AIBN annual report 2005

THE AUSTRALIAN INSTITUTE FOR BIOENGINEERING AND NANOTECHNOLOGY



THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

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AIBN annual report 2005

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AIBN
an overview

The University of Queensland's Australian Institute for Bioengineering and Nanotechnology (AIBN) is Australia's first fully integrated research institute to take a multidisciplinary approach to understanding and exploiting nanostructures, the genetic basis of cell activity, and opportunities at the interface between bioengineering and nanotechnology.

With internationally recognised researchers, AIBN merges the skills of engineers, chemists, biologists and computational scientists to focus research and development efforts, leading to new products and devices for improving human health and quality of life.

The AIBN has one of the most significant representations of scientists and engineers working in the areas of bioengineering and nanotechnology in Australia. This unique combination of scientists and engineers undertakes research in four main areas:

- nanotechnology for energy and the environment;
- cell and tissue engineering;
- systems biotechnology; and
- biomolecular nanotechnology and devices.

With its innovative technologies, cutting edge capabilities and acknowledged research leaders, AIBN enables the progression of ideas to products through partnering and contract research.

AIBN can add value through research and development of new processes, technologies, materials and devices.


Vice-Chancellor's report

The Australian Institute for Bioengineering and Nanotechnology is in the vanguard of The University of Queensland's new scientific institutes conducting research of global significance.

The AIBN is a pioneer in one of the most dynamic fields of modern science, and excels by combining basic and applied research and commercialisation with strong links to industry in a problem-solving capacity. This approach to bioengineering and nanotechnology makes it unique in Australia, if not the world.

Its diverse and interdisciplinary work encompasses: regenerative medicine; nanotechnology-based imaging for drug delivery and therapeutic products; novel protein expression using systems biotechnology and metabolomics; and applied nanotechnology for the benefit of industry and the environment.

UQ is constructing a $70 million complex to house the AIBN. This facility will be completed in 2006, and will be a research environment free of the traditional interdisciplinary borders.

The AIBN complex will eventually accommodate 350 researchers and support staff, including scientists of international stature. It will be a major addition to the critical mass of world-leading researchers not only at UQ, but also in Australia and the Asia-Pacific region.

This outstanding infrastructure has been made possible by a partnership between The Atlantic Philanthropies, the Queensland Government (through its Smart State Strategy) and UQ.

The AIBN will work closely with the Queensland Government's BioPharmaceuticals Australia, which allows Australian biotechnology companies to maximise the benefits of investment in research and development.

In collaboration with BioPharmaceuticals Australia, AIBN will service the Australian biotechnology industry. Its emphasis will include cell-line development, scale-up and bioprocess development, and the production and characterisation of the large, complex proteins of great importance to the new generation of therapeutics.

Additionally, AIBN scientists have a role in developing nanotechnology policy at both the state and national level. They serve on working groups including the Prime Minister's Science Engineering and Innovation Council and Expert Subcomittees for the National Collaborative Research Infrastructure Strategy.

This first Annual Report of the AIBN marks another stage in the maturation of an institute that will be counted as an asset to people worldwide whose lives are enriched by its research.

Professor John Hay AC

VICE-CHANCELLOR
THE UNIVERSITY
OF QUEENSLAND

Director's report

The year 2005 marked many important milestones for the AIBN as it grows to form a fully functioning institute. The year has seen major growth in both the intellectual capability of the Institute, with the appointment of a growing number of group leaders and their associated researchers, and in the construction of the custom-designed building which will house AIBN.

During the year, formal offers were made to senior researchers to become Group Leaders in AIBN. The initial appointments were to both senior researchers who have been actively involved with AIBN since its inception, and more recent employees who have moved to Brisbane to join AIBN. Active discussions are being held with an additional number of potential Group Leaders.

The fifteen Group Leaders are leading research groups which currently number over two hundred and thirty researchers, including more than eighty postgraduate research students. Current predictions are that there will be over two hundred and eighty researchers in the Institute when it moves into the new building in the second half of 2006.

This growth in AIBN's numbers has been made possible by the success of the Group Leaders, who attracted research funding from both competitive granting bodies and industry totalling $9.8 million during 2005.

During the year, AIBN's hard-working Executive Officer, Donna Hannan, oversaw the appointment of a number of additional administrative positions. Accordingly, all key managerial positions have now been filled, covering infrastructure, finance, IT, personnel, postgraduate studies and marketing for the Institute.

The Innovation and Commercial Development unit in AIBN has worked with the AIBN Executive and Group Leaders to draw up a manual of procedures for the operation of the Institute. The manual covers all aspects of confidentiality, maintenance of lab books, approval of disclosures and IP protection. Currently the unit is engaged in an IP census for the Group Leaders, and at their request has run workshops on IP and Commercialisation, and is becoming involved with an increasing number of discussions and negotiations on commercial licences and contracts.

Given the multi-disciplinary emphasis of AIBN, it has been particularly pleasing to see that a number of major new collaborative projects involving several group leaders have developed, which are helping to move AIBN from a group of highly successful research teams to a more united research community. These collaborations are taking many forms, and include the Challenge Projects identified in 2004 by AIBN as a means by which focus could be given to the Institute's major research themes of:

- Nanotechnology for Energy and the Environment
- Systems biotechnology
- Cell and tissue engineering
- Biomolecular Nanotechnology

The five Challenge Projects, more about which will appear later in this report, have encouraged new collaborations between AIBN Group Leaders and have already resulted in some exciting scientific outcomes.

The rationale behind these ambitious, long-term research endeavours is to deliver practical research outcomes, promoting interdisciplinary research activity.

AIBN researchers are also involved in a large number of research collaborations both across The University of Queensland (UQ) and with other Australian and international research groups and companies. Particularly pleasing is that research collaborations, and in many cases joint appointments, are now in place with the Institute for Molecular Bioscience, the Queensland Brain Institute and the Sustainable Minerals Institute, as well as many Schools and Centres from the Faculties of Biological and Chemical Sciences, Health Sciences, and Engineering and Physical Sciences and Architecture at the University of Queensland.

During the year, we have watched with anticipation as AIBN's purpose-built research facility has been constructed at the UQ's St Lucia campus. The building has been designed with specialist facilities to encourage research at the interface between the biological, chemical and physical sciences.

Progress on the building through 2005 has been rapid, and indications are that practical completion will be mid-2006. This will be followed by extensive testing prior to commissioning and a staged move-in by researchers. The AIBN building project has been expertly managed by the University's Property and Facilities (P&F) Division, and my thanks are extended to the ever-patient Director of P&F Alasdair McClintock and the AIBN Project Manager, Peter Sampson, for their excellent work.

