The Bulletin of BISMiS

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On the cover

BISMiS 2014 Delegates

The Bulletin of BISMiS

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BISMiS Business - Editorial Board Open Meeting

William B. Whitman

Apex International Hotel, 31-35 Grassmarket,
Edinburgh EH1 2HS, Scotland
April 9th, 2014 - 13:30-14:30

The Business and Editorial Board Meeting was held on April 9, 2014 during the Second BISMiS meeting in Edinburgh. Officers present:

Fred Rainey – President
Brian Austin – President-elect
Martha Trujillo – Secretary
Barny Whitman - Treasurer

The following Editorial Board members were present: Jongsik Chun, Brian Hedlund, Mike Goodfellow, and Paul Lawson. In addition, other BISMiS members joined the meeting.

Minute 1. Fred Rainey and Martha Trujillo reported about the current membership of the Society. At present there are 63 full members and 1 corporate member.

A general discussion was held to solicit ideas on how to boost membership. Proposals included contacting culture collections and private industries related with the field. The use of social networks (Facebook, Twitter, etc.) was also mentioned as a means of improving communication.

Minute 2. Barny Whitman the presented the financial report (see attachment). Whitman went through the financial report in detail.

Minute 3. Report from Paul Lawson, Editor in Chief of the BISMiS Bulletin. Paul informed that the next Bulletin issue is due to appear in approximately two months. The Bulletin is prepared by a student in his laboratory rather than using a commercial service to save money. Nevertheless, the aim is to deliver 2 numbers per year.

Minute 4. Officers elections. Elections were held in March for the positions of President-Elect and Secretary. On-line nomination and elections of new officers for BISMiS were held. Nominees for President-Elect were Lixin Zhang and Martha Trujillo and Kamlesh Jangid for Secretary. Fred Rainey announced the results of the election. The elected offices are Martha Trujillo (President-elect) and Kamlesh Jangid (Secretary).

Minute 5. The meeting was adjourned at 14:30.

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Meeting of Bergey's International Society for Microbial Systematics in Edinburgh, Scotland, 7-10th, April 2014

Paul A. Lawson

Figure 1. Amanda Jones

Firstly, it is my pleasure to introduce Amanda L. Jones as an Associate Editor of the *Bulletin*. Amanda is a Senior Lecturer in the Faculty of Health and Life Sciences at Northumbria University. After obtaining a BSc (Honours) in Biomedical Sciences at Sunderland University, Amanda worked for a number of years in microbial research at Freeman Hospital, who subsequently in 2000 received her PhD at Newcastle University under the supervision of Professor Michael Goodfellow. Amanda continued to work as a postgraduate research associate, in the field of microbial systematics at Newcastle University until the beginning of 2009, where she took her post as a Lecturer in Biology, at Northumbria University.

Amanda's research is based on the identification and classification of novel opportunistic pathogens within the order *Corynebacteriales*, with particular interest in the genus *Rhodococcus*, leading to contributions to the 2nd edition of *Bergey's Manual of Systematic Bacteriology*. Amanda's interest in the mycolic acid containing actinomycetes has resulted in her working on developing rapid identification systems and antibiotic sensitivity testing for opportunistic pathogenic actinomycetes. In addition Amanda's research also involves searching actinomycetes that have been isolated from diverse, extreme habitats for novel bioactive compounds. I first met Amanda at the inaugural meeting of BISMiS held in Beijing, China in 2011. Being a former student of Mike Goodfellow I was well-aware of Amanda and her work, during the formal meeting and social events we found we had some common interests and struck up a firm friendship.

Amanda was a member of the ISBA 14 Organising Committee, the 14th International Symposium on the Biology of the Actinomycetes, Newcastle upon Tyne, August 2007. In 2009, Amanda was appointed guest editor for the Antonie van Leeuwenhoek special issue from the 15th International Symposium on the Biology of the Actinomycetes, Shanghai.

In 2011, Amanda was appointed co-chair for the Emerging Pathogenic Actinomycetes at the 16th International Symposium on the Biology of the Actinomycetes, México and was guest editor for the Antonie van Leeuwenhoek special issue. In August, Amanda was appointed as an Associate Editor of IJSEM (International Journal of Systematic and Evolutionary MIcrobiology). She will be handling papers on *Thermoactinomycetaceae*, *Corynebacterineae*, *Actinobacteria*, *Micrococcineae*, *Micromonosporineae*, and *Streptomycineae*.

Figure 2. Amanda Jones in the laboratory

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Figure 2. The historic Edinburgh Castle, as viewed from breakfast table.

BISMiS 2014

Since the last issue, BIMiS 2014 (April 7-10th) was held in the historic city of Edinburgh, Scotland at the Apex International Hotel which overlooked the spectacular Edinburgh Castle The theme of the meeting was *"Defining Microbial Diversity in the Genomic Era."*

After welcome remarks by Fred Rainey and Brian Austin (the outgoing and newly elected President of the Society, respectively) the scientific program was opened by a keynote presentation by Hans-Peter Klenk entitled "The genomic encyclopedia of *Bacteria* and *Archaea* project and its use for microbial taxonomy" This was immediately followed by the presentation of the 2014 Bergey's Award.

An informal "welcome mixer" was attended by all delegates for a lively discussion of the upcoming program that was continued in a number of smaller groups that descended into the many pubs that surrounded the venue.

Figure 3. Hans-Peter Klenk (right) accepts the 2014 Bergey award from Fred A. Rainey (left).

Figure 4. BISMiS 2014 organizing committee. Jongsik Chun, Paul A. Lawson, Brian Austin, Martha Trujillo, William Whitman, Svetlana N. Dedysh, Fred A. Rainey, Iain Sutcliffe, Milton S. daCostaMike Goodfellow and Antonio Ventosa (Lixin Zhang and William G. Wade are not pictured).

The second day began with a keynote entitled "The state of microbial taxonomy today" by William "Barny" Whitman (University of Georgia, USA). This was followed by the first of the formal scientific sessions.

Session 1 - Use of genomic sequences in microbial taxonomy.

Keynote: Gene-by-gene approaches to characterizing genomic variation in bacterial populations. M.C.J. Maiden (*University of Oxford, United Kingdom*)

Keynote: Taxono-genomics: an example of genomic data incorporation in bacterial taxonomy equation
P.E. Fournier, *Aix-Marseille University, France*

Session 2 – Chemotaxonomy *in vitro* vs. *In silico*

Keynote: The ups and downs of chemotaxonomic analysis for bacterial systematics
M.S. da Costa, *University of Coimbra, Portugal*

Keynote: *In silico*: Reconciling computer conjectures with facts
G. Olsen, *University of Illinois, USA*

Session 3 – Microbial systematics in the Classroom

Keynote: Microbial systematics in the classroom. Stewardship of taxonomy for the 21st century
Paul Lawson, *University of Oklahoma, USA*

Session 4 Lessons for systematics from metagenomic studies

Keynote: How many species are out there? Balances after almost 40 years of use of 16S rRNA gene sequence in prokaryote systematics
R. Rosselló-Móra and P. Yarza, *Institut Mediterrani d'Estudis Avancats, Mallorca, Spain*

Each of the Keynote presentations were ably

supported by a strong program of related talks from well known experts in the field.

The final session was devoted to **"New approaches and new taxa"** with a number of presentations on topics ranging from the EzGenome software to 3-D graphic phylogenetic analysis of microbial groups to the use of MALDI-TOF-MS for describing and authentication of bacteria and finally the problems of describing rarely cultured organisms.

The formal scientific program was closed by remarks from Fred A. Rainey as the outgoing President of BISMiS and from Brian Austin the incoming president who were the co-chairs of the organizing committee. The meeting was adjourned for a few hours in preparation for the evening banquet.

In addition to the meeting itself, many delegates enjoyed the many museums, art galleries, the castle itself, local pubs, numerous whiskey tours and the various, traditionally dressed pipers that frequented the famous old streets.

Shortly after the meeting, it was announced that BISMiS 2016 will be held in Pune, India during September 12-15 2016 with our Secretary, Kamlesh Jangid, as the Convener of the local organizing

Figure 5. Fred A. Rainey receiving an honorary certificate as the outgoing President of BISMiS from Brian Austin the incoming president.

Figure 6. Student poster prize winners. Jessy Praet (left) from Ghent University and Carlos Vargas-Corona (right) from Instituto Politécnico Nacional, México.

Figure 7. Ramon Rosselló-Móra, Lena Pikuta and Karl-Heinz Schleifer.

Figure 8. Fruitful discussions in the "lab of life," the PUB! after sessions ended for the day

Figure 9. Nights on the town. Vartul Sangal, Kamlesh Jangid, Gary Olsen, Brian Hedlurd, Martha Trujillo, Iain Sutcliff and Hans-Peter Klenk (from left to right).

Scenes from BISMiS 2014 Banquet Dinner

Scenes from BISMiS 2014 Banquet Dinner

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Joseph G. Tully Remembered

Daniel R. Brown

Joseph G. Tully died of natural causes on July 24, 2013. Born in 1925 and raised in Colorado, he served in the U.S. Navy hospital corps during World War II, then received his PhD. in Microbiology from the University of Cincinnati in 1955. His early research interests involved the study of virulence antigens in *Shigella* at the University of Cincinnati from 1955-1957 and *Salmonella typhosa* at the Walter Reed Institute of Research in Washington, DC. from 1957-1962.

He began his long and productive studies on mycoplasmas at the National Institute of Allergy and Infectious Diseases, Mycoplasma Section, in 1962; a career of prodigious accomplishments which lasted until his retirement in 1999. He was instrumental in the establishment of both the American Society for Microbiology's Division G [Mycoplasmology] and the International Organization for Mycoplasmology (IOM), both in 1976. Tully served as Chairman of the IOM from 1976 to 1978 and remained a member of its Board of Directors from 1980 to 1996. His first contact with the Bergey's Trust was in 1984 when he was invited to serve on the Advisory Committee for the class Mollicutes. He wrote the description of the genus *Acholeplasma* and co-authored the description of the genus *Spiroplasma* for the 1984 edition of Bergey's Manual of Systematic Bacteriology. He subsequently served as a Trustee from 1991 through 1996 when he became a Trustee Emeritus.

Tully received ASM's J. Roger Porter Award sponsored by the U.S. Federation of Culture Collections for establishing what is now known as The Mollicutes Collection (World Federation of Culture Collections TMC; World Data Centre for Microorganisms) and the IOM's most prestigious Emmy Klieneberger-Nobel Award for outstanding contributions in research in the field of mycoplasmology, both in 1982, and the Bergey Medal in 2001.

Figure 1. Joseph G. Tully (provided by Daniel R. Brown)

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Reflections of a Budding Taxonomist

Crystal N. Johnson

As an emerging taxonomist, I feel lucky to be involved in the era of evolution in bacterial classification. I am graduating this semester with a PhD in Microbiology from the Department of Microbiology and Plant Biology at the University of Oklahoma, learning microbial systematics under the stewardship of Dr. Paul A. Lawson. My graduate studies have included a whirlwind of projects ranging from bacterial isolation, sequencing, chemotaxonomy to the environmental monitoring of petroleum infrastructure for corrosion mitigation. But what's next?

I am a lab soldier, who enjoys bench-work and the excitement of discovery. The recovery of previously uncultivable microorganisms has whetted my appetite for this. Some of these organisms include *Hoeflea anabaena* from brackish waters, *Peptostreptococcus canis* from canine dental plaque, *Youngibacter fragile* from natural gas condensate, *Peptoniphilus stercorisuis* and *Savagea faecisuis* from swine manure storage tanks, and *Proteiniphilum* sp. from corroded oil pipelines. These publications not only add to the known diversity of organisms on the planet but also provide insights into their biochemical potential and ecological importance.

I feel that a discipline as fundamentally important as microbial systematics deserves the assurance of continued interest and an enthusiastic legacy, particularly in the shadows of a sequencing era. The next generation of taxonomists must meet this challenge by embracing these new sequencing methods while maintaining the classical techniques that have provided a framework for proper microbial characterization for decades. Just like the *Macarena*, sequencing is easy to perform, can be streamlined like a line dance, and gets everyone up and moving with quick results.

Figure 1. Crystal N. Johnson working at the Center for Microbial Identification and Taxonomy (CMIT).

Is it really necessary to follow traditional phenotyping methods when less tedious genomic approaches are available? While phylogeny and general cellular attributes may be deduced from sequence-only data, bigger questions are left unaddressed. As a result, cultivation-independent techniques are commonly criticized for their lack of insight with regard to the ecological significance and environmental impact of representative sequences. Ultimately, *in-silico* characterization has yet to become reality, leaving classical phenotypic experimentation as important as ever.

Future efforts should focus on standardization of protocols and the merging of genotypic and phenotypic information in publically available databases. Descriptions of distinguishing features, including investigations into biochemical activities, can help evaluate the general ecological roles and environmental impact of pure culture isolates. For example, my first project began as a *simple* "fishing expedition" for novel anaerobes from an oil processing facility in Alaska. The aging infrastructure of pipelines and storage tanks at this site had become highly corroded. Which of my

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Figure 2. Preparing oil field samples for biocide optimization experiments in Alaska

Figure 3. (Right) Representing the University of Oklahoma at a rig site during pipeline corrosion evaluations

isolated organisms were contributing to the biofilm formation, sulfur reduction, and acid production that exacerbated metal deterioration? In order to address which bacteria were implicated in the decline of oil industry infrastructure, I expanded the biocorrosion project from isolation and characterization to include a corrosion potential evaluation. I developed methods for calculating metal loss of corroded pipelines and created 3-D models for assessing surface pitting using electron microscopy. These results have helped create an inventory of organisms "pathogenic" to energy industry infrastructure and are a great example of sequence data limitations.

