for industry commitment.

The number of formal industry partnerships (including multinationals such as L'Oreal, NeemBiotech, NuWater, BioDX, AgriProtein, AxoNova, Rhizobacter, CHR Hansen, Cirebelle, to name a few) (Figure 21.5) that have been established in a short period attests to the high quality and

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innovativeness of the research being conducted in IMBM, and that the academic expertise within the Institute is highly valued in serving multiple industries. Several initiatives targeted for the product development pipeline are already in the next phase, with the Institute's Flagship commercialisation product centred on a novel biosurfactant, initially discovered through a PhD project (Williams et al., 2019). The provisional patent has progressed to a PCT filing in Europe, a first for the Institute, for application in wastewater treatment, agriculture and cosmetics.

The Genomics Revolution

The IMBM's research repertoire is multi-disciplinary and diverse, which has been an important strategy focused on excellence and relevance, especially during the early period under the new leadership, to sustain the Institute through securing sufficient funding from a wide variety of sources. The current research themes cater for all sectors of biotechnology (health, agriculture, industrial and environmental) and correspond to scientific and technical advances that rely on indigenous biodiversity to develop innovative solutions to address societal needs.

Central to all the research programmes is the use of genomics. Consequently, IMBM has played a significant role in building capacity for genomics in South Africa. The Department of Biotechnology (in which IMBM resides) was the first institution in Southern Africa to bring next-generation sequencing capacity to academia in 2008, with the purchase of an Illumina GAII sequencer, spearheaded by Prof Jaspar Rees. Within two years of its acquisition the GAII had become obsolete as a result of scientific and technological innovations resulting in the rapid evolution of instruments, chemistries and techniques. Under the auspices of the IMBM, the Next Generation Sequencing platform was relaunched in 2011 as a national service platform, resulting from a successful bid through the NRF National Equipment Programme (NEP). Part of the IMBM mandate was to prepare the South African scientific research base for the expected dramatic rise in DNA and RNA sequencing as part of research projects enabled by these next-generation platforms. The belief in the genomics revolution served as a catalyst for the University Executive Management to provide two contract staff positions and funds towards other essential equipment. The platform stimulated high-quality research activities within the University and regionally, directly contributing to UWC's development as a leading research institution. High throughput sequencing has impacted every aspect of the biological and medical sciences globally,

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and even in fields as disparate as biosensors and nanobiotechnology. Given the rapidly growing interest throughout the country, it was not unexpected that most institutions started incorporating high throughput sequencing as an essential laboratory tool, with many institutions bringing sequencing capacity in-house.

The parallel evolution of other 'omics' technologies, also developed in the IMBM group, culminated in the launch of the first-of-its-kind-in-Africa Single Cell Genomics platform in 2018. Through an R11 m NRF NEP grant, the platform offers an integrated and streamlined workflow with specialised capabilities not available anywhere else in the country. Single-cell genomics has been identified as one of nine trends expected to shape the life science markets globally in the next five years, and access to this platform will revolutionise the research approaches employed by academics at UWC, supporting a wide range of research fields from fundamental and exploratory science to innovative (bio)technology approaches. Through this initiative IMBM continues to place UWC at the forefront of the revolution in genomics, securing for the Institute a leading position in genomics and metagenomics research and innovation in South Africa.

Expanding the International Profile

IMBM has always enjoyed significant international visibility, which has been boosted over the last 7 years by expanding the extensive network of scholars and industry partners across the globe (Figure 21.5).