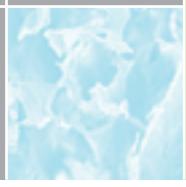
During the year appointments were made to AIBN's Scientific and Commercialisation Committee (SACC), which had its first meeting in December, to coincide with the very successful Sir Mark Oliphant Conference: 'BioNano: The Next Frontier' hosted by AIBN. We are delighted that such a distinguished group of international scientists and engineers from the USA, Europe and Asia has agreed to join SACC.

I would like to give my thanks to AIBN's Executive Committee, Professors Julie Campbell, Max Lu, Anton Middelberg and Matt Trau, who have worked in a tireless fashion throughout the year to further develop the Institute's activities.

Finally, I acknowledge the continued support of the Queensland State Government, Atlantic Philanthropies and the University of Queensland. In particular AIBN is indebted to the Vice-Chancellor Professor John Hay, Senior Deputy Vice-Chancellor Professor Paul Greenfield, and Deputy Vice-Chancellor Professor David Siddle, and to the AIBN's many friends and supporters in the University environment.

Professor Peter Gray
DIRECTOR, AUSTRALIAN INSTITUTE FOR BIOENGINEERING AND NANOTECHNOLOGY

CHALLENGE PROJECTS



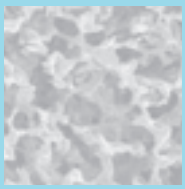
AIBN's Challenge Projects are ambitious long-term research endeavours focused on delivering practical research outcomes and promoting interdisciplinary research.

These projects are instrumental in establishing the AIBN's research reputation and include a competitive edge unique to the Institute. They involve more than one group and will lead to high quality research outcomes and visibility from a commercial viewpoint.

Tissue engineering the meniscus

CHALLENGE PROJECT | CHAMPION: ASSOCIATE PROFESSOR JUSTIN COOPER-WHITE

ELITE ATHLETES AND WEEKEND WARRIORS SHOULD WATCH WITH INTEREST THE PROGRESS OF AIBN RESEARCH TO DEVELOP AN ARTIFICIAL MENISCUS DESIGNED TO REPLACE THOSE DAMAGED DURING SPORT.



The meniscus is the cartilage spacer found between the thigh and shin bones. It prevents friction and absorbs approximately one third of the impact load the joint cartilage surface experiences.

The project, headed by Associate Professor Justin Cooper-White, and supported by UQ's Faculty of Health Sciences and the Mater Medical Research Institute, aims to develop a tissue engineered meniscus using tailored three dimensional scaffolds and mesenchymal stem cells.

"It is not only elite athletes that damage their meniscus," said Dr Cooper-White, "the general wear and tear of a normal life can cause damage requiring surgery.

"In fact, in any gathering of people, about 50 percent of the group will have a damaged meniscus or no meniscus at all.

"Unlike other body tissues, the meniscus does not repair itself because only a very small part receives blood, which is why surgery is often needed.

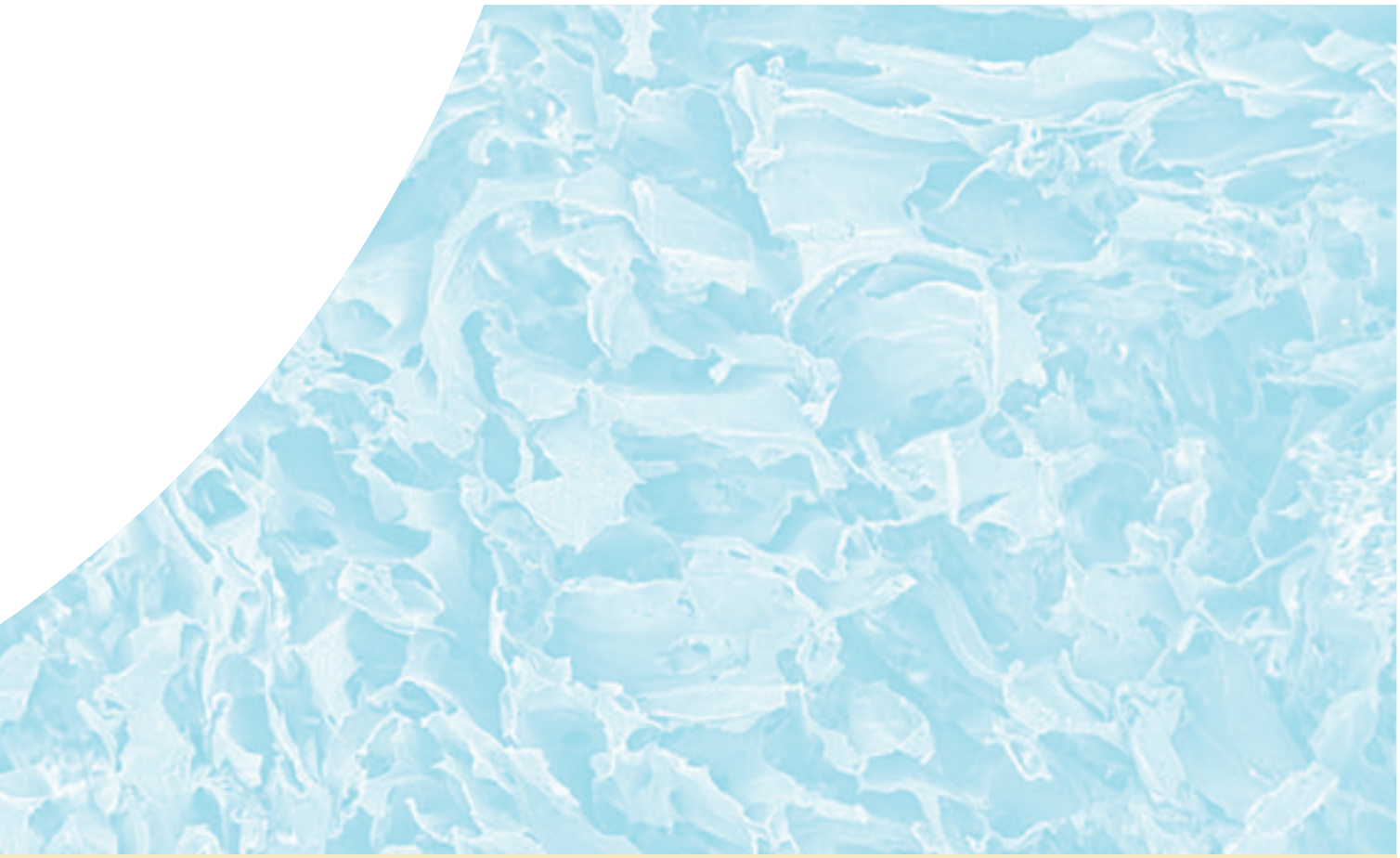
"While most patients quickly recover from a menisectomy, long-term issues such as early arthritis of the knee joint are common," he said.