The defining moment of my graduate training came while working on the North Slope of Alaska as a Conoco Phillips Exploration & Production Engineering intern. This helped shape a more global way of thinking because living on an oil rig and interacting with energy industry executives allowed me to understand issues far beyond the microscope and to see an application for my research. It was this opportunity that reminded me to look at the bigger picture, impressed upon me that my bench work could lead to real world results, and gave me the confidence to freely contribute ideas within interdisciplinary teams.

As an extension of the Lawson Microbial Systematics Laboratory, we established the Center for Microbial Identification and Taxonomy (CMIT), and I became the Director of Operations in 2011. Modeled after Deutsche Sammlung von. Mikroorganismen und Zellkulturen (DSMZ), CMIT offers services ranging from 16S rRNA sequence analysis to full physiological assessments, including chemotaxonomic markers such as fatty acids, lipids, and cell wall sugars. Although we cannot possibly compete with our friends and colleagues at Deutsche Sammlung von Mikroorganismen und Zellkulturen (DSMZ), Dr. Lawson wanted to introduce these methods into his lab to benefit his own students and teaching programme. It is our intention to provide laboratories with an affordable alternative to international culture collection analysis. Out-sourcing some of these methods may help labs streamline their characterization and publication rates, relieving the pressure of maintaining these activities in their own labs.

As a graduate teaching assistant, I have taught twelve semesters of laboratory courses that range from the "Fundamentals of Microbiology" to the senior level

Figure 4. Invited hosts for the 17th International Biohydrometallurgy Symposium in Changsha, China

class "Capstone in Microbiology." My classroom leadership skills led to my being awarded the Provost's Overall Outstanding Teaching Assistant. Among other honors, I was chosen as an American Ambassador and Master of Ceremonies for the International Biohydrometallurgy Symposium in China (Figure 4), and have received the Lois Pfiester Award for Women in Science. Additionally, I have presented data at a number of national and international conferences, winning two first-place awards.

As a testament to my eagerness for discovery even outside of the laboratory, I have also identified and reported four previously unknown supernovae events, an asteroid, and a galaxy – but that is the story of another passion. Notably, I would have never found myself in Microbiology had it not been for my original love of Astronomy. There was a moment in college when I first looked down a microscope and became engrossed in these small organisms that could not be seen otherwise. Microscopes were just like telescopes, revealing an unseen world. There was nothing more thrilling than exploring various samples for living creatures that were impossibly small, yet capable of catalyzing the reactions/processes of the entire biological world. Thankfully, I found my life's passion, and it is the excitement of discovery that keeps me motivated. I love working hard to uncover things that no one knew before and to contribute to the understanding of life as we know it. Microbiology provides such a challenge, and the satisfaction in that struggle has been profound. As I continue to apply for jobs, I hope to find a career that continues to challenge my intellectual boundaries while enabling me to use my research experience to manage and mentor a team of scientists, establish the intellectual and research tone of a lab, and advance the agenda of industrial affiliations.

Editor's Note: Since writing this article, Niki has accepted a position as a post-doc at a microbiota transplantation laboratory in Europe.

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Life Under The Influence of Cultures

Lindsay I. Sly

I have never felt comfortable writing about myself. However, when my good friend and mentor Jim Staley pressed me to record my life as a bacterial systematist for historical purposes I acquiesced. I was honored and humbled that he would invite me and I apologize for the false starts. This story reflects on the people, events and opportunities that have influenced me and made a difference in my life, and hopefully helped me to make a difference in the lives and careers of others along the way. I have been very fortunate to share my life and career with so many wonderful people. The title of this article reflects on my career working with microbial cultures but also on the opportunities this brought to work with colleagues and students from so many different cultures and to travel and experience many of these cultures for myself.

Life, like systematic bacteriology, is punctuated by dichotomous decisions. I am not one to reflect too much on past decisions. However, writing this paper was cathartic and had me reflecting on "what if I'd made a different decision, what if I'd taken a different path?" I firmly believe that we make the right decisions each time and the only point in looking back is to appreciate your mentors and to learn by experience. The reality is that I never had a specific destination in mind when I set out on my life's journey in science but I did want to have a rewarding career, contribute to the community, and hopefully to make a difference for others following on behind me.

My journey can be broken down into small steps each with a goal and challenge in mind. Having said that, I am delighted with the final outcome and I am surprised at what I managed to achieve. Because my career path was somewhat unusual for a university academic, I never imagined that I could aspire to be a Professor until late in my career and thank my friend and colleague Peter O'Donoghue for his wise counsel. Over a 47-year period, I have traveled the path from student to Professor and technician to Head of Department, all in the one institution, the University of Queensland. While this was not a traditional path, it worked well for me. Over this period, the University of Queensland has undergone amazing development in facilities and achievements to become one of the top universities in Australia and in the top 50 worldwide.

I have witnessed and been part of many changes, outstanding progress and many successes during this period. There have also been some difficult times and dreams unfulfilled. Overall, I have been fortunate to have the opportunity of a career in which it was possible to discover something new each day, to interact with inspiring colleagues and students, to see new careers develop and prosper, to travel, to experience different cultures around the world, and to develop many life-long friendships. Throughout this time I have had the loving support of my wife Lynn and my family who have made many sacrifices for me along the way. It was wonderful that they also shared in the many enduring friendships made with students and colleagues.

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My Formative Years

So where did my journey begin? I was born two months premature on 2 October 1945 in Gladstone, Queensland in Australia-always eager to get off to a quick start! Since this was at the end of the Second World War, I became part of the "baby boomer" generation, which is now at retirement age. My elder brother Geoffrey was born at the beginning of that war in 1940. My younger brother David was born in 1948 and sadly, died in 2010. My father Allan, was an industrial chemist, and graduated in Agricultural Science from the University of Melbourne in 1937. He was born in Forbes in New South Wales where his parents had a 4000-acre sheep and wheat property before moving to Melbourne for his education. His first job after graduation was Head Chemist of the Maffra Sugar Beet Factory in Gippsland, Victoria, before he moved to Gladstone, Queensland, as the Head Chemist of the American-owned Swift Australia Meat Company. My mother, Heather (nee Mackay), was born in Mackay in Queensland and was a pediatric and infectious disease nursing sister and midwife at the Royal Brisbane Hospital before moving to Gladstone where she met and married my father in 1939.

You might say that I had the background and genes for an interest in science. My father instilled an interest in agriculture, botany, plant diseases, and food safety and preservation. My mother's graphic stories of hospital wards in the pre-vaccination era filled with children and adults suffering from polio, diphtheria, tetanus, and whooping cough sparked my interest in infectious diseases, reinforced particularly by images in the community of the consequences of polio. One of my friends bore the scar of a tracheotomy as a consequence of diphtheria and another class member died of tetanus. However, despite the same upbringing and influences, my two brothers became bank managers and successful businessmen. In 1952, the family moved from Gladstone to Brisbane following my father's appointment as Chief Chemist for Australia in the Swift Meat Company. He now had overall responsibility for chemical analysis and food quality in the Company's plants in Brisbane, Townsville, Maryborough and Melbourne. I very much enjoyed visiting the laboratory and watching him and his colleagues at work, and having him explain the methods and reasons for the tests being made. My school education commenced at the Gladstone State Primary School (1951-1952) for two years and then at the Yeronga State Primary School (1953-1959) in Brisbane. At that time, primary education consisted of the core subjects of English, mathematics, social studies including history and geography, and manual arts. I do not remember any formal teaching of science apart from mathematics, but the applied aspects of agriculture; health and engineering were covered in social studies. My first memory of an active interest in science was in primary school. On Saturday mornings the family would drive to the nearby Brisbane City Council library in Annerley to borrow the week's books. I have never been a great reader of fiction, preferring fact and utility. I became interested in the biographies of great scientists. I remember reading and re-reading the biographies of Louis Pasteur, Marie Curie, Edward Jenner, and Joseph Lister amongst others. I was fascinated with the research methodology and the excitement of scientific discovery and progress. I believe this reinforced and stimulated my innate interest in science and research. It was clear to me and to my parents that I would study science at secondary school.

My parents enrolled me at the Church of England Grammar School in Brisbane, which had excellent science laboratories and teachers. This was a classic education for this period consisting of English, foreign language (German in my case), mathematics, history, geography, chemistry and physics for the first two years (1960-1961). I was a solid, but not spectacular student. At this time I had maintained my interest in practical woodwork and metal work from primary school and even contemplated taking up a building trade. However, my teachers and parents strongly encouraged me to continue in science and I made the decision to do so – this was the first dichotomous choice that led me on my scientific journey. For my final two years, (1962-1963), I took English, mathematics, chemistry, physics, history and logic – ironically no biology was taught at this time, which might be seen as a disadvantage, but did not turn out to

be so. I took an extracurricular evening subject of geometric drawing and perspective at the Brisbane Technical College to allow me to also enter the engineering program at the university. I had begun to think about chemical engineering as a possible career. Discussions with my father and his industrial experiences had made me aware of large-scale fermentation processes that connected with my readings about Pasteur, microbiology and chemistry. This was a way for me to combine my interests in science and engineering and its applications.

Overall, my years at school were stimulating and enjoyable. I engaged in sport, mainly Australian football at primary school, and athletics, swimming and gymnastics at secondary school, but was not a star in any. I made many lifelong friends, but very few followed a career in science. In 1963, I gained my matriculation and entry to the University of Queensland. Thus began my 50-year association with the university to this day. By this time, I had begun to lose some confidence in my mathematical skills and in my second major decision decided against engineering and to follow a career in science.

The Skerman Era

In 1964, I enrolled in the Bachelor of Science program at the University of Queensland and took my first courses in biology. The science curriculum at that time was much more restricted and structured than it became later. There were compulsory prerequisites that needed to be passed before entry to higher-level courses that were recommended rather than obligatory later on, a mistake in my view that has largely been corrected. First year science subjects in my case consisted of chemistry, physics, mathematics and zoology. This was my first foray into biology, but the choice of subjects would allow me to pursue any one of these disciplines in the future. I passed all subjects but struggled with the mathematics, reinforcing the wisdom of my earlier decision not to pursue engineering as a career.

At the end of first year, I had to decide on the direction I would follow and the choice of majors for my science degree. This decision in many ways would determine my career path and was not to be taken lightly. I sought the advice of faculty members. I discussed the possibilities with my father and indicated that I was interested in microbiology. The next day, my father brought home his copy of the seventh edition of *Bergey's Manual of Determinative Bacteriology*. I still have this book on the shelf together with all the later editions of my own, and previous editions passed on by Professor Skerman. My father told me "I have met Professor Skerman at the Australian Institute of Agricultural Science meetings. He is well respected and doing very interesting work in bacteriology." He backed my decision to study microbiology, and I eagerly took his advice.

Having made my decision to study microbiology, the Faculty of Science prescribed my courses. My second university year in 1965 required me to take chemistry (inorganic, organic, and physical), biochemistry, microbiology, and an elective in botany. My third university year in 1966 required me to major in microbiology and minor in biochemistry to complete my Bachelor of Science degree. I still value this combination of subjects and recommend it to all budding microbiologists. Unless one has the background in chemistry and biochemistry including molecular biology in the current era, it is impossible to have a full understanding of microbes and their form, function and ecology. My only regret was not to have had an opportunity to study geology and mineralogy, which would have helped in my biogeochemical research later on. Of course, molecular biology was in its infancy when I began my studies. Watson and Crick had proposed the DNA double helix only a decade earlier and experimental research on the structure and function of DNA, RNA, and proteins was progressing rapidly. Bacterial genetics research was gathering pace, beginning to open the way to study the function of genes on which current modern genomics depended on, for so much annotation of the initial genomic sequences. Electron microscopy was developing rapidly giving new insights into the ultrastructure and function of prokaryotes and eukaryotes.

At this time and up until 1972, microbiology was

taught at the University of Queensland Medical School at Herston near the Royal Brisbane Hospital (conveniently near the Victoria Park golf course and club house), while other science subjects were taught at the main St. Lucia campus. Introductory second year Microbiology was taught on Thursday and Friday afternoons from 2-5 pm. Generally, the students in Microbiology II were comprised of those intending to major in microbiology and those who would take majors in chemistry, biochemistry or physiology. This meant that we would have lectures and laboratory practical classes at the St. Lucia campus until 1 pm and then have one hour to travel to the Medical School. I am not sure how the timetable programmers expected us to do this but we seemed to manage. A few of us had been able to obtain cars through vacation employment and we became the transport – I doubt public transport would have worked. I had an old Ford Prefect and later a Morris Mini into which we crammed five or so fellow students. The car had been baking in the tropical Queensland sun when we arrived at the car park in pre-air-conditioning days for the 10 Km journey to the Medical School at Herston, eating our molten sandwiches as we went. We arrived rather sweaty and tired, ready and prepared for 3 hours of intensive microbiology!

