

Biomedical Engineering

By Andrew Ruys

The history of Biomedical Engineering in the School dates back to the mid 1960s when Associate Professor Arthur Sherwood, working in collaboration with Professor Tom Taylor at the Royal North Shore Hospital, made the screws and plates which were used to straighten the spines of scoliosis sufferers [d'Alpuget 1965]. This was, however, followed by a long period of inactivity in the field and it was not until thirty years later in the 1990s that the School began a concerted effort in Biomedical Engineering research and teaching activities.

The commitment to establishing the BE Mechanical (Biomedical) in 1998 was taken by John Kent with the appointment of lecturer Lynne Bilston as the first degree coordinator. This was not Australia's first Degree in Biomedical Engineering (UNSW had launched the first Masters Degree in Biomedical Engineering in the 1980s) however it was the second ever biomedical program in Australia and Australia's first Bachelors' Degree in Biomedical Engineering. Today, twelve Australian universities offer Biomedical Engineering and as of 2013, ours is Australia's largest in student numbers by a significant margin.

The precursor to the establishment of this degree program was the rapid rise in biomedical engineering research in the school beginning in the early 1990s. Research in Biomedical engineering in the school began as spin-off research from two of the school's key research groups: Materials (see Materials Chapter) which drove the move into biomaterials research, and Rheology (see Rheology Chapter) which drove the move into soft tissue biomechanics research.

It was biomaterials research that really put the school on the map in the biomedical engineering field, and Yui Wing Mai can be credited with establishing it. Yiu-Wing Mai also recruited the three longest-serving members of the Biomedical Engineering research and teaching community in the school: Greg Roger in 1988; Mike Swain in 1990; Andrew Ruys in 1997. He also attracted two orthopaedic surgeons as Adjunct Associate Professors: Robyn Higgs in 1993 and Greg Roger in 2001.

Rheologists Nhan Phan-Thien and Roger Tanner played a significant role in the establishment of soft tissue biomechanics research in the school, a field in which the school made a smaller but nonetheless important impact in the early years. Nhan initiated the fledgling biomedical research area of soft tissue biomechanics. From his key speciality in rheology he moved into the rheological aspects of soft tissue biomechanics in his last few years in the school before moving to the National University of Singapore in 2000.

Nhan supervised two of the school's first three Biomedical Engineering PhD graduates, Jane Zizhen Liu (2001) and Philip Bendeich (2002) (see Rheology Chapter). His protégé Jane Liu took up an ARC fellowship in the school after graduating and went on to lead a number of research projects in soft tissue biomechanics in the school. Soft tissue biomechanics research went on for many years in the school, but it never gained great traction. After the departure of Lynne Bilston in 2001, it was carried on solely by Research Fellow Jane Liu, who left in 2008.

In the late 1980s, Yiu-Wing Mai initiated one of the formative steps in the rise of Biomedical Engineering in our school when he supervised the Engineering Masters research degree of Orthopaedic Surgeon and Sydney University Medical Graduate Greg Roger. Greg graduated with his M.Eng from our school in 1990 and went on to become one of the leading biomedical entrepreneurs of Australia. In 1994 he founded ASDM (Advanced Surgical Design and Manufacture), Australia's leading orthopaedics manufacturer and an employer of many of our graduates. Greg became an Adjunct Associate Professor in our School in 2001, a position he has retained ever since. After Yiu-Wing Mai, he is the longest serving figure in our School Biomedical Engineering community.

In 1990 when Professor Mike Swain from CSIRO was recruited by Yiu-Wing Mai to join the Materials Group in a part-time position, with CSIRO as his principal employer. Mike was a renowned fracture mechanics expert who had been a key developer of zirconia toughening, an Australian discovery from CSIRO that has now revolutionized the global orthopaedics industry. Mike had also been exploring zirconia toughening for dental biomaterials. Mai had a long research track record in the zirconia fracture mechanics area and Mike was asked by Mai to join his Materials research group (CAMT) and to take over the teaching of the Dental Materials course that the school was providing for Dentistry. This led to Mike becoming very involved with the Faculty of Dentistry.