This project has two parts; the first is to produce viable structural and functional scaffolds capable of promoting the growth of mesenchymal stem cells (precursors of the meniscus), and differentiation of these cells into meniscal tissue.

Secondly, the project will investigate the way these structures can be incorporated into the body.

"The holy grail would be to harvest some mesenchymal stem cells from the patient, combine them with the scaffolds and appropriate growth factors and then insert this matrix into the knee so the patient effectively re-grows their meniscus," he said.

"Alternatively, we are attempting to create an artificial environment as close as possible to that of the meniscus in which to grow and differentiate cells that make up a healthy meniscus.



"Both of these techniques require many years of research, and in order to be successful we need a thorough understanding of how mesenchymal stem cells interact with scaffolds and how to optimise conditions promoting the cell growth around these scaffolds.

"The scaffold, while encouraging cell growth, must also degrade at the correct rate so that all that remains is meniscal tissue.

"We don't know which approach will be clinically the most effective, which is why we are investigating the possibility of the artificial environment as well as the insertion method.

"We also need to be able to grow, or manufacture, the artificial meniscus reliably and quickly, suiting the circumstances of each patient," he said.

SINCE THE COMPLETION OF THE HUMAN GENOME PROJECT, IT HAS BECOME APPARENT THAT THE HUMAN GENOME CONTAINS CONSIDERABLY FEWER GENES THAN INITIALLY EXPECTED.

Scientists believe this 'high complexity, low gene number' anomaly has been overcome by processing genes into many more different proteins, which is significant for the production of complex proteins as human therapeutics.

Professor David James is championing this AIBN Challenge Project aimed at gaining greater understanding of rate limiting factors in recombinant DNA expression by mammalian cells.

"This understanding will allow metabolic engineering to be carried out to develop improved mammalian cell hosts with the ability to produce the specific protein or proteins for biopharmaceuticals," he said.

However, this is not a simple undertaking.

"Most proteins from the human genome are very complex, with variation arising from post-translational modification, resulting in different structures of the protein each with exquisite functions in the body.

"Proteins that have been post-translationally modified perform roles in signal transduction (the movement of signals from outside to inside the cell), proteolysis (breaking a protein down into its component amino acids) and glycosylation (the addition of sugars to proteins).

"These modifications have implications in understanding heart disease, cancer, neurodegenerative diseases and diabetes."

As a result, simply engineering a mammalian cell to express a particular protein of interest does not guarantee it will be useful as a human therapeutic.

Professor James believes a focused approach is required.

"To produce biopharmaceuticals in an economically viable manner we need to reliably reproduce the complexity of the desired protein structure using mammalian cells as the host cell for protein expression," he said.

Efficient biomanufacturing systems

CHALLENGE PROJECT | CHAMPION: PROFESSOR DAVID JAMES

"This requires proteomic and metabolomic approaches to understand the factors in recombinant DNA expression in mammalian cells."

Proteomics is the study of the proteins produced by an organism, with particular emphasis on their structures and functions. A logical extension of genomics, proteomics is considerably more complicated. This is because the genome of a mammalian cell remains constant from cell to cell, even during different environmental stimuli.

However, the proteome is in a state of flux, always responding to environmental stimuli, and varying from cell to cell. This variation in protein expression compounds the complexity of the proteome.

More information can also be derived by studying the consequences of proteomic variation. This is achieved by measuring the metabolites that arise from the biological function of proteins and is known as metabolomics.

This relatively new technique enables the direct observation of the biochemical consequences of mutations, changes in the environment and treatment with drugs, and will assist in the development of new drugs. It may also help us to understand how drugs work, interact and cause side effects.

"These approaches will eventually give us a clear idea of the biologically important molecules we should be using as therapeutics, as well as the means by which we can induce mammalian cells to produce these proteins.

"The end result will be more effective drugs with fewer side effects, produced more economically," Professor James said.

Nanoparticle-based cellular delivery carriers

CHALLENGE PROJECT | CHAMPIONS: PROFESSORS MAX LU & ANTON MIDDELBERG

EFFICIENTLY DELIVERING DRUGS TO THE REQUIRED SITE HAS LONG BEEN A PROBLEM FOR TRADITIONAL MEDICINES, BUT AIBN RESEARCHERS ARE INVESTIGATING THE USE OF NANOPARTICLES AS A QUICK AND SAFE METHOD OF ADMINISTRATION.

Oral delivery of drugs via tablets or capsules is largely inefficient due to exposure of the pharmaceutical agent to the metabolic processes of the body. Therefore, a large drug dose is often required and its maximum effectiveness is compromised.

Traditional intravenous (IV) administration is much more problematic. Specificity for IV injectable drugs is often low, necessitating large amounts of a drug be injected into a patient, creating a high concentration of the drug in the bloodstream that could potentially lead to toxic side effects.

While the pharmaceutical industry is currently focusing its efforts on liposomes and viruses as drug delivery tools, Professor Max Lu believes that nanoparticles have the added advantages of biological stability, customisation in terms of size, surface functionalities and molecular absorbing properties.

"Liposomes, viruses and nanoparticles all work on the principle of encapsulating the drug or DNA to ensure the correct dose arrives at the required site in the body (bioavailability)," he said.

"The advantage of nanoparticles is that unlike liposomes, which are round shells of phospholipids – the basic components of human cell walls – and viruses, which are well defined proteins, they are not subject to digestion in the stomach and should be easily absorbed in the bloodstream for delivery."

This is an exciting prospect and one sure to generate interest in the pharmaceutical industry, particularly in the area of gene therapies.

"Viruses and liposomes present a variety of problems for gene therapy patients, particularly toxicity, immune and inflammatory responses and targeting issues; however, we believe that nanoparticles can be more easily adapted to overcome these problems," Professor Lu said.

"The project can be broken down into three main parts. Firstly, we want to optimise synthesis of inorganic nanoparticles of customised size and charge density to efficiently deliver DNA into cells for gene therapy or monoclinic antibody production.

"To improve our delivery of these nanoparticles we will use molecular modelling to understand how the nanoparticles will be absorbed and what happens in transfection, a chemical process used to make a cell wall 'leaky' and allow absorption of DNA.