I first met Professor Vic Skerman in 1965. In truth our first face-to-face meeting was at the end of 1966 when I applied to undertake my Microbiology Honors course during the fourth year of my Bachelor of Science degree. In 1965, our meeting was between Professor and student. He entered the Mayne Lecture Theatre at the University of Queensland Medical School promptly at 2 pm and the first impression was of a man of large stature in a short white laboratory coat and booming voice - it was only later that we learned he was profoundly deaf and often had difficulty modulating his voice. Those of you who have interacted with him will recall this vividly. The Mayne Lecture Theatre was steeply tiered in the old style of university lecture theatres, with wooden bench seats and dark mahogany paneling. There was no Microsoft PowerPoint in those days, rather talk and chalk. Professor Skerman had embraced the Kodak slide carousel whole heartedly and entered the room with two full carousels, copies of differential tables and dichotomous keys for the taxonomic group of the day, and an attendant and a long wooden pointer. The attendant was dispatched to the projection booth high up at the back of the lecture theatre to operate the slide projector. Professor Skerman immediately turned the lecture theatre into complete darkness leaving it virtually impossible to read or take notes in legible handwriting. Although there was a remote control for advancing the slides, Professor Skerman preferred to communicate this instruction to the attendant (John Burke, Dick Freeland or Terry Pegg as I recall) by hitting the wooden pointer hard onto the top of the lecturer's demonstration desk and shouting "next slide," presumably in case the attendant misinterpreted the instruction with the pointer! I suspect that the real purpose of this behavior was more likely to keep us students awake and paying attention after the energy-sapping journey from St. Lucia to the Medical School. Every now and then, the bright lights would be turned on for him to write something on the blackboard in chalk, usually the name of an eminent international microbiologist, a meeting he had attended, or international committee he was on - then darkness again. Of course Professor Skerman's A *Guide to the Identification of the Genera of Bacteria* (Skerman, 1959) and the *Microbial World* of Roger Stanier, Michael Doudoroff and Edward Adelberg were the core resources for our theoretical and practical education in general microbiology and bacterial taxonomy, but Professor Skerman also drew heavily on the most recent taxonomic papers published in the research journals and in Bergey's Manual.

It is worth recalling that at this time in the early 1960s, the Department of Microbiology was in its infancy. Although to us students, it had a feeling of longevity, strength, international connection, vibrancy and collegiality. It is also important to dwell a while on the formation and ethos of the Department of Microbiology. The foundation period of the Department was 1948-1972. The first mention of the need for an independent Department of Bacteriology at the University of Queensland was in 1947. At this time bacteriology was taught in the Department of Pathology. The Faculty of Medicine considered a report from the Professor of Pathology to plan for staff to provide

teaching in general bacteriology for medical science and science students as well as to conduct professional courses for medical, dental, veterinary and agriculture students. In 1950, Vic Skerman was appointed Chief Lecturer in Bacteriology, but the Department of Bacteriology remained as part of the Department of Pathology. Skerman graduated with a Diploma of Agriculture from the Queensland Agriculture College at Lawes west of Brisbane in 1938, followed by a Bachelor of Agricultural Science from the University of Queensland in 1941. He began work as a bacteriologist at the Dairy Research Laboratories of the State Department of Agriculture and Stock before returning to complete an Honors Degree in Agriculture majoring in microbiology. He took up a Demonstrator (Practical Tutor) position in bacteriology at the University of Melbourne in 1944, rising quickly to Senior Lecturer by 1948. Now back at the University of Queensland, he continued to develop the Department of Bacteriology, which changed its name to the Department of Microbiology in 1961 and became a separate independent Department in 1962 with Vic Skerman the first Head and Professor of Microbiology.

Skerman was an innovator and reforming force in bacterial systematics and nomenclature. He had an enormous influence on my life, career and ambitions as my teacher, colleague and mentor over a period of 30 years (Figure 1). He left an enormous legacy for microbiology and bacterial systematics about which I have written before (Sly, 1995). Under his stewardship, the Department of Microbiology developed its broad teaching and research in microbiology, comprehensive theoretical and practical training, excellent staff and demand for graduates – but it was the research and reform in bacterial systematics led by Vic Skerman that earned the Department its international reputation during this period. Skerman told me that it was his experience with the parlous state of bacterial nomenclature, classification and identification he experienced during his work as a bacteriologist at the Dairy Research Institute which was the stimulus for his crusade to establish a better foundation for bacterial taxonomy and nomenclature.

As I mentioned before I digressed, Microbiology

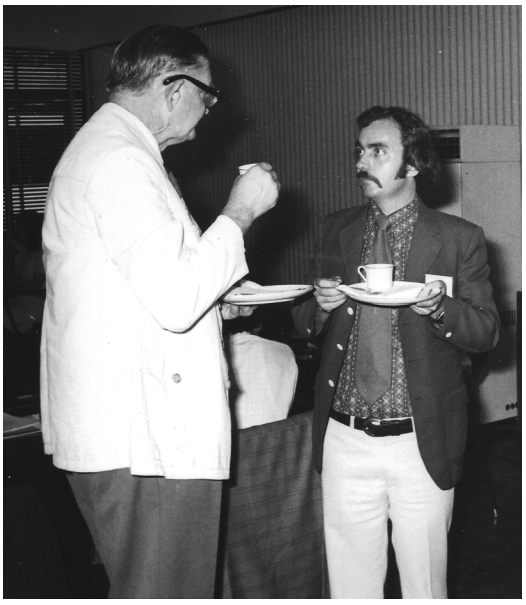

Figure 1. Vic Skerman (Left) and Lindsay I. Sly (Right) in typical discussion mode.

was taught on Thursday and Friday afternoons, each day having a one-hour lecture and a two-hour practical session. The curriculum consisted of general microbiology (bacteria, yeasts, filamentous fungi, algae and viruses) as well as introductory immunology and serology. As expected, the lectures and practical classes contained a significant amount of microbial diversity and taxonomy delivered by Vic Skerman, Chris Hayward (Plant Bacteriology), Gordon Davis (Medical Microbiology), Ian MacRae (Environmental and Soil Microbiology), and Horst Doelle (Microbial Metabolism and Industrial Microbiology). In addition, Animal Virology was taught by John Atherton, Plant Virology taught by David Teakle, and Immunology and Serology by Bill Halliday. The practical sessions taught the basic aseptic techniques, microscopy and stains, as well as important microbiological principles. In the context of this article, considerable time was given to taxonomic characterization, observation and interpretation of biochemical tests, and identification. Observing these characteristics and techniques to measure metabolic products to predict pathways and enzymes in diagnostic tests was illuminating to me linking microbiology, biochemistry and chemistry.

I could see the benefit of testing all strains against all tests in the context of numerical analysis pioneered by Peter Sneath and Robert Sokal. This

had been embraced in the teaching and research philosophy of the Skerman School. However, for many students reading numerous negative tests was a "turn-off." Students who went on to major in biochemistry, often mentioned that they found microbiology a descriptive and subjective science, and biochemistry by comparison a quantitative science which seemed more attractive at the time. To some extent this was true, but the tide was turning as we entered the era of numerical analysis, chemotaxonomy, and DNA analysis. Of course, DNA analysis at this time was generally confined to Mol % G + C base composition, but DNA-DNA and DNA-rRNA hybridization was emerging, and of course bacterial genetics was developing rapidly. At that time, we dreamed of the precision, objectivity, and power of bacterial phylogeny and identification delivered by DNA sequencing in the molecular biology era in the 1980s and beyond.

I thoroughly enjoyed my time as a student of microbiology and biochemistry. From the beginning, I had no doubt that I had made the right decision to pursue a career in microbiology. In fact, the lectures and laboratory sessions opened up a whole new universe of microbial biodiversity that I had not been aware of from previous studies. In particular, the range of energy sources and metabolic pathways available to microorganisms fascinated me. Especially bacteria that also included species later found to belong to the Archaea. The knowledge that nutrient cycles for carbon, nitrogen and sulfur included transformations solely undertaken by anaerobic bacteria, chemolithotrophic bacteria that derive energy from inorganic compounds such as hydrogen and ammonium, anaerobic photosynthetic bacteria, that could respire with alternate electron acceptors such as sulfate and nitrate in place of oxygen, and that bacteria could fix atmospheric nitrogen with and without symbiotic relationships was a revelation to me and inspired my future research. Suddenly, the importance of microorganisms in the nutrient cycles, the sustainability of ecosystems in the environment, agriculture, human, animal and plant health, industrial applications (now biotechnology) and waste treatment (now bioremediation) was opened up to me.

In my final year, we continued our studies in general microbiology, taxonomy, metabolism and immunology. In addition, we had the choice of specializing in elective courses in medical microbiology and animal virology, or industrial microbiology and plant virology – another dichotomous decision. I chose the latter combination as I continued to follow my interest in microbial diversity, environmental processes and ecology, and industrial applications. During my final undergraduate year, I undertook a small research project with Chris Hayward as supervisor, on the isolation of *Microcyclus* (now *Ancylobacter*) as I recall. This project opened my mind to research methodology and techniques and excited me about the prospect of further studies in microbiology leading to a career in research.

In 1967, I commenced my research career as a major part of my Honors degree year. I accepted a position in the laboratory of Horst Doelle to undertake a one-year project on the purification of glucose-6-phosphate dehydrogenase from *Zymomonas mobilis* and 6-phosphogluconate dehydrogenase from *Escherichia coli* which led to my first research publications (Sly and Doelle 1968a, 1968b), a very exciting moment. Suddenly, the opportunity to put theory into practice was available and I loved it. I had found my niche and flourished above all my personal expectations. To have this opportunity under Horst Doelle's supervision and in the company of like-minded Honors student Graham Fleet (later Professor of Food Science, University of New South Wales, Australia) and PhD candidate Graham Manderson (later academic in biotechnology, Massey University, New Zealand) was fantastic. In fact, the broader Honors year group of ten had a wonderful experience in a supportive collegiate Department and many of us made lifelong friendships not only with each other, but also with the academic, technical and administrative staff.

Horst Doelle provided us excellent supervisory support, but also the freedom to develop as independent research scientists, something I have always valued and encouraged in my students. Also during this year, I was offered and took up a tutor position to assist in microbial physiology,

metabolism and industrial microbiology laboratory classes for the following final year's undergraduate students – the student became the teacher. Having been mentored by excellent senior tutors Helen Griffin, Alan Mortimer and John Kennedy, tutoring proved to be a wonderful experience that inspired my lifelong desire to pass on my knowledge to the next generation of microbiologists.

In many respects, 1967 was a bittersweet year. Everything was working out perfectly, but in October as I was writing my research thesis, my father was diagnosed with lung cancer. I was devastated by this news. The mortality of my best friend and mentor was being challenged. Suddenly my studies seemed less important and I contemplated deferment. However, Horst Doelle offered his sagely advice and support and I completed my thesis and four three-hour examination papers to complete the year. On the brighter side of life, my loving wife and lifetime soul mate Lynn Brown and I began our life together. Lynn had majored in microbiology in 1966 with me, but in medical microbiology and animal virology, and completed a second major in parasitology while I completed my Honors year in 1967. Good news arrived at the end of 1967; Lynn graduated BSc with majors in Microbiology and Parasitology and I was awarded a BSc with First Class Honors in Microbiology, followed soon after by an Australian Postgraduate Scholarship to undertake an MSc or PhD.

Having experienced research in my Honors year, I was committed to a career in microbiological research – this was now my goal. I was harboring thoughts of undertaking a Master of Science degree for entry into the United States to undertake a PhD, hopefully in the Stanier School at the University of California, Berkeley. My good friend and laboratory colleague Graham Fleet was also setting out on this research path and secured a PhD position in the laboratory of Herman Phaff at the University of California, Davis. However, for me, there was an obstacle that had to be overcome. At that time of international turmoil, the Australian Government had introduced military conscription to support its efforts in various conflicts. However, the conscription was not for everyone, but for 20-year-old males who were selected from a national ballot. Well, in 1964, I won the prize. I was granted exemption to complete my BSc studies after which I would need to undertake two years army service and three years in the Reserve. Now that I had completed my studies, I sought to have an extension to allow me to study for a PhD overseas. I was advised I would not be granted a passport to leave Australia until I had completed my military service. However, having been granted an Australian Postgraduate Scholarship, I would be eligible for further exemption, subject to annual appraisal, to complete my PhD in Australia. This is what I decided to do as I was not sure I could come back to study again after such a long absence.

I commenced my PhD under the supervision of Horst Doelle on the Growth and Nutrition of *Moraxella* and *Acinetobacter* in 1968. I worked in a stimulating atmosphere in Horst Doelle's laboratory and the department as a whole with academic staff and postgraduate students undertaking excellent research. The department was acquiring state-of-the-art equipment. I continued to tutor practical classes with increasing responsibility for class administration. Sadly, my father died in October 1968. To this day, I miss our conversations on science and his support and keen interest in my progress.