In 1998 Mike was appointed Head of the Biomaterials Science Unit at ATP, a joint position between our School and Dentistry. In the period 1998 to 2003, Mike Swain assisted the biomedical engineering undergraduate program in supervision of a large number of undergraduate thesis projects. In 2003 Mike took up a professorship at Otago University, New Zealand, but has remained actively involved as an Emeritus Professor, supervising or co-supervising students with Qing Li and holding joint ARC grants with Wei Li.

The next step in the rise of Biomedical Engineering was the 1993 appointment of Robin Higgs to the first adjunct Biomedical Engineering Associate Professorship in the school. Robin offered his services unpaid as an Adjunct Associate Professor from 1993-2002. Robin taught orthopaedic engineering, which at that time was an elective for Mechanical Engineering students. He took our students to hip-replacement operations (where on occasion students fainted.)

His original connection with the school came through his daughter Liz Higgs who had graduated from the school in Mechanical Engineering in the late 1980s. Yiu-Wing Mai had supervised her final year thesis and she did work experience with Mike Swain at CSIRO that year. Years later, Liz did her PhD with Mike Swain, as would her brother Bill in the late 1990's. So the Higgs family had a long and fruitful association with the school.

One other key contributor in laying the foundations of biomedical engineering research in our school was Professor Grant Steven. In the 1990s, in the then separate Department of Aeronautical Engineering (which merged with our Department in 2001), Grant supervised three key PhD students in the computational biomedical engineering realm: Qing Li; Wei Li; and Michael Lee. Qing Li returned to our School in 2006 as a Senior lecturer in Biomedical Engineering. Wei Li has remained in our school ever since completing her PhD.

In 1998 the BE Mechanical (Biomedical) degree was launched. Head of Department John Kent appointed Lecturer Lynne Bilston as the course coordinator of this new initiative. Lynne had graduated as University Medallist in Mechanical Engineering in 1990, completed her PhD at the University of Pennsylvania and had returned to the school as a lecturer in 1994.

It is well known that Mechanical Engineering has been a traditionally male-dominated field, with typically ninety per cent male and ten per cent female students. The Biomedical Engineering program overcame this problem. Right from the start, the male to female ratio was redressed. There were only two students in the BE Mechanical (Biomedical) first intake in 1998, both female: Zeina Barto and Kathryn Grant.

It is unclear why Biomedical Engineering seems preferable to Mechanical Engineering for female students. Perhaps it is due to the more nurturing aspects of the health industry, in contrast to the more traditionally masculine field of machinery, the domain of Mechanical Engineering. Whatever the reason, over the years the male-to-female student ratio in Biomedical Engineering stabilised at about sixty per cent male and forty per cent female.

The fledgling BE Mechanical (Biomedical) degree enrolments grew very slowly in the early years. The program suffered a setback in 2001 when Lynne Bilston left to take up a position as Associate Professor at the Prince of Wales Medical Research Institute, University of NSW. In 2002, Associate Professor Dennis Bobyn, a prominent orthopaedics researcher, became course coordinator. Dennis was a Visiting Associate Professor from McGill University Canada who had joined the school only a year earlier in 2001. At the end of 2002 he returned to McGill. Robyn Higgs also stepped down from his role as Adjunct Associate Professor at around the same time. Thus in a couple of years, the school had lost three of its four biomedical engineering teaching staff.

Andrew Ruys had been a member of the Biomedical Engineering research and teaching community since 1997, when he had been appointed as a U2000 Fellow, and in 2003 he was appointed Senior Lecturer in Biomedical Engineering and became course coordinator. In 2004, Professor Lin Ye was appointed Head of School and supported the fledgling Biomedical Engineering program. In 2003, there had been fifteen enrolments. By 2008, Biomedical Engineering achieved the highest first year enrolment of any course in the Faculty of Engineering with seventy-four students.