"Secondly, we are also interested in creating new polymeric or organic-inorganic hybrid nanoparticles for drug delivery with highly controllable release kinetics and the ability to target specific cell types.

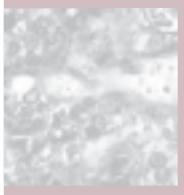
"Finally, we wish to develop biomolecular-based virus-like nanoparticles or hybrids for DNA delivery."

The key outcome for this Challenge Project is to produce one or more platform technologies using nanoparticles for efficient and cost-effective drug and DNA delivery.

Development of a novel commodity polymer from sugarcane

CHALLENGE PROJECT | CHAMPION: PROFESSOR LARS NIELSEN

ONE OF QUEENSLAND'S MOST IMPORTANT CROPS, SUGAR, MAY SOON HAVE ANOTHER STRING TO ITS BOW WITH THE DEVELOPMENT OF AN AIBN RESEARCH PROJECT TO TURN CANE JUICE INTO PLASTICS.



Currently the manufacture of plastics, polymers, surfactants and the like is dominated by the petrochemical industry. However it has been suggested that biotechnology, in the form of metabolic engineering, will account for as much as 15 percent of the US$250 billion polymer market in the next ten years.

Metabolic engineering is the process of rational redesign – typically using genetic engineering – of organisms to meet commercial objectives.

Traditional chemical industries are already shifting from chemical to biological processes and new opportunities are continuously emerging in the pharmaceutical, food and biomedical areas.

AIBN's Professor Lars Nielsen said that using sugarcane to manufacture plastics has several advantages over the traditional methods of production.

"Higher yields, greater purity, lower energy use and less waste make bioplastics very attractive to industry," he said.

"More important is the possible reduction of xenobiotics in the environment and the reduced load on landfills if biodegradable polymers are used.

"It also overcomes the major shortcomings of organic synthesis, namely long product lead time and expensive plant design to handle toxic compounds at high pressure and temperature.

"However we shouldn't get too excited. While the use of renewable resources and a lower environmental impact are attractive factors, these products also have to compete functionally and economically with traditional production methods.

"Currently chemical synthesis accounts for only a small fraction of global petrochemical consumption, and the energy used for polymer processing amounts to more than the actual chemical content.

"As a result, low-cost raw materials, efficient bio-catalysis, and product innovation are all key determinants of success.

"Sugarcane juice is a readily fermentable low-cost feed stock, and the waste material, bagasse (the dry pulpy residue left after the extraction of cane juice), is an excellent source of low-cost green process energy, fermentables and aromatic compounds," he said.

The main research aim is to improve production of polyhydroxyalkenoates (PHAs) in sugarcane, potentially providing a replacement for polyesters, the key ingredient in thermoplastic or elastomeric materials often used in packaging material.

PHAs are linear polyesters produced in nature by bacterial fermentation of sugar or lipids. More than 100 different monomers can be combined within this family to give materials with extremely different properties.

This project continues Professor Nielsen's world-first research into PHA production in a species of grass and could lead to the establishment of a sugar mill associated bioprocessing plant for production of PHAs and other bulk chemicals to the world market.

It may also offer possible product diversification for cane growers, as well as reducing the reliance by Queensland's rural sector on the price of sugar.

Professor Nielsen said: "because only a few potential bio-commodities have been identified, there is a need for close collaborations between bioengineers developing new production methods, and material scientists capable of developing novel products.

"By 2020 it is conservatively estimated that around 20 percent of the 150 million tonne polymer market will be produced from renewable resources representing a market value of AUD$30-60 billion."

Energy interface architecture for power systems

CHALLENGE PROJECT | CHAMPION: PROFESSOR JOHN DRENNAN

ONCE THOUGHT OF AS INFINITE, THE WORLD'S RESERVES OF TRADITIONAL FUELS ARE RAPIDLY DIMINISHING. IN ADDITION, IT IS BECOMING CLEAR THAT CLIMATE CHANGE ASSOCIATED WITH OUR USE OF FOSSIL FUELS IS DEVELOPING INTO A REAL PROBLEM THAT MUST BE SOLVED IN THE COMING DECADES.

As a consequence, science needs to find new and efficient ways of using fuels in the production of energy.

Fuel cell systems is one area with the potential to make a significant impact on the efficient production of energy. With no moving parts, electricity is produced by simply separating fuel and air on either side of a conducting membrane. Efficiencies in the order of 60-70 percent can be achieved and complete systems can be self sustaining, produce useful heat, and in some systems produce water as the exhaust gas.

With the aim to produce fuel cells that can be applied to systems as diverse as motor vehicles and lap-top computers, this Challenge Project is applying expertise in materials design at the nano-scale to build components that can be incorporated into a new generation of fuel cells.

The simplicity of the process that produces the power in a fuel cell masks the difficulties in materials engineering that must be overcome before fuel cell systems become commercially viable.

The systems must operate at elevated temperatures; greater than 100°C in the case of polymer based cells and greater than 750°C in the case of the larger solid oxide fuel cells. It is still a major challenge to find materials that can sustain exposure to various fuel types, are robust enough to remain in one piece with changes in operating conditions and can continue to operate efficiently for prolonged periods at these temperatures.

It is this challenge that the AIBN's Professor John Drennan is addressing through the design of robust interface structures and new materials.

The key to improving fuel cell efficiency and reliability lies in the interface structures that interlock the various components making up the fuel cell assembly.

Professor Drennan is working on designing a range of novel electrodes and electrolytes that can be used to construct various fuel cell types, but also may find application in secondary batteries.

He is confident that in a wide range of systems associated with energy production and storage, improved efficiency, greater power density and longer lifetimes could be achieved by controlling the atomic and molecular exchanges occurring at interfaces within any system.

He said the expertise available within the AIBN in materials design and characterisation at the nanometre scale provide a unique opportunity to develop new architectures for interface structures.

"This is the first time we have been able to exactly define the architecture we want and then be able to manufacture it," Professor Drennan claimed.

"We are developing coordinated groups of researchers examining components of energy related devices."

In the first instance the group will concentrate on solid oxide fuel cells (SOFC), however as the technology and testing regimes are developed, attention will be focused on other systems in which interface design has the potential to improve efficiencies.

Working at high temperatures, SOFCs will be used as stationary power units for households and heavy industry. A major advantage is that these systems can use a variety of fuels including natural gas, which makes them particularly attractive for remote stand-alone applications.

Power is generated by the transfer of oxygen ions through an oxygen ion-conducting ceramic membrane which separates the fuel and air gas streams. Particular challenges within these systems are associated with the stability of the electrode/electrolyte interface structures at these high temperatures.