Lynn and I were married in February 1969 and honeymooned on idyllic Lord Howe Island off the New South Wales Coast. Lynn's career in biochemical pathology was developing at Royal Brisbane Hospital and she was a great encouragement for me to complete my PhD research. By the middle of 1971, I had completed my laboratory bench work and was writing my thesis. In December that year, I was in the common room when I felt a tap on the shoulder from Vic Skerman who said "see me in my office when you're finished" – this was usually not a good omen. I approached his office wondering what I had done and what was in store for me. Instead, we had a friendly chat and then out of the blue, he offered me the position of Curator of the Department of Microbiology Culture Collection. The collection at this stage comprised about 400 diverse cultures used for teaching and research.

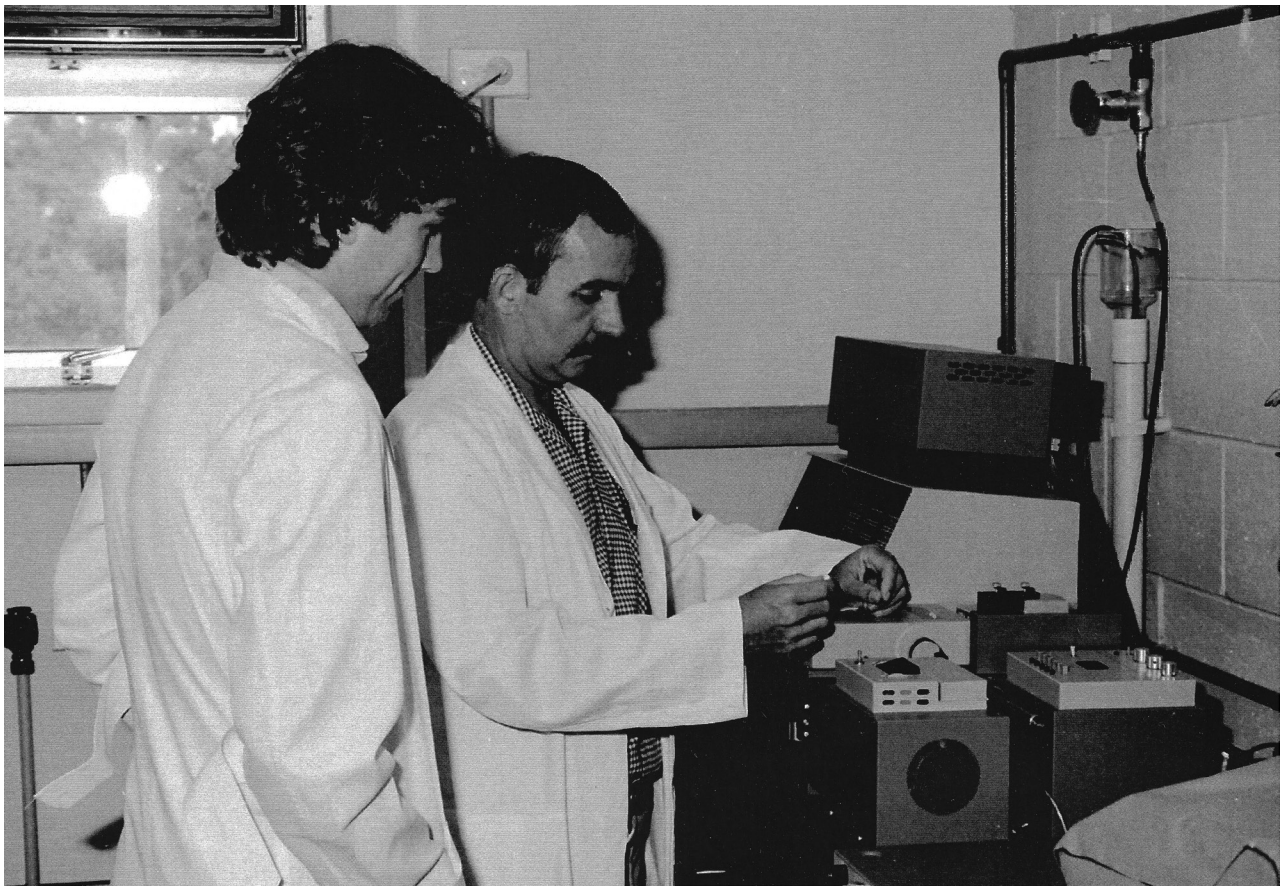

Figure 2. Lindsay I. Sly (right) demonstrating DNA analysis on the Gilford spectrophotometer.

My brief would be to develop a comprehensive collection representative of newly described species required for the Department's expanding taxonomic teaching and research as well as to develop facilities for chemotaxonomy and DNA analysis.

The department already had its own electron microscopy facility and I would concentrate on gas chromatography of metabolic end products, DNA base composition, and DNA hybridization for which a Gilford spectrophotometer (Figure 2) had been purchased. This was another key dichotomous decision; a once in a lifetime opportunity, and I commenced as Curator on 21 December 1971. A new full-time job would slow the writing of my thesis but provide an opportunity that would shape the direction of my future career. Now that I was working full-time, I was required to undertake a medical examination for national service. While taking care of this, there was a change of Federal Government and the new Prime Minister Gough Whitlam abolished national Service in 1972. National Service was to no longer influence my decisions but it had had a profound effect on the direction of my career.

The Department of Microbiology still shared the Medical School with the Department of Pathology. From the moment the department was established, Vic Skerman had embarked on a mission for more room and purloined space. Even corridors were used to house centrifuges and freezers, as well as polarographic equipment for measuring dissolved oxygen. The culture collection I took over in 1971 was housed in the old Medical School morgue. It is no wonder stories of strange events like the rattling old lift moving to another floor at midnight without anyone in it, and doors and windows closing without reason were often talked about by late-working research students. Eventually, the department outgrew its space at the Medical School and the rooms and laboratories were outdated for microbiology. The decision was then made for the department to move to the St. Lucia Campus. After a few false starts due to insufficient funds, a new building was built in 1972 and the department to

what is now the Skerman Building.

I completed writing my PhD thesis part-time in 1973 and was awarded the degree in 1974-the thirteenth PhD from the Department. Life was good but I was aware of Lynn's lust for travel, which continues to this day. Without the National Service restrictions, I was eligible for an Australian Passport. Lynn and I then took our first overseas trip in 1974 to the Philippines and Hong Kong. We had a most enjoyable experience which sparked a life-long desire to travel and experience different cultures. Unfortunately Lynn was not always able to travel with me to conferences due to family and work commitments and I always felt guilty about this. Fortunately, the opportunities for us to travel together improved over the years and we took advantage of this whenever possible.

At this time, I also had an urge to explore the possibility of taking up a postdoctoral position overseas to expand my scientific horizons and experience. I applied for a position with the Shell Company on research producing proteins from hydrocarbons at Sittingbourne in the United Kingdom, which looked promising until the research program was suddenly closed. This was very disappointing especially at a time when other opportunities were not forthcoming. I took the decision that I needed some certainty in my life with the prospect of developing my career in bacterial systematics. The department was one of the best places in the world at that time to undertake this research and it was an easy decision to stay in my current position.

The 1970s were vibrant and exciting times for the department. The new building was wonderful in comparison with the old Medical School laboratories. It was refreshing to be on the beautiful St. Lucia Campus with the other science departments. The collection had new facilities and with two assistant curators to support me, we were expanding the holdings of the collection and increasing involvement in taxonomic research. I commenced research collaborations, particularly with Vic Skerman until his retirement, and with Chris Hayward until now, as well as establishing my own independent research projects. Undergraduate student numbers were increasing, and the number of graduate students undertaking PhD studies was also rapidly increasing as the University developed into a research-intensive university.

The period spanning the 1970s and 1980s was a very active and productive one for bacterial systematics, nomenclature and culture collections within the Skerman group and around the world. The ambitions of Vic Skerman and like-minded microbiologists including Peter Sneath, Steven Lapage, Ed Lessell, Heinz Seeliger and Bill Clark to reform bacterial nomenclature were reaching the implementation stages. This work was underpinned by the considerable efforts of many taxonomic subcommittees of the International Committee for Systematic Bacteriology (ICSB) as well as individual taxonomists, but was not always without its critics. Vic Skerman realized early in his career that reform of bacterial nomenclature and removal of excessive synonymy would require working closely with the international organizations that drafted, reviewed and administered the rules. He also recognized that culture collections were an integral part of these reforms and he made significant contributions to the documentation of the World's culture collection resources and nomenclatural type cultures (Sneath and Skerman, 1966).

I was in awe of Vic Skerman's capacity to foster and drive these reforms with committees across the world, his tenacity, and the vast volumes of correspondence generated by his excellent and devoted secretarial staff. I learnt so much from his example and resolved to also make service to bacterial systematics and culture collections a high priority in my career. During this period, Vic Skerman was Chairman of the ICSB (1966-1978), a member of the Judicial Commission of the ICSB (1958-1982), Chairman of the Subcommittee on Numerical Taxonomy of the ICSB, a member of the Advisory Council of the International Association of Microbiological Societies (IAMS) (1962-1978), and Chairman of the IAMS Section on Culture Collections (1962-1970).

The reforms culminated in the publication of

the Approved Lists of Bacterial Names in 1980 (Skerman, McGowan and Sneath, 1980), and a new starting date for bacterial nomenclature from the beginning of 1981. Having been part of the group which helped to check and cross check names and strain numbers and proofread the manuscripts, I well remember the euphoria and relief when the issue of the IJSB was published and later when the bound copies of the Approved Lists arrived and were distributed. Getting to this point had taken a long period, and Peter Sneath, a close colleague in achieving the reforms, paid tribute to Skerman's vision and persistence over the period 1949 to 1981 to achieve the outcome (Sneath, 1986). Of course, getting to this point required several steps: the revision of the International Code of Nomenclature of Bacteria (1976 Revision) (Lapage, Sneath, Lessel, Skerman et al., 1975) to allow the changes; agreement on a new starting date for bacterial nomenclature; compilation of the Approved Lists of Bacterial Names; and establishment of the official procedures and rules for recording, publishing and validating new names, including the effective statutes of the ICSB and its Judicial Commission to avoid relapsing into the previous chaotic situation. It seems to me that the reforms leading to the removal of excessive synonymy and invalid names, including those without a type culture, were well received and hailed as a new fresh platform on which to build bacterial systematics. Of course, the changes were not free of criticisms and there were a few errors and names that had to be revived, but overall, it is remarkable how orderly the process went considering how contentious taxonomic opinion can be at times.

Also during this period, Vic Skerman had revitalized his taxonomic research. With a group of excellent PhD students, they set about to isolate and characterize a range of novel Australian fresh water bacteria. His group had considerable success using the Skerman micromanipulator (Skerman, 1967) and a dilute growth medium strategy. Use of the micromanipulator, which was one of Skerman's greatest technological innovations, allowed slow growing minority members of the population usually overgrown on standard nutrient media to be detected and isolated as single cell isolates. I worked closely with his and other research groups particularly on DNA analysis (Sly, Blackall, Kraat, Tian-Shen et al., 1986). Along with his students, I spent many hours working with him on his dual-head microscope to isolate novel bacteria by micromanipulation. I got a real appreciation of his keen observational skills of natural processes and microbial interactions. Sometimes he would move the microscope stage so quickly that you felt motion sickness!

Taxa studied by Vic Skerman and his graduate students included the myxobacteria with Keith McNeil (McNeil and Skerman, 1972), the *Azotobacteraceae* with John Thompson (Queensland Wheat Research Institute) (Thompson and Skerman, 1979), *Chitinophaga* and *Saprospira* with Vullapa Arunpairojana (later Thailand Institute for Scientific and Technological Research) (Sangkhobol and Skerman, 1981a, 1981b), *Herpetosiphon* and other sheathed bacteria with Gillian Quinn (Skerman, Quinn, Sly and Hardy, 1977, Quinn and Skerman, 1980a, 1980b). During these studies new Australian species were described including *Chitinophaga pinensis*, a new genus of gliding bacteria (Sangkhobol and Skerman, 1981a), *Conglomeromonas largomobilis* subsp. *largomobilis* (Skerman, Sly and Williamson, 1983), later found to belong to *Azospirillum* (Falk, Johnson, Baldani, Dobereiner et al., 1986; Ben Dekhil, Cahill, Stackerbrandt and Sly, 1997). A second subspecies *Conglomeromonas largomobilis* subsp. *parooensis* was later reclassified as the type species of *Skermanella*, *S. parooensis* (Sly and Stackebrandt, 1999).