Andrew Ruys's attempts to create an 'esprit de corps' around Biomedical Engineering were successful in three areas. First was the foundation of SUABE: Sydney University Association of Biomedical Engineers, in 2004. In the same year he implemented the SUABE Lunchtime Industry Seminar program, in which once-a-month lunchtime seminars facilitated links between the school and visiting prominent speakers and their employers. Thirdly, Andrew began the 'Magical Mystery Tour' in 2006.

Each Wednesday, for the second half of Semester 2 each year, he took his Third Year Biomedical Design and Technology class by bus to visit companies from the Biomedical Industry. (The 'Tour' name derives from the 1960's publicity stunt by British pop group the

Beatles, who travelled the UK in a yellow bus labelled “Magical Mystery Tour”, named after their latest album.) In 2006 a large “Magical Mystery Tour” Beatles poster was stuck to the side of the (purple) charter bus and it reappears every year.

With the introduction of the ME and MPE in Biomedical Engineering, “Magical Mystery Tour” numbers grew to eighty students by 2009, and it became necessary to ration visits as many companies could not accommodate eighty students arriving by bus on their doorstep.

From its inception in 1998 until 2006 the BE Mechanical (Biomedical) degree management had one academic full-time staff member. First there was Lynne Bilston (1998-2001), then Dennis Bobyn (2002), then Andrew Ruys (2003-2006). They were supported part-time by a small collection of honorary, adjunct and research staff. In the early days, these adjunct staff were Mike Swain and Robin Higgs, then after Robin’s departure, from 2001, Greg Roger.

Other important casual lecturers have included: Dr Elizabeth Clarke, the Murray Maxwell Director of Biomechanics at Royal North Shore Hospital Clinical School, and one of our original graduates (BE Mechanical Biomedical 2004, PhD 2007); Dr Tim Scott from Royal North Shore Hospital Clinical School; Dr Jane Liu, our earliest Biomedical PhD graduate in 2001; Dr Jean Nightingale from Health Sciences; and Dr Philip Boughton, one of our Biomedical PhD graduates in 2007, who was later appointed an Associate Lecturer in our Biomedical Engineering program in 2012. In 2010, Arthur Brandwood, Managing Director of Brandwood Biomedical, was appointed an Honorary Professor in the School and created a new industry driven elective in medical regulation. In 2011 the Innovation manager of Cochlear Professor Paul Carter was appointed as an Honorary Professor in the school and created a new industry-driven elective in neuromodulation.

With only three full-time teaching academics, and about sixty-five Biomedical Engineering thesis projects per year by 2011, major assistance with thesis supervision in the school has come from our adjunct honorary and research staff. In the early days it was primarily adjunct professor Mike Swain, and visiting Associate Professor Cheol Kim.

More recently, we have had generous assistance from: Associate Professor Hala Zreiqat, NHMRC Senior Research Fellow and Head of the Biomaterials and Tissue Engineering Research Unit in our school; Dr Wei Li, ARC Australian Research Fellow in Biomedical Engineering in our School; Dr Philip Boughton (UNSW Materials Science); Dr Ashish Mitra (Harvard); Dr Giang Tran (UNSW Medical School); Professor Lynne Bilston (UNSW Medical School); Dr Elizabeth Clarke; and Dr Jane Liu. Dr Philip Boughton, appointed an honorary lecturer in 2008, has been a particularly stalwart supervisor of biomedical engineering thesis projects. We have also had many people from industry co-supervise thesis projects, especially from ASDM, ResMed and Cochlear.

In 2006, with the exponential growth in Biomedical Engineering enrolments, Head of School Lin Ye called for a new academic full-time staff member to be recruited to the discipline.

As a result, Dr Hala Zreiqat was recruited from the Faculty of Medicine, University of NSW. Hala was a Medical Scientist whose research specialty was bone biology, tissue engineering and

biomaterials. Hala was the first non-engineer appointed to the staff of the School of AMME, in January 2006. Just prior to taking up her Senior Lectureship in AMME, Hala was awarded a five-year NHMRC Senior Research Fellowship which she took up at AMME and she established the Biomaterials and Tissue Engineering Research Unit in the school.