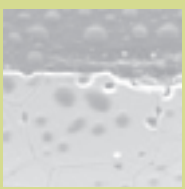
"If we can improve the efficiency of ion transfer taking place at this interface, we stand to boost the power output of these fuel cells, possibly lowering the temperature at which they operate," he said.

"What's more, these improvements can realistically be applied to other fuel cell systems, advanced battery systems and energy storage devices.

"To achieve our goals we are constructing a comprehensive electrical testing lab in the AIBN; designed to rapidly assess fuel cell components and prepare novel interface designs.

"This laboratory will be in close proximity to scientists developing novel nanostructured materials, as well as a comprehensive suite of instrumentation for materials characterisation," he said.

The coming together of these groups in one location provides a unique opportunity to develop multidisciplinary teams to tackle technological problems – in this case novel designs for fuel cell components.



To build a vibrant research institute with a national and international reputation for high quality research and related programs requires scientists with a demonstrated ability to lead highly successful independent research programs.

As such, AIBN Group Leaders form the core of the Institute.

The following pages document the research interests of AIBN's Group Leaders.

GROUP LEADER RESEARCH PROJECTS

Stem cell biology and vascular development

GROUP LEADER: PROFESSOR JULIE CAMPBELL

OUR CURRENT MAJOR RESEARCH INTEREST IS TISSUE ENGINEERING REPLACEMENT ORGANS FROM THE PATIENT'S OWN CELLS USING THE PERITONEAL (ABDOMINAL) CAVITY AS A BIOREACTOR.

To date, the Centre for Vascular Research, headed by Professor Julie Campbell, has been successful in growing myofibroblast tissue around appropriately shaped polyethylene moulds of tubes or bulbs in several animal species.

"This takes 2-3 weeks," said Professor Campbell, "and when grafted into arteries, bladder, vas deferens or uterus to replace resected segments, the myofibroblast tissue differentiates into structures identical to the host organ and remains functional for at least 16 months.

"To prevent the possibility of unwanted adhesion formation to the bowel during the development of this tissue, and in preparation for human clinical trials, we have recently designed, patented and successfully tested a 'device' within which the tissue grows.

"Insertion of the device and subsequent harvesting of the tissue is minimally invasive and we are now developing a replacement ureter and a cathetiserable bladder outlet using the same technology."

She said they were using fluorescence-activated cell sorting, microarray technology and bioinformatics to examine the precise origin of the cells forming the myofibroblast graft tissue and the factors that influence its differentiation.

"This information will be used to maximise growth tissue and optimise its characteristics."

In collaboration with polymer chemists, Professor Campbell's group is also participating in the AIBN Challenge Project with Associate Professor Justin Cooper-White, to develop an artificial knee meniscus by populating a novel scaffold with mesenchymal stem cells and differentiating them along different cellular pathways according to function.

"In addition, we aim to grow functional kidneys through the incorporation of 'stem' cells into embryonic kidneys transplanted to the peritoneal cavity of adult hosts," she said.

Other studies focus on the cell biology of the artery wall in health, and in disease states such as atherosclerosis and restenosis after angioplasty. Another long-term interest of the team is smooth muscle phenotype and factors affecting the cells' sub-structural compartments.

Tissue engineering and microfluidics leading to new structures and systems

GROUP LEADER: ASSOCIATE PROFESSOR JUSTIN COOPER-WHITE

ENGINEERING ARTIFICIAL ORGANS AND TISSUES IS JUST ONE OF THE RESEARCH INTERESTS OF AIBN'S ASSOCIATE PROFESSOR JUSTIN COOPER-WHITE.

The team is also interested in microfluidics, the multidisciplinary study of the behavior of fluids at the microscale and mesoscale.

Both research areas are rapidly emerging and exciting fields, with microfluidics central to the development of DNA microarray technology; now a crucial tool in many areas of biological and medical research investigating human development disease and treatment.

Tissue engineering can perhaps be best defined as the use of a combination of cells, engineering materials, and suitable biochemical factors to improve or replace biological functions.

Dr Cooper-White said tissue engineering was a revolutionary strategy to treat patients requiring organ or tissue replacement as a result of accidents or disease.

"We are investigating novel methods of manufacturing polymeric scaffolds and methods of surface engineering these scaffolds for drug delivery and tissue engineering applications," he said.

"Additionally we are also focusing on enhancing cell-specific adhesion and maximising tissue growth throughout three dimensional scaffolds, which will ultimately find uses in the controlled growth and expansion of stem cells and the generation of vascularised soft tissues within *in vitro* and *in vivo* environs."

Dr Cooper-White's interest in microfluidics has led to extensive collaborations with groups at the University of Queensland, the University of Melbourne and Massachusetts Institute of Technology (USA).

He said exciting new avenues for creating and tailoring new biotechnology and nanotechnology products will result from understanding the flow behaviour of non-Newtonian fluids within micrometre- to nanometre-flow conduits.

"The most mature application of microfluidics is ink-jet printing and DNA microarray technology; however, other potential applications include pharmaceutical, biotechnology and public health areas.

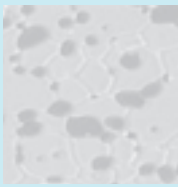
"Because fluids behave differently at the nanoscale, microfluidic devices require different methods of construction and design.

"It is therefore imperative we understand this behaviour so we can maximise the opportunities presented by this enabling technology," he said.

Microscopic detail to improve power

GROUP LEADER: PROFESSOR JOHN DRENNAN

THE ABILITY OF NANOTECHNOLOGY TO DELIVER NEW AND IMPROVED DRUGS, BIOMEDICAL DEVICES AND MORE EFFICIENT ENERGY PRODUCTION DEPENDS LARGELY ON THE ABILITY TO SEE WHAT IS OCCURRING ON THE NANOSCALE.



To do this requires world-class microscopy facilities with leading-edge data storage and visualisation packages.

Professor John Drennan, AIBN Group Leader and Director of the Centre for Microscopy and Microanalysis (CMM) said the ability to characterise the synthesis efforts of the AIBN researchers was critical to their success.

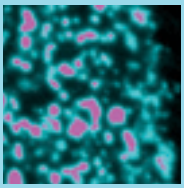
"We know carbon nanotubes, currently the most popular tool in nanotechnology, are hollow only because they have been characterised using electron microscopy," Professor Drennan said.

"We are presently building our resources for occupation of the AIBN's new building, moving four electron microscopes and a comprehensive suite of preparation and ancillary equipment to take up room on the ground floor.