Other novel species described by the Skerman group at this time include *Agitococcus lubricus*, a lipolytic twitching coccus from freshwater (Franzmann and Skerman, 1981), and *Gemmata obscuriglobus*, a new species of budding bacteria (Franzmann and Skerman, 1984) with Peter Franzmann (later University of Tasmania and CSIRO, Perth). The planctomycete *Gemmata obscuriglobus* has proven to be an interesting discovery. Later research carried out by John Fuerst's group in the department over a long period provided evidence that *G. obscuriglobus* has a compartmentalized cell structure including nucleoid DNA surrounded by a double membrane

Figure 3. Participants and teachers at a culture collection training course at the Department of Microbiology, University of Queensland in 1980. Front row: S. Bulong, E. Morales, Vic Skerman, S. H. Parsono, P. Foorakul; Second row: Vullapa Sangkhobol, Yue Jing-Zhu, H. Ahmed Mohamed, E. T. Cetin, R. de Torres, F. Karani, Horst Doelle, D. P. de Alwis, G. Wolf; Back row: Lindsay I. Sly, E. Brose, Chris Hayward, F. Azam, Peter Franzmann, A. McGregor.

envelope, analogous to the membrane-bounded nucleoid of eukaryotes. Thus *G. obscuriglobus* became a model bacterium for the study of prokaryotic - eukaryotic evolution (Lee, Webb and Fuerst, 2009). However, as often happens, new technology provides new insight and conflicting evidence. A recent study using 3D reconstruction of electron tomograms of *G. obscuriglobus* endomembranes concluded that the cells are not compartmentalized as the spaces formed by the membrane invaginations are not closed, but are interconnected. Thus, *G. obscuriglobus* appears to have a very complex form of a classical Gram-negative bacterial membrane system (Santarella-Mellwig, Pruggnaller, Roos, Mattaj, et al, 2013). I expect that there will be many more studies of this interesting model bacterium to unravel the mysteries of its properties and evolution.

This period in the 1970s and 1980s was also a golden age for microbial culture collection development worldwide, fostered by the World Federation for Culture Collections (WFCC) and supported by UNESCO, UNEP, ICRO and other organisations. The WFCC World Data Centre on Microorganisms (WDCM) was established in the Department and became UNESCO's first MIRCEN (Microbial Resources Centre) in a network that has expanded since around the world. With data input from culture collections in 65 countries, the first World Directory of Collections of Cultures of Microorganisms was published in 1972 (Martin and Skerman, 1972). Further updated editions were published in 1982 (McGowan and Skerman, 1982) and 1986 (McGowan and Skerman, 1986). In those days, compilation of this data was a mammoth effort. Not only was the data collected via paper questionnaires, the compilation and printing was done using computer punch cards and later punch tapes. Vicki McGowan, Lesley Bryant, Annette McLennan and information systems specialists Bill Leveret and Ian Holmes did a fantastic job producing

these directories which proved extremely valuable in laboratories and culture collections around the world for locating cultures and collections. Prior to Vic Skerman's retirement in 1986, we tried unsuccessfully to obtain funds from the Australian and Queensland governments to continue the operation of the WDCM within the department. Subsequently, the WFCC put the hosting of the WDCM up for international tender. We were very pleased to see the WDCM transferred to the RIKEN Institute in Japan, firstly under the directorship of Professor Kazuo Komagata, and subsequently under Professor Hideaki Sugawara at RIKEN and then at the National Institute of Genetics. Since 2011, the WDCM has been located at the Institute of Microbiology, Chinese Academy of Sciences (IMCAS) in Beijing, with Professor Juncai Ma as the Director. The WDCM has continued to develop and flourish and embrace new digital technologies. The latest initiative of a WFCC Global Catalogue of Microorganisms is an excellent development towards realizing the vision of Vic Skerman and colleagues when establishing the WDCM and publishing the first World Directory in 1972.

This was also a period where UNESCO was extremely influential in funding training courses to assist culture collection curators in developing countries with training in culture collection management, data organization and analysis, preservation by cryopreservation and freeze drying, and microbial taxonomy. These training courses were run in a local institution under the auspices of the WFCC and other organizations including ICRO and UNEP. Edgar Da Silva was a key supporter and driving force of these activities promoting UNESCO objectives in scientific training in developing countries and the importance of microorganisms in biodiversity and biotechnology.

Edgar and Vic Skerman as well as Horst Doelle had an excellent rapport over many years and their contributions were very significant. In 1975, we ran a UNESCO/UNEP/ICRO/WFCC training course in the department through the World Data Centre with the support of the Department and the University of Queensland. In fact most of the academic and technical staff of the Department were mobilized and contributed to running the training course. I continued to contribute to training courses for most of my career. We held a second training course in the World Data Centre in 1977 and a third in 1980 (Figure 3).

In 1976, I attended my first International Congress for Culture Collections (ICCC IV) in Bombay (now Mumbai), India. This was a fantastic experience for me to hear at first hand the latest developments in culture collections and to meet curators of international collections, but also to gain insight into the workings of the WFCC, its committees and objectives. During the Congress, Stephen Lapage, Head of the National Collection of Type Cultures in London asked me if I would consider editing a WFCC Newsletter. My acceptance was the catalyst that saw my involvement in the administration of the WFCC and its activities continuously over a period of 34 years.

The Post-Skerman Period

In 1981, Vic Skerman stepped down as Head of the Department. He had been appointed permanent Head in 1961, but by 1981 the concept of permanent heads at the University was nearing an end and the academic staff elected Heads usually for a period of five years. Dr John Atherton became the new Head, but Vic Skerman continued his research and as Director of the World Data Centre. I continued to work closely with Vic Skerman and his laboratory, but I now had also developed my own research programs in the collection. Also, during this time I was increasingly invited to give lectures in bacterial systematics to undergraduate students and to supervise research projects, along with Masters and PhD students. I embraced this opportunity as a transition to an academic position, which became my new goal. Vic Skerman retired as Professor of Microbiology in 1986 ending 36 years with the department. He harbored unfulfilled ambitions to continue research on the isolation of novel bacteria. Unfortunately he was not able to make progress before his untimely death in 1993, but he left a legacy of a strong department for which he is internationally recognized.

Meanwhile, my wife, Lynn had a career change in 1975, leaving her position in Biochemistry at the

Royal Brisbane Hospital Department of Pathology to return to microbiology. She took up positions at the University of Queensland tutoring medical students and Queensland University of Technology demonstrating to Medical Laboratory Science students in 1976. We built our family home in 1976 at Brookfield in the rural outskirts of Brisbane where we still live. Our first son Andrew was born in 1978, and Cameron in 1981, heralding a new, exciting and busy era of family life. Lynn took a break from full-time work until both boys were in primary school but continued with part-time tutoring at QUT. In 1989, she also began working in the laboratory designing experiments and preparing practical classes for Science and Medical Laboratory Science students. She was very happy being back working in microbiology. In 2001, Lynn retired from QUT ending a very enjoyable and rewarding career in biochemistry and microbiology spanning 34 years.

After Vic Skerman's retirement, the University was now looking to appoint a new Professor of Microbiology. Chris Hayward was Acting Head when Erko Stackebrandt was appointed and took up the position of Professor and Head of Department in 1990. I was delighted with this decision. I had greatly admired Erko Stackebrandt and his phylogenetic research, and in my view, he was the perfect person to take the department into the RNA era of bacterial phylogeny and taxonomy. At this time, the department had outgrown the Skerman Building, which we occupied in 1972. Planning and building of the Molecular Biosciences Building was well under way, and in 1991 the department moved to the new building that we shared with the Department of Biochemistry.

Erko Stackebrandt, of course, was a great supporter of the Collection. We moved to new purpose built facilities that housed the Collection and my expanded research laboratory. Erko and I together with Linda Blackall and John Fuerst established the Centre for Bacterial Diversity and Identification to foster research and postgraduate training in bacterial phylogeny, ecology and taxonomy. The collection became a fundamental resource for the Centre and was renamed the Australian Collection of Microorganisms in recognition of its standing and increasing service role in Australia. The ACM now had the most diverse collection of bacteria in Australia and was the major supplier of bacterial cultures to research, industry and education in Australia up until my retirement in 2010.

In 1992, the Faculty decided to fill the academic position in environmental microbiology vacated several years earlier by Ian MacRae when he retired. I saw this as an opportunity to move from the Professional to the Academic staff and to further my research and teaching career in this area. However, I was not successful, and my excellent long-term colleague Linda Blackall was appointed. Unexpectedly, I was delighted when the University decided to appoint me to a lectureship in bacterial systematics with continued responsibility for the culture collection. I gladly embraced this unique opportunity to meld my two passions of bacterial systematics and the culture collection. My new academic career and research strengthened, and the collection developed extensively during this period. I was promoted to Senior Lecturer in 1995, Reader (Associate Professor) in 2001, and Professor in 2008.

In 1993, Erko Stackebrandt returned to Germany as Head of the Deutsche Sammlung für Mikroorganismen und Zellkulturen in Braunschweig. He had a short but outstanding tenure at the department, and for me, those years were stimulating, opening up opportunities to introduce new molecular technologies into the collection, to collaborate in the description of new species, and to investigate the phylogeny of various groups using molecular techniques previously not available to me. I very much enjoyed our productive collaboration that continued afterwards and I was fortunate to undertake a very enjoyable sabbatical with Erko at DSMZ in 2008.

John Mackenzie replaced Erko Stackebrandt as Professor of Microbiology and Head of Department. In the 1990s, changes were afoot at the University to amalgamate departments to create schools of complementary departments. What was happening at various Universities around the world was the elimination of teaching duplication and competition for students between departments,

in order to encourage research collaboration and new initiatives. Of course, it was also to save costs by reducing the number of administrative centers. The teaching and research focus of the department was changing to align with cellular and molecular aspects of bacteriology and virology and with less emphasis on microbial ecology and systematics. In 1995, the Department of Parasitology elected to join the Department of Microbiology and we briefly became the Department of Microbiology and Parasitology. We squeezed into the same Molecular Biosciences Building. Due to budget pressures, there was restructuring in 1997 and I was informed that the department could no longer support the Culture Collection as taxonomic teaching. In addition, research had declined and most of the collection's services except for my research were directed outside the Department and the University. I was devastated by this decision. Everything I had worked for was under threat. The two excellent, dedicated and innovative assistant curators Susan Ben Dekhil and Kris Geerssen with a combined 12 years experience in the collection would be made redundant in two weeks – a very difficult time for them and myself. This was time for another key dichotomous choice in my life – I could take refuge in my academic life, or try to keep the collection going. I resolved that the reasons for the collection and its importance to bacterial diversity and taxonomy, and to the Australian microbiology community, were as important, if not more important, than when I set out on this journey. If the collection continued to operate, there was always the chance that a funding opportunity might arise. At this stage, we had built services provided to over 400 customers around Australia to the extent that the income paid for the maintenance of the collection and supported an Assistant Curator focused on service. From now on, the collection had to be focused on service and quality control, but new accessions ceased. The collection operated in this mode for the following 13 years until my retirement with the dedicated work of Lucy Rivas, Jenny Spratley, Marian Cahill and Kris Hilman. My research staff and students had always contributed greatly to the operation of the collection as well, and their commitment over this difficult period was appreciated even more.

In 2000, the reorganization of the University had reached a point where a new School of Molecular and Microbial Sciences was established combining the Department of Microbiology and Parasitology, the Department of Biochemistry, and the Department of Chemistry. Alastair McEwan was appointed Head of Department of Microbiology and Parasitology. In 2002, I became the last Head of the Department and in 2004 it was resolved that the University would no longer have departments. The School was renamed the School of Chemistry and Molecular Biosciences, and Microbiology became a discipline. Last year, the University celebrated the 50th anniversary of the formation of the Department of Microbiology. It was a nostalgic celebration of the history and achievements of the Department, but particularly of the vision, contributions and achievements of Vic Skerman.

My Teaching

As an academic, I was always mindful of the important responsibility I had for the education of the next generation(s) of scientists in microbiology. I taught at Levels 1, 2, 3, 4, 6, 7, and 8 with class sizes from 20 to 400, and at each level I tried to ensure that the course content prepared students for their next level of study and ultimately for their work as a scientist, chemical engineer, environmental engineer, agricultural scientist, physiotherapist, or biotechnologist.

Much of my teaching was in general microbiology dealing with microbial diversity and systematics, growth and nutrition, metabolism, microbial ecology, and biotechnology. It is always challenging to present some of this material in an interesting way that includes what I regard as minimal factual knowledge for progression to the next level and learning how this information is applied to solve problems or understand natural processes. I tried to emphasize learning in a global context which values the past, present and future discovery of scientific information. I believe it is essential for student learning to understand how discovery leads to current knowledge and how the educated mind will use this knowledge in the future for advances to be made.

Scientific education is not static and I have been involved in many changes in curriculum and teaching and learning methodology during my career as an academic. I have been part of the progression from talk and chalk both as student and teacher, through overhead projection, slides, to PowerPoint presentations. Students now expect PowerPoint presentations in advance of the lecture and for the lecture to be available by video afterwards – so much for taking notes by hand in the dark. I aimed to convey my enthusiasm for the study of microbial diversity, ecology and biotechnology to students at all levels and to instill an appreciation that the effective study of ecology, sustainability of ecosystem function, and biotechnology is dependent on a thorough knowledge of microbial diversity, accurate taxonomy, and accurate and rapid identification.

My Research

One of the most pleasing and rewarding aspects of academic research was the opportunity to train a group of outstanding graduate students. I was involved in the supervision of 35 research higher degree students undertaking MSc, MPhil and PhD degrees, and 45 Honors degree students in microbiology and biotechnology.