Hala was appointed in March 2006 as a member of the Bosch institute, Faculty of Medicine. In November 2006 she founded the Sydney University Tissue Engineering Network, an initiative that crossed various key Faculties at the University of Sydney including Medicine, Pharmacy, Science, Vet Science, and Dentistry.

When Hala immediately became a full-time externally-funded researcher, the School recruited another staff member. In mid 2006, Qing Li was recruited to the school as a Senior Lecturer in Biomedical Engineering. Qing was a former PhD graduate of the school from the year 2000, who had gone to Cornell as a Postdoctoral Fellow then taken up a Senior Lectureship at James Cook University.

Qing's expertise was in computational biomedical engineering and he quickly formed a large research group, as well as teaching and assisting with student recruitment and year advisor tasks. He was a stalwart supporter at Open Days and enrolment week and helped develop the degree program from strength to strength.

In 2007, Biomedical Engineering first year enrolments exceeded seventy for the first time. Incoming Head of School Steven Armfield asked the Biomedical teaching team to recruit a third member. Associate Professor Colin Dunstan was recruited from the ANZAC Research Institute, Concord Hospital (NSW) in 2008. Colin was a Medical Scientist who had worked for many years at AMGEN, a USA biotechnology company. By now total student numbers had grown to over two hundred.

In 2008, University upper management took a decision that coursework masters degrees were to be a new major initiative. Qing Li was asked by the Faculty to create and oversee the new MPE (Master of Professional Engineering), not only in Biomedical Engineering, but in fact the MPE for all disciplines in the school of AMME. The MPE was implemented in 2009 and the students on the whole have fitted in very well with the undergraduate students.

Ever since the faculty retreat in 2007, there had been murmurings from other schools in the faculty, who were experiencing falling enrolments with the decline in traditional engineering disciplines, that Biomedical Engineering was a multidisciplinary degree that was doing very well and that the school of AMME should really share some of its Biomedical Engineering success with the other schools.

In response to this, in 2008, Associate Dean (Research) Assaad Masri (Combustion Group) began the push towards moving Biomedical Engineering from an AMME-school-based activity to a faculty-wide activity. Assaad organized a faculty-wide symposium and workshop on Biomedical Engineering at the end of 2008. Twenty researchers from the electrical, computing, and chemical engineering schools were invited to present their research from a bio perspective, as well as four biomedical engineering academics from our school. Seminar topics included

signal processing, electronics, e-medicine, medical records cataloguing, image analysis, environmental science, biophysics and food technology, as well as biomaterials, tissue engineering, medical devices, and biomechanics from our school. After the symposium, Assaad directed a workshop which sought to identify a common task which all biomedical engineering researchers in the faculty could address. A consensus was reached with a grand plan for a faculty-wide coordinated research program on a brain-computer interface, an initiative which has been pursued as a faculty-wide project ever since, culminating in a Faculty-driven 2011 Sydney University Research Networks grant application on the topic.

As a direct result of Assaad's initiative, three major developments followed within the year. The first was that in 2009/2010, the School of Electrical and Information Engineering developed a new degree program, BE Electrical (Bioelectronics), which was implemented in 2011, and then scrapped in 2012. While it had only one student enrol in its first intake in 2011 compared to seventy-two in the BE Mechanical (Biomedical) in the same year, three more students transferred across from Biomedical engineering to Bioelectronics during 2011, and this new degree reflected the general feeling in the faculty that Biomedical Engineering was now the domain of the faculty, not the school of AMME.

In early 2010 the second major development occurred when our Faculty Dean formalised Assaad Masri's initiative and appointed David Feng from the School of Information Technology to the newly created position of Director of Biomedical Engineering (Research) for the Faculty. During 2010 and 2011 Feng established the Biomedical Engineering and Technology Research Institute (BMET), which was housed in the fifth floor of the School of Information Technology building.

The third major development was in early 2010, when Andrew Ruys became Director of Biomedical Engineering (Education) for the Faculty as co-director of the BMET with David Feng. By that year, enrolments were two hundred and fifty across all years. By now there were also about two hundred and fifty graduates from our biomedical degree in the workforce.