"Accompanying this equipment will be staff to meet the service and training requirements for the instrumentation. As a result AIBN, will have the latest instrumentation, essential for activities both in bioengineering and nanotechnology."

In addition to his role with CMM, Professor Drennan said he was also interested in developing micro-energy systems in collaboration with Professor Max Lu as part of an AIBN Challenge Project.

"My early work focused on oxide materials with highly conducting properties, and has evolved into developing materials for solid oxide fuel cells, an efficient means of producing power with minimal greenhouse emissions.



"Understanding the effect of contaminants on the electrical properties of the fuel cell materials has progressed into the means by which these contaminants can be controlled and minimised.

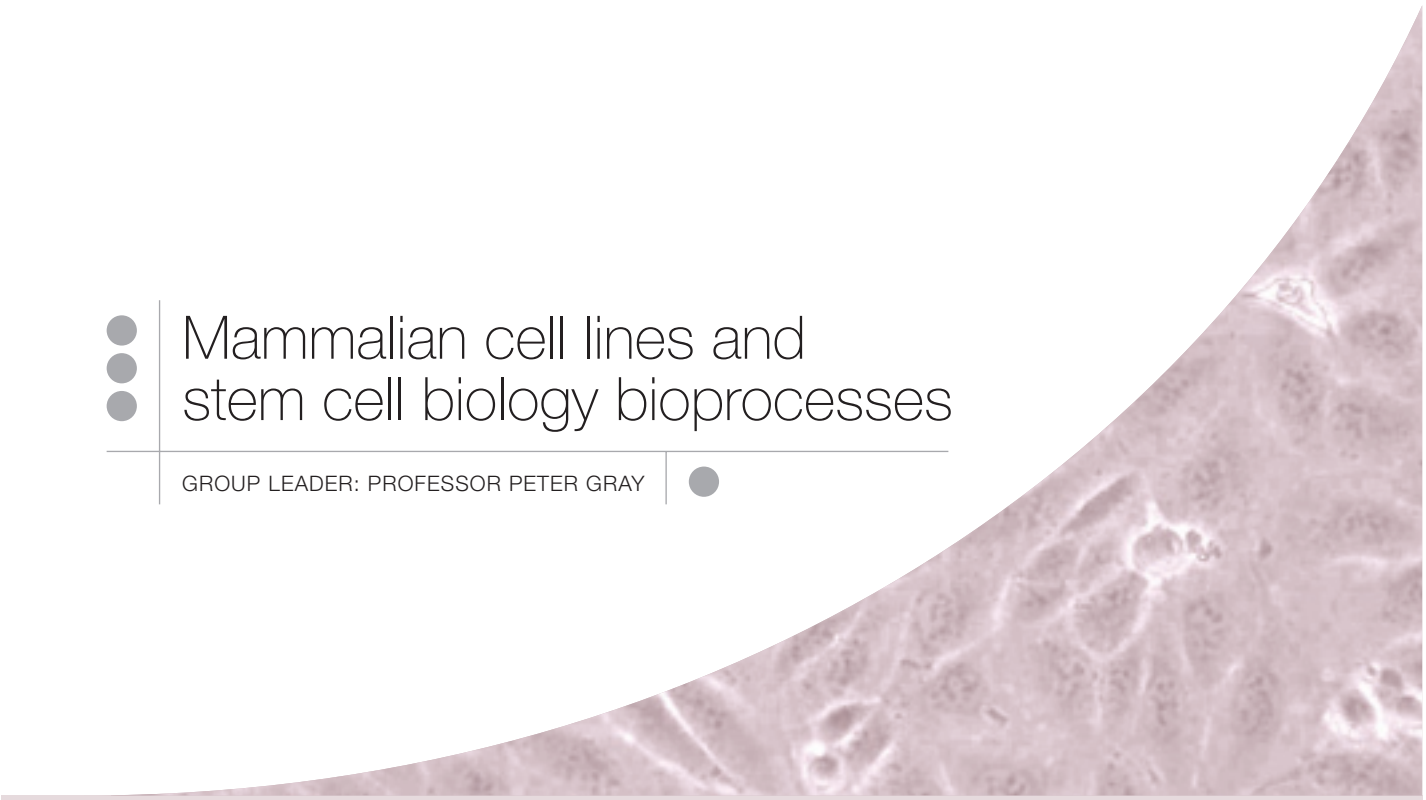
"In 2006, in order to accelerate our progress we intend to appoint additional researchers to our Challenge Project to help design and set up an automated test rig for screening materials for use in micro-energy systems.

"AIBN PhD student, Mr Kwok Cheung, is working on designing and implementing data storage systems that interrogate different experimental data and present them in a flexible visualisation package for engineers and scientists to use in experimental design.

"Also moving to the AIBN is Ms Ruth Knibbe, who is presently funded through an industrial partner, to examine the interfacial characteristics of solid oxide fuel cells."

Mammalian cell lines and stem cell biology bioprocesses

GROUP LEADER: PROFESSOR PETER GRAY



NEW BIOPHARMACEUTICALS, THE CLASS OF PROTEIN-BASED HUMAN THERAPEUTICS USHERED IN BY THE DNA REVOLUTION, ARE BEING DEVELOPED BY LEADING-EDGE RESEARCH AT AIBN.

The biopharmaceutical sector is experiencing very rapid growth; over 20 percent per annum, with products currently accounting for more than US$40 billion per year in sales.

AIBN Director and Group Leader Professor Peter Gray commented that over one quarter of all new drugs now being approved by regulatory authorities, such as the US Food and Drug Administration (FDA) were biopharmaceuticals, with half of these being recombinant DNA-derived monoclonal antibodies.

He said complex proteins such as monoclonal antibodies were not easy to make (express), and had to be produced in mammalian cell cultures, which are slow and difficult to grow.

“Consequently there is strong interest in research which can improve the efficiency of mammalian cells as production systems,” Professor Gray said.

“A major bottleneck in producing complex proteins in mammalian cell culture is the long time required to develop cell lines stably expressing the protein of interest. Our research aims to address this rate-limiting step.

“High throughput techniques, such as fluorescent activated cell sorting (FACS) linked to a more detailed understanding of cellular metabolism, are being used to develop improved transient and stable mammalian cell expression systems.

“Transient systems allowing rapid production of many proteins over a period of several weeks have been developed, but stable systems are also needed to produce larger amounts of the desired protein for pre-clinical and clinical trials,” he said.

These approaches, when linked to the understanding at the ‘omics’ (genomics, proteomics) level of what constitutes the ideal host cell, offer the opportunity to translate research findings into improved expression systems of use to both researchers and the biopharmaceutical industry.