My research was concerned with exploring the microbial diversity of Australian environments, including its ecology, taxonomy, and biotechnological applications. The research focused on four areas: microbial ecology and environmental microbiology; microbial systematics and taxonomy; microbial biotechnology; and microbial diversity and conservation of microbial resources. My strategy was to run basic and applied research projects in parallel. I found that applied research raised fundamental questions that needed to be resolved before the applications could progress, and likewise that basic research opened opportunities for biotechnological applications. In the Australian research-funding environment it was not possible to have too narrow a focus in order to sustain the research program. However, it was my interest in bacterial diversity that underpinned all my research which was supported by a wide range of funding bodies including: the Australian Research Council, Horticulture Australia, Sugar Research and Development Corporation, Land and Water Resources Research and Development Corporation, Australian Water Research Advisory Committee, National Energy Resources Research and Development Corporation, Urban Water Research Association, Industrial Research Development Board, Commonwealth Scientific and Industrial Research Organization (CSIRO), Cooperative Research Centre (CRC) for Tropical Plant Pathology, Cooperative Research Centre (CRC) for Tropical Plant Protection, Cooperative Research Centre (CRC) for Water Quality and Treatment, and the University of Queensland.

A staff appraisal committee once told me that they were having difficulty determining my research specialty as I had research collaborators and students in so many different faculties including Science, Agriculture, Dentistry, Medicine and Engineering. I replied, tongue in cheek, that my specialty was my generality, but went on to explain that my research specialty of microbial systematics empowered me to study the microbial diversity and ecology of almost any environment where problems needed to be investigated or solved.

Funding of bacterial taxonomic research has never been a priority in Australia but I always tried to find a way to characterize and describe novel taxa discovered in our research. Student research projects were the best way to achieve this with the benefit of taxonomic training for the student as well. In my view, we have a responsibility to expand knowledge on microbial diversity and the most effective way to do this currently is to discover and describe novel taxa. Cultures are the unwritten intellectual property of a publication providing researchers the opportunity to extend knowledge in light of new discoveries or technologies, which in microbiology may not be possible based on the written word alone. Description of taxa and accession of type and reference cultures in permanent collections conserves our microbial heritage (Sly, 1986), enhances the value of the literature, and often catalyses research on the new taxon as other researchers connect their research to yours.

This ability to connect has become almost instantaneous since the availability of 16S rRNA gene sequences in public databases such as GenBank. I was sometimes criticized by reviewers of grant applications for working on esoteric species rather than well known species that somehow in their eyes were considered more important. However, in more than one case, descriptions of so-called esoteric bacteria have catalyzed research surrounding the newly described taxon. Examples described in collaborative research include the genus *Porphyrobacter* (Fuerst, Hawkins, Holmes, Sly et al., 1993) now with five additional species, and *Thauera* (Macy, Rech, Auling, Dorsch et al., 1993) with nine new species.

Microbial ecology and environmental microbiology.

This line of research was concerned with investigating the microbiology of various natural and industrial environments including agricultural soil, fresh and marine water, biofilms in drinking water distribution systems and bioreactors, agricultural crops and insect pests, and bioleaching environments.

Examples include an ecological investigation of manganese oxidation and deposition in drinking water distribution systems (Sly, Hodgkinson and Arunpairojana, 1990). During research with Vullapa Arunpairojana (nee Sangkhobol) and Mark Hodgkinson we discovered that a novel *Pedomicrobium* sp. was the major bacterium responsible for biological manganese oxidation and deposition in Australian drinking water distribution systems (Cox and Sly, 1997; Sly, Arunpairojana and Hodgkinson, 1988). Vullapa, a former PhD graduate of Vic Skerman, used micromanipulation to isolate the slow growing *Pedomicrobium* (Sly and Arunpairojana, 1987) from biofim and dirty water sediments. A further collaboration over many years with Eloise Larsen, Alastair McEwan, Justin Ridge and Maryanne Lin in my laboratory led to the discovery of the first metabolic functional gene in *Pedomicrobium* and showed that the *moxA* gene codes for a novel form of multi-copper oxidase which is essential for manganese oxidation and laccase-like activity (Larsen, Sly and McEwan, 1999; Ridge, Lin, Larsen, Fegan et al., 2007). Interestingly, Jim Staley while undertaking a sabbatical with Vic Skerman in 1978 observed the common occurrence of *Pedomicrobium* in Australian freshwater lakes (personal communication).

Research on the microbial ecology of the leaf sheath of sugarcane led to the discovery that the novel species *Gluconacetobacter sacchari* (Franke, Fegan, Hayward, Leonard et al., 1999) is an endophyte of sugarcane in Australia similar to its closest phylogenetic relative *Gluconacetobacter diazotrophicus* (Franke-Whittle, O'Shea, Leonard, Webb et al., 2005). This bacterium had previously been shown to be associated with the sap-sucking pink sugarcane mealy bug (Ashbolt and Inkerman, 1990) but our research in collaboration with Graham Leonard and Michael O'Shea (Bureau of Sugar Experiment Stations), and Ingrid Franke, Chris Hayward and Mark Fegan in my laboratory suggests that the mealy bug most likely acquires the bacterium by feeding on the sugarcane sap (Franke, Fegan, Hayward, Leonard et al., 2000; Franke-Whittle, O'Shea, Leonard and Sly et al., 2004; Franke-Whittle, O'Shea, Leonard and Sly, 2005; Franke-Whittle, O'Shea, Leonard, Webb et al., 2005).

In a collaboration with Dierdre Mikkelsen, Alastair McEwan and Ulrike Kappler (University of Queensland) and David Dew (BHP Billiton, South Africa) on the archaeal diversity and biochemistry of commercial hyperthermophilic chalcopyrite bioleaching reactor cultures it was shown that the microbial community was composed of Archaea belonging exclusively to the *Sulfolobales,* including phylotypes related to *Sulfolobus shibatae*, *Stygiolobus azoricus*, *Metallosphaera* sp. J1, *Acidianus infernus*, and a novel phylotype related to *Sulfurisphaera ohwakuensis* (Mikkelsen, Kappler, McEwan and Sly, 2006; Mikkelsen, Kappler, McEwan and Sly, 2009). The research also demonstrated for the first time that these hyperthermophilic archaea utilize both the 'contact' and 'non-contact' indirect mechanisms for the dissolution of pyritic ores, and that the role of the bioleaching microorganisms is thus to maintain sufficient levels of Fe^{3+} and acid during pyrite leaching for maximal mineral dissolution (Mikkelsen, Kappler, Webb, Rasch et al., 2007).

Microbial systematics and taxonomy.

This research was concerned primarily with the systematics of novel microorganisms from Australian environments, particularly water and soil, but also clinical and animal sources, isolated in the course of ecological studies, from collaborative studies, or sometimes referred to the collection for identification. We followed the principles of polyphasic taxonomy integrating phenotypic, biochemical, and molecular characteristics promoted by Rita Colwell (Colwell, 1970) that evolved over time to include emerging chemotaxonomic and phylogenetic features. In the course of this work, taxonomic revisions of existing taxa were sometimes found necessary and carried out. New genera described included *Blastomonas* (Sly, 1985; Sly and Cahill, 1997), a novel budding bacterium from fresh water; revival of the cellulolytic genus *Cellvibrio (*Winogradsky 1929, Blackall, Hayward and Sly, 1985) not included in the Approved Lists because of the absence of a type culture at that time; *Chrysiogenes* (Macy, Nunan, Hagen, Dixon et al., 1996), the type and only genus of the deep-branching order *Chrysiogenales; Delftia* (Wen, Fegan, Hayward, Chakraborty et al., 1999), a new genus of the *Comamonadaceae*; *Helicobacter* (Goodwin, Armstrong, Chilvers, Peters et al., 1989) to accommodate the transfer of *Campylobacter pylori* Marshall et al., 1985; *Lewinella* (Sly, Taghavi and Fegan, 1998), a new genus in the *Flexibacter-Bacteroides-Cytophaga* phylum for marine herpetosiphons (Lewin, 1970); *Methylobacter* (Bowman, Sly, Nichols and Hayward, 1993), a new genus of methanotrophs; the mulberry-like coccus *Morococcus* (Long, Sly, Pham and Davis, 1981) from a brain abscess; *Porphyrobacter* (Fuerst, Hawkins, Holmes, Sly et al., 1993), for aerobic chlorophyll-synthesizing budding bacteria from fresh water; *Skermanella* (Sly and Stackebrandt, 1999) for a sodium-sensitive, mixed-flagellated bacterium isolated from fresh waters by Vic Skerman; *Telluria* (Bowman, Sly, Hayward, Spiegel et al., 1993), a soil bacterium with the ability to degrade a variety of complex polysaccharides; and *Thauera* (Macy, Rech, Auling, Dorsch et al., 1993), a new member of the beta subclass of *Proteobacteria* with a novel type of anaerobic respiration.

New species described include *Azospirillum largomobile* (Ben Dekhil, Cahill, Stackebrandt and Sly, 1997) (transferred from *Conglomeromonas largomobilis* (Skerman, Sly and Williamson, 1983); *Blastomonas natatoria* (Sly and Cahill., 1997) (transferred from *Blastobacter natatorius* (Sly, 1985); *Cellvibrio mixtus* (Blackall, Hayward and Sly, 1985); *Chrysiogenes arsenatis* (Macy, Nunan, Hagen, Dixon, et al., 1996); *Gluconacetobacter sacchari* (Franke, Fegan, Hayward, Leonard et al., 1999); *Helicobacter muridarum* (Lee, Phillips, O'Rourke, Paster et al., 1992); *Helicobacter nemestrinae* (Bronsdon, Goodwin, Sly, Chilvers et al., 1991; Sly, Bronsdon, Bowman, Holmes et al., 1993); *Methylomonas aurantiaca* (Bowman, Sly, Cox and Hayward, 1990); *Methylomonas fodinarum* (Bowman, Sly, Cox, Hayward, 1990); *Morococcus cerebrosus* (Long, Sly, Pham and Davis, 1981); *Porphyrobacter neustonensis* (Fuerst, Hawkins, Holmes, Sly et al., 1993); *Skermanella parooensis* (Sly and Stackebrandt, 1999); *Streptococcus gallolyticus* (Osawa, Fujisawa and Sly, 1995); *Telluria mixta* and *Telluria chitinolytica* (Bowman, Sly and Hayward, 1988; Bowman, Sly, Hayward, Spiegel et al., 1993); *Thauera selenatis* (Macy, Rech, Auling, Dorsch et al., 1993).

Phylogenetic studies of bacteria belonging to the *Methylococcaceae* (Bowman, Sly and Stackebrandt, 1995), *Comamonadaceae* (Wen, Fegan, Hayward, Chakraborty et al., 1999), *Pedomicrobium* (Cox and Sly, 1997), *Gluconacetobacter* (Franke, Fegan, Hayward, Leonard et al., 1999), *Herpetosiphon* and *Lewinella* (Sly, Taghavi and Fegan, 1999), *Caulobacter, Asticcacaulis*, and *Brevundimonas* (Sly, Cahill, Majeed and Jones, 1997; Sly, Cox, and Beckenham, 1999), and *Ralstonia solanacearum* (Li, Dorsch, Del Dot, Sly et al., 1992; Li, Dorsch, Del Dot, Sly, et al., 1993; Taghavi, Hayward, Sly and Fegan, 1996; Fegan, Taghavi, Sly and Hayward, 1998) and *Chitinophaga* (Sly, Taghavi and Fegan, 1999) were also undertaken to resolve and strengthen taxonomic decisions.

I would like to acknowledge a number of important collaborations without which these taxonomic studies would not have been possible. As mentioned earlier, Chris Hayward (University of Queensland), for whom I have great admiration, taught bacterial

taxonomy and plant bacteriology in my first and second years in microbiology and supervised my first research project in my final undergraduate year. It was therefore very pleasing that after I was appointed as curator of the collection, Chris and I established a career-long collaboration. This collaboration later included our colleague Mark Fegan (Cooperative Research Center for Tropical Plant Pathology and Department of Microbiology) and Erko Stackebrandt (Department of Microbiology, University of Queensland). Mark Fegan and I had a very close and successful collaboration of joint research and student supervision. We shared a laboratory and had adjoining offices for many years. I will always be indebted to Mark for his contributions, support, humor and enduring friendship.

Research was involved with the study of microbial diversity in agricultural soils and the molecular phylogeny and development of molecular diagnostics for serious plant pathogenic bacteria including members of the *Ralstonia solanacearum* species complex (Fegan, Taghavi, Sly and Hayward, 1998), *Acidovorax avenae* with Aimin Wen (now at North Dakota State University) and *Xanthomonas arboricola* pv. *pruni* with Emma Ballard (Queensland Department of Primary Industries) (Ballard, Dietzgen, Sly, Gouk et al., 2011), as well as the ecology and taxonomy of *Gluconacetobacter sacchari* in sugarcane with Ingrid Franke (Franke, Fegan, Hayward, Leonard et al., 1999; Franke, Fegan, Hayward, Leonard et al., 2000; Franke-Whittle, O'Shea, Leonard and Sly, 2004; Franke-Whittle, O'Shea, Leonard and Sly, 2005; Franke-Whittle, O'Shea, Leonard, Webb et al., 2005) (now at University of Innsbruck), *Cellvibrio* with Linda Blackall (Blackall, Hayward and Sly, 1985) (now at Swinburne University of Technology), and dextran-utilizing bacteria (Hayward and Sly, 1976; Hayward and Sly, 1984; Blackall, Hayward and Sly, 1985).