One of the catalysts to increasing our international visibility was an invitation I received in 2012 to participate as the lead African partner in the EU-FP7 PharmaSea project, involving 24 international institutions (from academia and industry). This not only represented the start of a new theme in marine biotechnology in the Institute, it has also been the largest research programme at IMBM and continues to expand with the numerous additional multi-national programmes initiated. The projects focus on accelerating the development and commercialisation of novel drugs for the treatment of a number of diseases, or on ingredients for nutrition or cosmetic applications, from marine microbes. Culturing and (meta)genomic strategies are employed to identify novel biosynthetic gene clusters and metabolites from bacterial symbionts associated with marine invertebrates endemic to South Africa. IMBM now boasts a rich collection of marine bacteria representing novel species, hundreds of which display a range of potent antimicrobial activities against pathogens

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and multidrug-resistant infectious agents, as well as anti-inflammation, neurological and anti-cancer activities. Through extensive academic and industry collaborations, parallel approaches are employed to isolate, identify and develop novel compounds for the drug discovery pipeline. Our proposal on the development of marine microbe-derived drug compounds was identified by the African-owned innovation fund (ANDI), as one of the six most promising technologies from Africa, and has been presented to potential funders including pharma industry representatives and entrepreneurs who have successfully developed and commercialised drug-related products.

Figure 21.5 IMBM collaborators and partnerships since 2007.

Developing the next generation of research leaders

Since the launch of IMBM in 2007, some 117 postgraduate biotechnology graduates (54 Hons, 45 MSc, 18 PhD), with the following demographics: 78% African/Coloured, and 50% female, have become proud IMBM alumni. Prior to 2009, females represented less than 40% of the students trained; however, the IMBM has steadily strengthened its female cohort with over 60% representation currently. Of the IMBM graduates, 95% are South Africans, indicating that IMBM has made a significant contribution to the country's transformation agenda through capacity development in a number of scarce skills, and more importantly, building a critical mass to assist South Africa in executing the national bioeconomy strategy

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for economic growth using science and technology. The IMBM has additionally trained over 60 postdoctoral fellows, the majority of whom have been international scholars, and it would not be surprising if IMBM continues to hold the record of the most postdoctoral fellows hosted in a single laboratory at UWC.

IMBM has a holistic approach to the development of next-generation research leaders. The above-mentioned international partnerships have facilitated numerous exchange visits to and from partner laboratories for many of the IMBM postgraduate students. For almost all of the students, these exchanges have been their first opportunity to travel on an aeroplane and venture outside of South Africa's borders. They are life-changing experiences, both academically and personally. Together with opportunities for most MSc and PhD students to present and defend their research at national and/or international conferences, their training has prepared them for the engagement with the broader scientific field and to promote themselves for opportunities in career advancement. To embed social responsibility as part the value system of its graduates, the IMBM, through the active participation of its postgraduate students, has continued to increase and strengthen its community engagement activities, focusing on building long-term relationships with a number of schools and socially engaged entities. IMBM postgraduate students are exposed to a wide range of other opportunities that encompass more than just the traditional research training, ensuring that they enjoy a holistic experience, while also receiving recognition where they excel. Many have taken up senior positions in South Africa and abroad, either in academia, policy development or in industry, indicating that they have been equipped with a versatile set of skills suitable for employment in many different sectors.

Conclusion

The Fourth Industrial Revolution, well advanced in the developing world, has rapidly transformed the way people interact, transact and learn. The 2019 White Paper on Science, Technology and Innovation identifies biotechnology as central to crafting an innovative edge to enable South Africa's effective participation in this new world order. IMBM is well-positioned to make significant contributions to the national imperatives. However, UWC still has some way to go towards developing a more innovation-enabling mindset and culture. It is well-understood that modern biotechnology has the particularity of long research and

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development lead times, where a bio-product or process requires many years to reach the market. Innovative research and the training of highly skilled people are only some of the components required to foster an entrepreneurial environment. It is a challenge for any emerging research university to decide how best to use limited resources to transform the collective research and development enterprise in a manner that increases its competitiveness and innovation capability. What Prof Brian O'Connell managed to achieve with a moderate internal budget to turn UWC around is remarkable. Through his exceptional and inspiring leadership, he created a fertile environment for science, technology and innovation to shape a different South Africa. I, and many IMBM ambassadors, am deeply grateful to him for equipping us to play a small part in the transformation that he led at UWC.

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