Andrew created a new faculty-wide degree called the BE Biomedical, with majors in each school: Mechanical/Mechatronic, Electrical, Chemical, and Information Technology. Associate Dean (Education) Doug Auld helped to set up this degree over 2010/2011, and it was approved by university upper management in 2012 for implementation in 2013. At this point, biomedical engineering became the first degree in the faculty of engineering that was not school-based. Philip Boughton was appointed Associate lecturer in Biomedical Engineering in our school in 2012 and played an important role in the implementation of this new degree in 2013.

Andrew Ruys was appointed Professor of Biomedical Engineering in 2012. After the forty-five year history of Biomedical engineering in the school, and a very active history over the two decades since 1990, the school had come to a major crossroads with the first experiment in the new era of non-school-based horizontal structures for Sydney University: the faculty-wide BE Biomedical. The implementation of this new degree in 2013 was very successful with over one hundred and twenty students in the first intake, putting Sydney University Biomedical Engineering into the number one position of the twelve Australian Universities now offering biomedical engineering.

More about SUABE

The Inaugural SUABE formal dinner took place in March 2004, with about sixty in attendance, which was virtually the entire BE Mechanical (Biomedical) student body at that time, plus staff and affiliates. It was held in the less-than-glamorous AMME Drawing Office. The inaugural SUABE AGM was held a week later with Tim Escott elected the first President. In 2005 SUABE president Howard Lau introduced SUABE T-Shirts for distribution at O-Week, which became an institution every year thereafter. From small beginnings SUABE grew to be a very successful student club hosting a formal dinner every March. By 2007, this event was attracting over one hundred and fifty attendees: students, alumni, and industry guests. In 2006 SUABE President Nicole Yu initiated the first SUABE Spring Cocktail Party.

2008 graduate Jowveria Mufti, 2013 SUABE alumnus of the year, was responsible for initiating the first SUABE student prize. In 2010, Jowveria was instrumental in persuading her employer, SORI (Sydney Orthopaedic Research Institute) to instigate the first Biomedical Engineering Prize, the Six Degrees of Freedom Thesis Prize. Our inaugural recipient was Jiao Jiao Li, University Medalist and 2009 graduate. Jowveria was also instrumental in initiating the SORI collaborative thesis project program with our students, commencing in 2009.

In 2012, Boon Quah (Grad 2009) became the inaugural SUABE Alumnus of the Year. Boon Quah graduated with a High Distinction average in 2009, and was recruited straight from university to prestigious global medical device company Stryker, where he rapidly rose to prominence. Two years later, he was instrumental in initiating the first Stryker internship program for students of our course, which began in Summer 2011/2012 with three interns, growing to fourteen interns in 2012/2013. He was also instrumental in initiating the first Stryker collaborative thesis project program with our students in 2012.



Figure 1 SUABE 2009 Executive at the Annual SUABE Formal Dinner all in their 2009 SUABE shirts with alumnus Pratik Gidwani (wearing suit, back centre) and Professor Andrew Ruys (back far right), and 2009 President Michael Kalonikas (front centre).

Many alumni affectionately remember the Magical Mystery Tour, and how it gave them their first real exposure to the Biomedical Engineering industry. Alumni are now amongst the teams hosting the visit at their respective companies. Alumni at our three largest employers ASDM,

ResMed and Cochlear have assisted, as well as Paul O’Byrne (Grad 2008) at Medtronic, Boon Quah (Grad 2009) at Stryker, and Pratik Gidwani (Grad 2008) at St Jude Medical.

Pratik Gidwani was 2008 SUABE president and 2013 SUABE Alumnus of the year. He instigated several new initiatives. He was the only Australian student who was accepted in to Stanford University's 2009 Summer Institute of General Management, where he won the Dean's award of Excellence and Distinction. In January 2007, he travelled to the Philippines with Engineers Without Borders to assist in various charity tasks. He has recently helped establish an internship program at St Jude Medical for students of our course.