Research made significant advances in clarifying the diversity and phylogeny of *Ralstonia solanacearum,* the family *Comamonadaceae* with Aimin Wen, and the family *Methylococcaceae* with John Bowman as mentioned earlier. John Bowman made a major contribution to the taxonomy of methanotrophic bacteria during his PhD research (Bowman, Skerratt, Nichols and Sly, 1991; Bowman, Sly, Cox and Hayward, 1990; Bowman, Sly and Hayward, 1991; Bowman, Sly, Nichols and Hayward, 1993; Bowman, Sly and Stackebrandt, 1995) and has since pursued an excellent career in the taxonomy and ecology of Antarctic bacteria and in establishing the Australian Collection of Antarctic Microorganisms at the University of Tasmania. His work has been internationally recognized and he is currently an Associate Editor of the International Journal of Systematic and Evolutionary Microbiology.

I also collaborated over a number of years with my colleague John Fuerst (Department of Microbiology, University of Queensland) on the taxonomy and ecology of various bacteria from fresh water including *Legionella* with PhD student Simon Toze (now with CSIRO) (Toze, Sly, Mac Rae and Fuerst, 1990; Toze, Sly, Hayward and Fuerst, 1993; Toze, Cahill, Sly and Fuerst, 1994), and research on the aerobic bacteriochlorophyll-synthesizing bacteria belonging to *Porphyrobacter* which John led. I unknowingly described the first strain of *Porphyrobacter* as an unidentified budding bacterium at the same time as *Blastomonas natatoria* (Sly and Hargreaves, 1984; Sly, 1985; Sly and Cahill, 1997). John Fuerst and his research group went on to isolate more strains and the new genus and species *Porphyrobacter neustonensis* were described (Fuerst, Hawkins, Holmes, Sly et al., 1993). Interestingly, *Blastomonas natatoria* was later also found to be an aerobic photosynthetic bacterium (Hiraishi, Kuraishi and Kawahara, 2000). A proposal was made to include *Blastomonas natatoria* in the genus *Sphingomonas* (Yabuuchi, Kosako, Naka, Suzuki et al., 1999), but there is strong phenotypic, chemotaxonomic and phylogenetic evidence that *Blastomonas* is distinct from *Sphingomonas* (Hiraishi, Kuraishi and Kawahara, 2000).

I have had a productive and enjoyable collaboration on the taxonomy and phylogeny of novel Australian bacteria with my friend and colleague Erko Stackebrandt beginning at the University of Queensland and continuing when he later moved to the Deutsche Sammlung für Mikroorganismen und Zellkulturen in Braunschweig. I will be forever grateful to Erko and his laboratory for helping my

laboratory and I move from the DNA era to the RNA era of bacterial systematics. This research was often interwoven with my collaborations with Chris Hayward, Mark Fegan, John Fuerst and Joan Macy. Key outcomes of this collaboration were phylogenetic studies of the *Methylococcaceae* including the recognition and description of the genus *Methylomicrobium* (Bowman, Sly and Stackebrandt, 1995), and those which led to the description of the species *Telluria mixta* and *Telluria chitinolytica* (Bowman, Sly and Hayward, 1988; Bowman, Sly, Hayward, Spiegel et al., 1993); *Gluconoacetobacter sacchari* (Franke, Fegan, Hayward, Leonard et al., 1999); *Porphyrobacter neustonensis* (Fuerst, Hawkins, Holmes, Sly et al., 1993); *Skermanella parooensis* (Sly and Stackebrandt, 1999); and *Thauera selenatis* (Macy, Rech, Auling, Dorsch et al., 1993).

I was very fortunate to collaborate briefly with the late Joan Macy (UC Davis and Latrobe University, Melbourne) and Joanne Santini (Latrobe University) on the phylogeny, physiology and biochemistry of novel environmental bacteria. Joan was a wonderful person with an infectious enthusiasm for bacterial diversity and bioremediation. My contribution to the collaboration was in the area of molecular taxonomy, but it was Joan who drove the isolation and biochemical investigation of a number of bacteria with novel biochemistries, often from harsh mining environments. The genus *Chrysiogenes* was shown to belong to a novel deep branching phylum *Chrysiogenetes* of the Domain Bacteria and remains the only known member of the order *Chrysiogenales*. The type species *Chrysiogenes arsenatis* is an arsenate-respiring bacterium isolated from gold mine wastewater (Macy, Nunan, Hagen, Dixon et al., 1996). The description of the genus *Thauera* stimulated international research which resulted in the description of a further nine species to date with some showing remarkable ability to utilize aromatic hydrocarbons under anoxic conditions via unique pathways. The type species *Thauera selenatis* possesses a unique mechanism for anaerobic respiration that allows it to use selenate as an electron acceptor without interference by nitrate (Macy, Rech, Auling, Dorsch et al., 1993). Other research with Joan Macy involved phylogenetic studies of new arsenite-oxidizing chemolithotrophic α-*Proteobacteria* isolated from Australian gold mining environments (Santini, Sly, Schnagl and Macy, 2000; Santini, Sly, Wen, Comrie et al., 2002) and a strain of *Desulfomicrobium* sp. which rapidly reduced arsenate at the same time it reduced sulfate (Macy, Santini, Pauling, O'Neill et al., 2000).

I collaborated with Stewart Goodwin (University of Western Australia) on the taxonomy of *Helicobacter*. Stewart led this research and my contribution was in the area of molecular taxonomy and the genus and species descriptions. This research obtained the evidence to erect the new genus *Helicobacter* (Goodwin, Armstrong, Chilvers, Peters et al., 1989) for the gastric and peptic ulcer causing bacterium *Campylobacter pylori* that had been isolated and described by Barry Marshall and Robin Warren (Marshall and Warren, 1984; Marshall, Royce, Annear, Goodwin et al., 1984). This collaboration also led to the description of *Helicobacter nemestrinae* found in the stomach of a pigtailed macaque (*Macaca nemestrina*) (Bronsdon, Goodwin, Sly, Chilvers et al., 1991; Sly, Bronsdon, Bowman, Holmes et al., 1993) which some workers now consider a strain of *H. pylori*. During the same period, I collaborated with Adrian Lee at the University of New South Wales who was isolating novel strains of *Helicobacter* from various animals, which led to the description of *Helicobacter muridarum* from the intestinal mucosa of rodents (Lee, Phillips, O'Rourke, Paster, et al., 1992).

I also had an interesting collaboration with Ro Osawa who was isolating and describing tannin-protein degrading *Streptococcus* sp. in the faeces of various native animals including the Australian Koala (Osawa and Sly, 1991; Osawa and Sly, 1992) while he was working at the Lone Pine Sanctuary in Brisbane. This work resulted in the description of the gallate-degrading bacterium *Streptococcus gallolyticus* formerly assigned to *Streptococcus bovis* (Osawa, Fujisawa and Sly, 1995; Sly, Cahill, Osawa and Fujisawa, 1997).

Applied microbial ecology and biotechnology.

This area of my research was concerned with investigation of industrial problems using ecological techniques, and the development of biotechnologies to solve major industrial problems using bacterial diversity studied in our basic taxonomic and ecological studies. Much of this research is buried in reports, but wherever possible we published the results.

Examples of highlights include the determination of the factors which cause and control manganese oxidation and deposition in drinking water distribution systems that leads to manganese-related dirty water with substantial economic loss (Sly, Hodgkinson and Arunpairojana, 1990). The research showed that manganese deposition occurred by both chemical and microbial processes. Chemical deposition occurred when Mn(II) not removed during water treatment penetrated the filters and entered the distribution system, where it was oxidized by chlorine and chlorine dioxide used for disinfection. Microbial oxidation and deposition occurred in areas with insufficient chlorination to control the growth of manganese-depositing biofilm. This research also showed that water velocity significantly influences the nature and physiological activity of the biofilm during early development and colonization. Biofilm developed at a velocity of 0.5 m s^{-1} actively oxidized and deposited manganese, but at 0.01 m s^{-1} no manganese was deposited Sly, Hodgkinson and Arunpairojana, 1988). The budding bacterium *Pedomicrobium* was the dominant microorganism observed depositing manganese but a variety of other organisms and morphotypes of *"Metallogenium"* were also present in the biofilms (Sly, Arunpairojana and Hodgkinson, 1988). This work led to the adoption of a new guideline level of 0.01 mg manganese per liter by many water authorities in Australia to control Mn deposition and manganese-related dirty water. The research was conducted through a very enjoyable long-term multidisciplinary collaboration with David Dixon (Surface Chemist, CSIRO and University of Melbourne), Barry Chiswell (Analytical Chemist, University of Queensland), and Geoff Hamilton (Water Treatment Engineer, Gold Coast City Council and GH Consultant Engineers). During research with Vullapa Arunpairojana (nee Sangkhobol) and Mark Hodgkinson we discovered that a novel *Pedomicrobium* sp. was the major culturable bacterium responsible for biological manganese oxidation and deposition in Australian drinking water distribution systems (Sly and Arunpairojana, 1987; Sly, Arunpairojana and Hodgkinson, 1988; Cox and Sly, 1997) and that the extracellular polysaccharides of *Pedomicrobium* are able to bind colloidal MnO_2 as well as Mn(II) which it oxidises (Sly, Arunpairojana and Dixon, 1990).

Biotechnological research, which developed from our investigation of manganese oxidation in drinking water distribution systems, was the development of a fluidized bioreactor for the oxidation and removal of manganese using *Pedomicrobium* immobilized on small magnetite particles (Sly, Arunpairojana and Dixon, 1993). Our observation that *Pedomicrobium* biofilms were able to withstand high fluid velocities in water distribution pipes (Sly, Hodgkinson and Arunpairojana, 1988) and that microbial cells strongly adsorbed to magnetite (MacRae and Evans, 1983) formed the basis of this novel biotechnology (Sly, Arunpairojana and Dixon, 1995). We also undertook a number of successful small and large-scale pilot plant trials of this process but so far it has not been commercialized. Eloise Larsen also undertook a pilot plant trial to use this technology to successfully remove radionuclides from a uranium mine retention pond (Martin, Larsen, Dixon and Sly, 2004), which showed promise for polishing the water before discharge. The manganese oxide formed continuously by the *Pedomicrobium* is used to bind the radionuclides and remove them from solution.

In parallel with our basic taxonomic research on methanotrophs, we undertook with John Anderson (Department of Mining Engineering, University of Queensland) the development of a continuous trickling biofilter for the removal of methane from coal mine atmospheres using a biofilm of *Methylomonas fodinarum* isolated from a coal mine (Sly, Bryant, Cox and Anderson, 1993). While the rate of methane removal was too slow for an industrial application due to the low solubility and low concentration of methane, the principle

has continued to attract interest for the removal of methane where physicochemical removal of this important greenhouse gas and other gases is impractical or too expensive.

Our research on the microbial diversity of various bioleaching environments discussed earlier also resulted in a better understanding of the microbiology of thermophilic bioleaching environments as well as development of the molecular diagnostic tools to monitor the presence of the species present (De Wulf-Durand, Bryant, and Sly, 1997; Mikkelsen, Kappler, McEwan and Sly, 2009).

Microbial diversity and conservation of microbial resources.

This area of my research was centered around my responsibilities as Director of the Australian Collection of Microorganisms, Co-Director of the UNESCO MIRCEN with Horst Doelle, and foundation coordinator of the Australian Microbial Resources Research Network (AMRRN) (Sly, 2004). This work involved assessment of Australian microbial diversity and culture collection infrastructure in Australia (Sly, 1998) and proposals for facilities needed to support microbiology, industry and education in Australia (Sly, 2003; Sly, 2008; Sly, 2010). This material was used to establish and develop the Australian Microbial Resources Information Network (AMRiN) (Sly, 2006). The website fosters collaboration between taxonomic researchers, culture collection resources, and scientists for applications in biodiscovery, biotechnology, research, industry, and education and will become the data aggregation hub for Australian collections of microorganisms in the on-line Atlas of Living Australia for access to data in collections of animals, plants and microorganisms (http://www.ala.org.au).

Finally, I would like to pay tribute to my research staff and graduate students. The 100 or more, who worked in my laboratory, came from more than 20 countries and enriched the cultural experience of the laboratory - Friday morning teas became an institution of ethnic cooking delights. Clearly it is not possible to name them all and it is fraught with danger to name but a few in case of offending. However, I would like to make special mention of the contributions made by postdoctoral research fellows Vullapa Arunpairojana, Justice Baiano, Pascale De Wulf-Durand, Mark Fegan, Ingrid Franke, Tim Hurse and Justin Ridge for their outstanding research and project supervision in the laboratory; research assistants Susan Ben Dekhil, Kris Geerssen, Lalette Bryant, and Marian Cahill for their major contributions over a long period; and graduate students John Bowman, Tracy Cox, Ingrid Franke, Eloise Larsen, Deirdre Mikkelsen, Mohsen Taghavi and Aimin Wen who contributed to many research publications coming from my laboratory. I would also like to thank Rick Webb, John Hardy, Tony Macgregor and Jane Westcott for their outstanding electron microscopy, Anthony Fowler for his computer and technical equipment skills, instrument makers Bob McCorquodale, Tom Chun and Steve Bradic for their outstanding skills constructing specialist equipment, and Gerda Wolf, Miriam Camilleri and Lucy Brancato for excellent media preparation which helped me and the laboratory over a long period of time.