Professor Gray is also interested in applying these approaches to maximising the therapeutic opportunities presented by stem cell biology.

He said the absence of a reliable technology platform for stem cell production was preventing stem cells being used to treat diseases.

“Biopharmaceuticals have required the development of systems to grow large quantities of crucial cells.

“The next research challenge is to use approaches similar to those used for Chinese Hamster Ovary (CHO) cells to develop stem cell processes enabling production in a reliable and repeatable fashion to the satisfaction of regulatory authorities.”

Rheology and processing of biopolymers

GROUP LEADER: ASSOCIATE PROFESSOR PETER HALLEY

BIODEGRADABLE PLASTICS AND IMPROVED MEDICAL DEVICES BOTH RELY ON A DETAILED UNDERSTANDING OF RHEOLOGY, BIOPOLYMERS AND NANOSTRUCTURED POLYMERS.

Rheology, the study of the physical and chemical properties of fluids, plays a vital role in developing industrial processes in the manufacture of many everyday objects, particularly those made of plastic which rely on injection moulding, extrusion, blow moulding and rotational moulding.

Polymers are the building blocks of plastics and are made by reacting monomers into linear chains or a three-dimensional network of polymer chains. Polymer is a generic term used to describe the very long molecules that consist of structural units and repeating units connected by covalent chemical bonds.

Biopolymers represent the most abundant organic compounds in the biosphere and constitute the largest fraction of cells. They can be generated from renewable natural sources, are often biodegradable and not toxic to produce. They can be produced by biological systems or chemically synthesised from biological starting materials such as sugars, starch or oils.

Associate Professor Peter Halley said his research was aimed at understanding the physical and chemical properties of polymers with a view to developing new plastics.

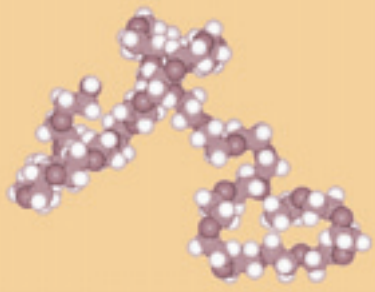
"Polymers, as the basic building blocks of plastics, can be manipulated to build new materials with the features required for new medical, agricultural or food devices," he said.

"For example, much work was done to develop degradable plastics in the 1980s. However these plastics generally did not degrade or they did not survive typical product lifetimes.

"As a result we became interested in controlled-lifetime thermoplastic starch-based polymer products.

"In this study we have obtained both commercial products and a fundamental understanding of the relationships between the structure, properties, processing and biodegradation of starch-based polymers.

"Our work links laboratories from diverse fields such as chemical engineering, chemistry, materials engineering, mechanical engineering, dentistry, anatomy and biomedical sciences," he said.



Cellular function to produce new therapeutics

GROUP LEADER: PROFESSOR DAVID JAMES

SEARCHING FOR HIGH-VALUE THERAPEUTIC RECOMBINANT PROTEINS TO FIGHT AGAINST MANY COMMON HUMAN DISEASES IS THE FOCUS OF AIBN'S PROFESSOR DAVID JAMES.

The aim of this group is the development and use of cutting-edge technologies to improve the production, processing and analysis of recombinant proteins produced by mammalian cell factories.

Much interest in this field has focused on monoclonal antibodies which are produced by the body to seek out all disease-causing bacteria, viruses and other infectious agents (antigens) and destroy them.

Antibodies are extremely useful for two reasons. Firstly, they are extremely specific, with each antibody targeting only one particular antigen. Secondly, some antibodies confer life-long resistance against particular diseases (for example measles and chickenpox).

It is the specificity of monoclonal antibodies that make them so valuable, Professor James said.

"Not only can antibodies be used therapeutically to protect against disease, they can also help diagnose a wide variety of illnesses and can detect the presence of drugs, viral and bacterial products, and other unusual or abnormal substances in the blood."

In addition to the group's work on monoclonal antibodies, post-translational modification and bioactivity, the team is also interested in the particular cellular mechanisms controlling phenotypic function or performance of animal cells *in vitro*.

They are also interested in rapid production of sufficient quantities of candidate protein products in the host cell factory likely to be employed in the final production process.

"The two key questions about the culture of animal cells *in vitro* are: what cellular processes limit cell performance, and what enables cells to survive in some environments and not in others?

"To answer these questions we are applying current technologies to monitor and compare functional gene expression and protein modification implicated in the functional competence of animal cells in culture.

"We believe this work will lead to a greater understanding of cellular processes and their regulation, yield novel options for cell engineering, as well as enhance our knowledge of the network of events that govern cell function *in vitro*.

This research will be of importance for improving therapeutic protein production and may have implications for animal cells used in cell- and tissue-based therapy.

"It is for this reason that multinational biopharmaceutical companies have recognised the importance of our research and development by providing significant investment support," Professor James said.

Functional nanomaterials research to improve energy, environment and health

GROUP LEADER: PROFESSOR MAX LU

MICROELECTRONICS, MANUFACTURING, MEDICINE, ENERGY AND THE ENVIRONMENT ALL DIRECTLY AFFECT THE QUALITY AND MANNER OF OUR LIVES.

Nanomaterials and nanotechnology will have a profound impact on these industries. AIBN's Professor Max Lu argues that Australian research and development in this field should target those most relevant to our economy in order to reap maximum benefits.

As Director of the Australian Research Council's Centre for Functional Nanomaterials and AIBN Group Leader, Professor Lu said clean energy, the environment and health care had been identified as areas where nanostructured materials would have significant early impacts and as a result the Centre had developed specific research projects in these fields.

"We are applying to these areas novel synthesis and characterisation, and new materials such as nanoparticles, nanotubes, thin films, nanoporous and nanocomposite materials," Professor Lu said.

He said these materials were constructed by self-assembly at the nanometre scale and possessed improved properties and unique functionalities, such as high surface areas, nanosize and quantum confinement effects, ordered porosity and high adsorbing and sensing abilities.

This makes them ideal materials for adsorbents, catalysts, sensors, fuel cells, and battery systems. They are also attractive for biotechnology applications due to the ability to control protein-material, cell-material, and tissue-material interactions.

"Our research activities are divided into five research programs defined by the dimensionality of the nanostructures.

"In each case we aim to develop new techniques and methods for the synthesis, characterisation and evaluation of nanomaterials for specific targeted applications.

"We are applying these techniques to three main areas; clean energy production and utilisation, environmental technologies and health care.