ASDM, ResMed, and Cochlear have been the longest serving sponsors, but many other companies have sponsored SUABE over the years including: Medtronic; Stryker; Russell Symes & Co; Baxter IP; Uscom; ide+; Sunshine Heart; Bain and Co; Nanosonics; Portland Orthopaedics; Ventracor; and Columna. SUABE and the Magical Mystery Tour forged the strong Biomedical Industry links for the school. Many of the SUABE sponsors went on to support industry collaborative research ARC Linkage Grants, student internships, and graduate employment.

The SUABE annual magazine (published at Christmas 2010) ran a humorous story called “Three Wise Men” (Fig. 2) in which the three Associate Professors who ran the BE Mechanical (Biomedical), Andrew, Colin and Qing, were shown dressed up in Nativity regalia. The picture was accompanied by an amusing half-fun half-serious article. It was a testament to the esprit de corps that had developed in Biomedical Engineering over the years.



Figure 2 Three wise men. Left to right: Colin Dunstan, Qing Li, Andrew Ruys.

We have had two prominent biomedical engineering students in the global sporting arena. Andrew Wilson competed for Australia in a series of International Rowing Championships between the years 2004 and 2006, including the 2005 Australian Men's Under 23 Quad Scull, the World Cup in Lucerne and the Under 23 World Rowing Championships in Amsterdam. His sporting activities did not affect his studies: Andrew was our first Biomedical Engineering student to graduate with the university medal. In 2008, our Biomedical Engineering student body produced its first Olympian. Lachlan Renshaw, who competed at the 2008 Beijing Olympic Games running the four hundred metres while he was a third year BE Mechanical (Biomedical) student.

Up until 2011, more than half of our graduates have gone to work in the biomedical industry, primarily the medical device sector. All of them are good ambassadors for our course.

List of SUABE Presidents

Year	President
2004	Tim Escott
2005	Howard Lau
2006	Nicole Yu
2007	Susan Graham
2008	Pratik Gidwani
2009	Michael Kalonikos
2010	Andrew Tsang
2011	Calla Klafas
2012	Junior Taurail

Andrew Ruys

Andrew Ruys has a long background in Biomedical Engineering. After he was awarded his BE (UNSW 1987; Hons 1) and PhD (UNSW 1992) he worked as a postdoctoral fellow in the Graduate School of Biomedical Engineering, University of NSW, before being recruited to our school in 1997 by Yiu-Wing Mai, as one of the two U2000 Fellows in the school (the other was Howard See). The U2000 scheme was inaugurated in 1997 by Sydney University as a Sesquicentenary initiative to recruit promising postdoctoral researchers to Sydney University, and Andrew undertook research on ZTA nanocomposites and functionally graded biomaterials.

When appointed Senior lecturer in 2003, Andrew Ruys was an ARC Queen Elizabeth II Senior Research Fellow in the school and leader of the Biomaterials Research Group. In 2012 he was promoted to Professor, the School's first Professor of Biomedical Engineering.

Since 1986, Andrew has worked in bioceramics research, especially hydroxyapatite (HA). He has taught twenty-three different units of study since that time. Hydroxyapatite (HA) ceramics are chemically similar to bone mineral, and uniquely bond with bone in the body. Unfortunately, HA is as brittle as glass and cannot be used as a load-bearing implant, only as a porous tissue scaffold or a bioactive coating on a metal implant. Thus HA is a highly promising bioceramic, but its full potential is far from realised. Andrew has researched just about every aspect of HA and has achieved several world firsts. He pioneered silicon-doping of HA for enhanced bioactivity, later commercialised by Cambridge University; discovered the HA blowhole phenomenon; produced the first HA with toughness comparable to bone; published the first paper on electrophoretic deposition of HA; discovered the impurity-catalysed dehydroxylation phenomenon. Other bioceramics he researches include bioglass, ZTA, functionally graded bioceramics, and diamond-like-carbon biocoatings. More recently he has been researching bioactive polymers for soft tissue scaffolds. He also has spent many years teaching and researching medical device design for orthopaedic and blood-interfacing implants. Andrew has over one hundred and sixty publications and has been awarded over five million dollars in research grants.