Giving back

I have been so fortunate during my career to be guided and supported by so many wonderful teachers and colleagues who have willingly taught me, shared their knowledge and mentored me to achieve my goals. These experiences inspired me to give back to the community that enabled me to achieve my goals. This is why teaching and training was always a significant and rewarding part of my life, passing knowledge and skills onto the next generation of scientists. Following Vic Skerman's example I became involved in international activities early in my career and carried it through until now.

As soon as I graduated I became a member of the Australian Society for Microbiology and served on the committee of the Queensland Branch in a number of capacities including Branch Chair (1986), and helping to organize national scientific meetings in 1972, 1976 and 1983 in Brisbane. At the national level I was foundation Chair of the ASM Culture Collection Special Interest Group (1981-1986),

Figure 4. At the opening of the ICCC 9 Ninth International Congress for Culture Collections held in Brisbane in 2000. (From left) Vanderlei Canhos, Makoto Watanabe, Erko Stackebrandt, Dagmar Fritze, Lindsay Sly, Jean Swings and Ipek Kurtböke.

which was proactive in fostering the interests of collections and training through symposia and workshops on microbial preservation, quality control cultures, quarantine compliance and culture collection management. After Vic Skerman stood down, I became the Australian representative on the IUMS International Committee on Systematic Bacteriology (1981-1993), and served as Vice-Chair (1994-1999). I was honored to be appointed an Associate Editor of the International Journal of Systematic and Evolutionary Microbiology during 1999-2004. Regrettably, I found this a difficult task due to various work pressures. Compared to many of my colleagues, I am a relatively slow reader and writer and was overwhelmed by the quantity of papers to deal with. To all those who suffered from my slow reviews, I take this opportunity to apologize.

In 1992 following the signing of the Convention on Biodiversity in Rio there was growing concern amongst microbiologists that microorganisms were rarely mentioned in the Convention despite their importance in sustaining the global environment and for valuable pharmaceuticals and other biotechnologies. I became a member of the IUBS/IUMS International Committee on Microbial Diversity (1993-2000) with Rita Colwell and David Hawksworth and prepared material (Sly, 1994) for presentation to the parties to the convention to raise awareness. Likewise the efforts of Vanderlei Canhos, Barbara Kirsop, David Smith and Dagmar Fritze amongst many others were significant in raising the awareness of the role of collections in the conservation of microorganisms and their value for biotechnological applications. I was also a co-convener with my good colleagues Jim Staley and Erko Stackebrandt of the Scientific Program on Microbial Diversity and Conservation for the ICSU/IUBS/IUMS/SCOPE/UNESCO DIVERSITAS International Program of Biodiversity Science and International Biodiversity Observation Year (IBOY) (1999-2001) to communicate the importance of biodiversity to the earth's ecosystems to a broad audience.

I am very proud of my long association since 1975 with the World Federation for Culture Collections (WFCC). The WFCC evolved from the IAMS Section on Culture Collections and is a Multidisciplinary Commission of the International Union of Biological Sciences (IUBS) and a Federation within the International Union of Microbiological Societies (IUMS). The WFCC is the umbrella organization

for the world's microbial culture collections and fosters the collection, authentication, maintenance and distribution of cultures of microorganisms and cultured cells for science, industry and education. It was very rewarding to be involved with so many dedicated and progressive culture collection curators with a vision for the future of collections and their important global role in microbial diversity, taxonomy and conservation; patent cultures and commercialization; biosafety and biosecurity. I was very proud to be chosen by my peers to be WFCC President for the period 1992-1996, and served on various committees for the Executive Board and in various capacities over the period 1976-2000. I was honored to be Chair of the World Data Centre for Microorganisms Steering Committee 1988-1992 and 1996-2000 following its move from the University of Queensland to Japan. I was particularly pleased to host the WFCC Ninth International Congress for Culture Collections (ICCC 9) in Brisbane in 2000 (Figure 4). Information exchange and training is central to the ethos of the WFCC and it should be no surprise that we ran three training courses during ICCC-9 on culture collection management, cryopreservation and IATA regulations for shipping infectious cultures. Following the training courses in the World Data Centre organized by Vic Skerman, I contributed to the ASEAN Workshop on Culture Collections in Bangkok (1977), and coordinated the UNESCO/UNEP/ICRO/WFCC Training Course in Cairo in 1980. Following these there were the UNESCO/WFCC/ICY/TISTR Training Course on Yeasts: their identification, preservation and use in biotechnology, Bangkok (1984), Australian Society for Microbiology Training course, Perth (1985), WFCC Training Course on the use of computers in culture collections, Beijing (1992). I found these training courses wonderfully rewarding and genuinely appreciated. They fulfilled my lifelong desire to pass on my knowledge to others. I met so many wonderful people both participants and teachers, many of whom became close life-long friends. In particular, Ivan Bousefield, Vanderlei Canhos, Dieter Claus, Rita Colwell, Horst Doelle, Dagmar Fritze, Peter Green, Chris Hayward, Barbara Kirsop, Kuzuo Komagata, Micah Krichevsky, Agnes Onions, Christine Rhode, Hideaki Sugawara, and David Smith deserve special mentioned for their prolonged contributions to the training courses that I have been involved with.

Retirement and Beyond

For me retirement is an opportunity to rebalance the pressures and demands of life, a time for reallocation of priorities. Science and microbiology will always be an important part of who I am, but now in an honorary capacity. Lynn retired from the QUT in 2002 after 26 years and was looking forward to my retirement. We are travelling more and I have returned to the golf course enjoying the exercise and friendship with fellow veteran golfers. We are very proud of our sons and their achievements. Andrew graduated with a Bachelor of Arts in geographical sciences and planning from the University of Queensland and is currently working as a Senior Development Manager with the Queensland Government, and Cameron graduated with a Bachelor of Surveying from the Queensland University of Technology and is currently working as a Surveyor Manager for Landpartners built-environment consultants. The boys are well settled and have wonderful partners who we are very proud to have as part of our family.

I always knew I would retire in 2010, the year of my 65th birthday (Figure 5). For some curious reason academic staff of the University of Queensland appointed before 1994 were excluded from the age discrimination laws and therefore had a mandatory

Figure 5. At my retirement with my wife Lynn in 2010.

retirement age of 65. In preparation, my research and postgraduate supervision was tapering down, but the collection was still performing well supplying cultures to around 400 laboratories in Australia. I was taken by surprise in late 2009 when required to vacate the purpose built collection facilities and research laboratory and move to a smaller laboratory which could not support collection activities. The timing was unfortunate, as I had not finalized a plan for the succession of the collection. The thought of spending my last year relocating and closing my laboratory and the collection twice did not excite me as a fitting way to end my career – in my final dichotomous decision I decided to retire a little early in January 2010.

Looking back I feel satisfied with my achievements, although there are always loose ends, unfinished lines of research, and things I could have done better with hindsight. It is difficult to suddenly switch off the research button in retirement, but thoughts of unfinished research and manuscripts needing one more experiment for publication mellow as other interests and priorities take over. In many ways I was prepared and ready to retire. I do not miss the grant writing, milestone reports and onerous regulatory compliance, but I do miss the people and the excitement of scientific discovery – the Eureka moments!

One passion, which has not diminished in retirement, is culture collections in Australia. My vision of a network of well-supported national microbial culture collections in Australia remains unfulfilled and will always disappoint. I wrote soon after my appointment as curator of the need in Australia for a national policy and support for microbial collections to conserve our microbial biodiversity and to underpin advances in research, industry, and education (Sly, 1978). Others and I have continued to argue this need to many national infrastructure reviews right up until now. While various reviews and government agencies support the need, funding success has not followed. The decline in the teaching of taxonomy in Australian universities is a worry shared by many; so many functions of government and industrial compliance depends on sound taxonomy yet the realization has not yet dawned. I believe that the model we adopted for the training of graduate taxonomists within the culture collection provided synergies for the collection, research outcomes, and training. Within a decade there will be insufficient taxonomists remaining to train new taxonomists.

Regrettably, I was also unable to put the ACM on an independent sustainable financial basis and therefore the important service provided to Australian microbiologists has been sadly lost. However, the collection is in safe hands with Rob Capon at the Institute of Molecular Biosciences at the University and will continue to be used by him as a research collection for biodiscovery, and for genomic studies in the Australian Centre for Ecogenomics headed by Phil Hugenhholtz. Plans are underway to secure funds for the continued maintenance of the collection but it is very unlikely that the sales and services I carried out for nearly 40 years will return in the absence of specific funding and facilities. One big change I have noticed over my career is the shift in the way some of the major service collections now operate which makes it most unlikely that a sustainable service collection can operate in Australia – the opportunity has been lost. The change has largely been driven by financial pressures but is inexorably linked to the designation of reference and quality control cultures in standard methods of analysis and the inflexible interpretation of these by accreditation bodies. Since the 1980s, collections have increasingly been required to recover more of their operating costs and with this came tighter restrictions on distribution and re-sale by other collections. While researchers have looked to collections as custodians of the cultures deposited from their research, the economic imperative has seen an increasing shift in attitude towards ownership of the cultures by some collections.

I would like to pay a special tribute to the Assistant Curators who shared my vision for the Australian Collection of Microorganisms. I especially thank Susan Ben Dekhil, Marianne Cahill, Kris Geerssen, Dawn Grassick, Jenny Heatley, Kris Hilman, Kris Kastrissios, Lucy Rivas and Jenny Spratley who were in charge of the operation of the collection at various times. They were such dedicated and supportive colleagues who helped me so much and

Figure 6. Receiving the WFCC Medal at ICCC 12 in Brazil with other recent Presidents. (from left) David Smith, United Kingdom (2004-2010); Lindsay Sly, Australia (1992-1996); Philippe Desmeth, Belgium (2010-2013) and Vanderlei Canhos, Brazil (1996-2000).

assisted somany microbiologists around Australia providing cultures and information, importing cultures, as well as identification and undertaking freeze-drying.

In 2010 after my retirement we held the first ever meeting of microbial collection curators and heads in Australia and formed the Council of Heads of Australian Collections of Microorganisms (CHACM). For the first time in Australia microbial collections have a united voice. CHACM is a partner in the Atlas of Living Australia (ALA) project (http://www.ala.org.au) aiming to establish the infrastructure to electronically link the databases of Australia's animal, plant and microbial collections to provide access to data, and the tools for analysis. The Australian Microbial Resources Information Network (AMRiN) website (http://amrin.org) which I established at the University of Queensland will be updated and moved to the Atlas shortly and become the data aggregation hub for microbial collections in Australia. Currently 31 microbial collections are involved in the project – seven have already provided their data and the number is steadily increasing. Funding is definitely required for the curation and maintenance of collections, but the recognition by government of the importance of microbial collection data is a very important first step towards the necessary national support we have been seeking.

My expectation when setting out on my career was to have an enjoyable and productive career in microbiology and to try to make a difference in microbial culture collections and bacterial taxonomy. I have never sought accolades, rather preferring to fly under the radar, and be quietly assertive in realizing my goals. It is up to others to judge my contributions and it was therefore very pleasing to be awarded a Fellow of the Australian Society for Microbiology in 1989, Fellow of the Australian Institute of Biology in 1992, and a Fellow of the Queensland Academy of Arts and Sciences in 2007. It was unexpected and very special to receive the Bergey's Award in 2001

for contributions to bacterial systematics and the WFCC Medal in 2010 for contributions to culture collections (Figure 6). The recognition by my peers gives me great pleasure and it is indeed humbling to be on the lists of recipients with people I have admired for their achievements during my career. I could not have wished for more. The fact that I was able to contribute to Bergey's Manuals gave me great pleasure and completes the circle from receiving my father's Bergey's Manual in 1964. I know that he would have been proud and pleased with the advice and encouragement he gave me at the time.

It is interesting to observe that there have been three recipients of Awards from the Bergey's Manual Trust for contributions to bacterial systematics associated with the Department of Microbiology and all three are former Heads of the Department. These were a Bergey's Medal to Vic Skerman in 1994, the 1991 Bergey's Award to Erko Stackebrand and the 2001 Bergey's Award to myself. This I believe is the highest recognition for contributions to bacterial systematics made over a 50-year period by the Department of Microbiology at the University of Queensland. I am very proud to be in the company of my colleagues, teachers and mentors Vic Skerman and Erko Stackebrandt, both of whom had a profound influence on my career. From my point of view I find it difficult to accept the decline in the teaching and research in bacterial taxonomy in the Department and across Australia. This is part of a wider issue which fails to recognize the impact of taxonomy in wide ranging areas such as animal, plant and human health; industry; environment; biodiversity; agriculture; trade; quarantine; research and education.

Retirement in some ways brings a sense of relief from the pressures, timelines and milestones of a working life in research and teaching. It also brings freedom and opportunities for more travel previously restricted. Lynn and I are spreading our wings and loving the opportunity to travel in Australia and overseas and to continue experiencing different cultures and catching up with the wonderful friends we have made during our lives, ticking off the bucket list.

I am fortunate to have had such a fulfilling and rewarding life under the influence of cultures, both microbial and ethnic, and I thank all of you for being part of it and helping me along the way.

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