"This will lead to viable industries in hydrogen production and storage, improved fuel cells and high energy batteries, photo-catalytic reduction of pollutants in water and air, economic removal and recovery of inorganic vapours, greenhouse gas reduction and utilisation, as well as biomaterials for orthopaedic and cardiovascular applications and tissue repair," he said.

All Centre projects seek to enhance nanoscale science and to exploit the knowledge and understanding gained through fundamental studies to establish the processing performance relations.

Nanostructural biomaterials for medical device components and tissue engineering

GROUP LEADER: DR DARREN MARTIN

DR DARREN MARTIN'S RESEARCH INTERESTS INCLUDE EVALUATING AND IMPROVING THE DURABILITY, COMPATIBILITY AND PERFORMANCE OF BIOMATERIALS USED IN MEDICAL DEVICES AND TISSUE ENGINEERED MEDICAL PRODUCTS.

By investigating the structure-property relationships in polymeric materials, biomedical polyurethanes and nanocomposites, Dr Martin and his team will substantially improve medical plastics and biomaterials with the potential for use in such things as surgical gloves, synthetic tri-leaflet heart valves and artificial spinal discs.

Dr Martin said the core focus for the last 12 months was the detailed study of nanoscale reinforcement effects in "nanocomposite" biomedical polyurethane rubbers supplemented by nanoscopic synthetic clay particles.

"We investigated how tensile strength was improved, by an astounding 127 percent, without stiffening the rubbers or adversely affecting their dynamic mechanical performance by looking at the structural origins of these mechanical property improvements," he said.

"This work was assisted by small angle x-ray scattering (SAXS) experiments performed at the Argonne synchrotron in Chicago, and small angle neutron scattering experiments (SANS) performed at ISIS in the UK.

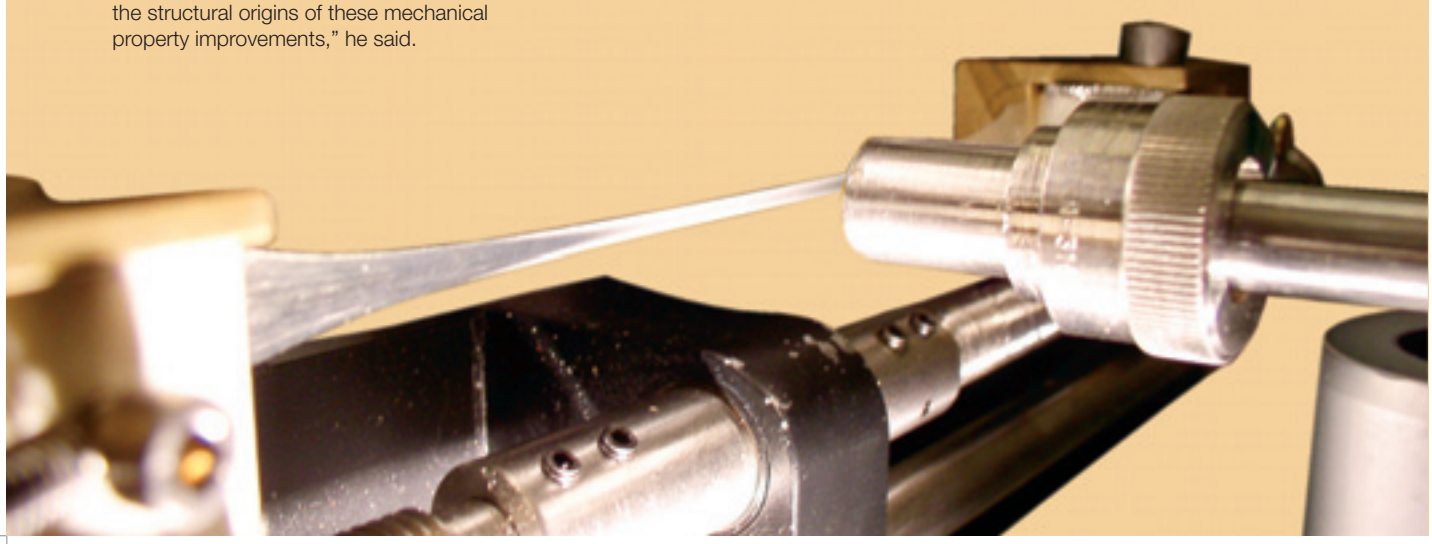
"This published work demonstrates that the influence of clay particle dimensions on nanocomposite tensile properties is considerable, particularly for the smallest particles, where, surprisingly, significant strengthening and toughening effects are observed.

"We demonstrated that these nanoparticles were capable of superior dispersion, delamination and preferred orientation during tensile deformation of the system by using synchrotron SAXS coupled with other characterisation techniques."

He said that contrary to conventional thinking, it appears that low aspect ratio or small layered silicate nanofillers offer superior benefits with regard to achieving desirable mechanical properties. This work led to the filing of an international patent application in May.

"Our research also builds expertise in the important area of biomechanical testing of new biomaterials, scaffolds and tissues, where we have continuing and emerging projects in the areas of bone, cartilage and vascular tissue engineering," Dr Martin said.

"We are also building expertise and linkages in the field of nanoparticle biocompatibility, for example, carbon nanotubes and other inorganic nanoparticles, and nanotoxicology."



New bio-inspired products from biotechnology and nanotechnology

GROUP LEADER: PROFESSOR ANTON MIDDELBERG

DESIGNING, CREATING AND MANUFACTURING NEW BIO-INSPIRED PRODUCTS BY DEVELOPING AND APPLYING CUTTING-EDGE KNOWLEDGE IS THE FOCUS OF PROFESSOR ANTON MIDDELBERG AND HIS TEAM.

Professor Middelberg, an Australian Research Council Federation Fellow, said his group's research addressed both existing and new problems in the manufacture of complex chemical and biological products.

"At one end of the spectrum we are examining the questions behind the design and self-assembly of peptide nanostructures, and how assembly is affected by local physico-chemical factors such as pH and shear stress," he said.

"This has led to new technology that can potentially revolutionise the way emulsions are viewed and processed.

"Emulsions are made by mixing two immiscible liquids, and are important because they are found everywhere, in goods ranging from mayonnaise to products for delivering chemotherapy agents and other drugs.

"We are looking at the design of nanostructures at interfaces, with a particular focus on exploring how emulsions and foams can be switched on and off at will. Our technology allows very quick separation of the oil and water, and then reversible re-formation of the emulsion.

"Basically you can have your emulsion, and break it too!"

He said that at the other end of their work they were interested in how to self-assemble virus-like particles for use as vaccines, therapeutic and diagnostic products.

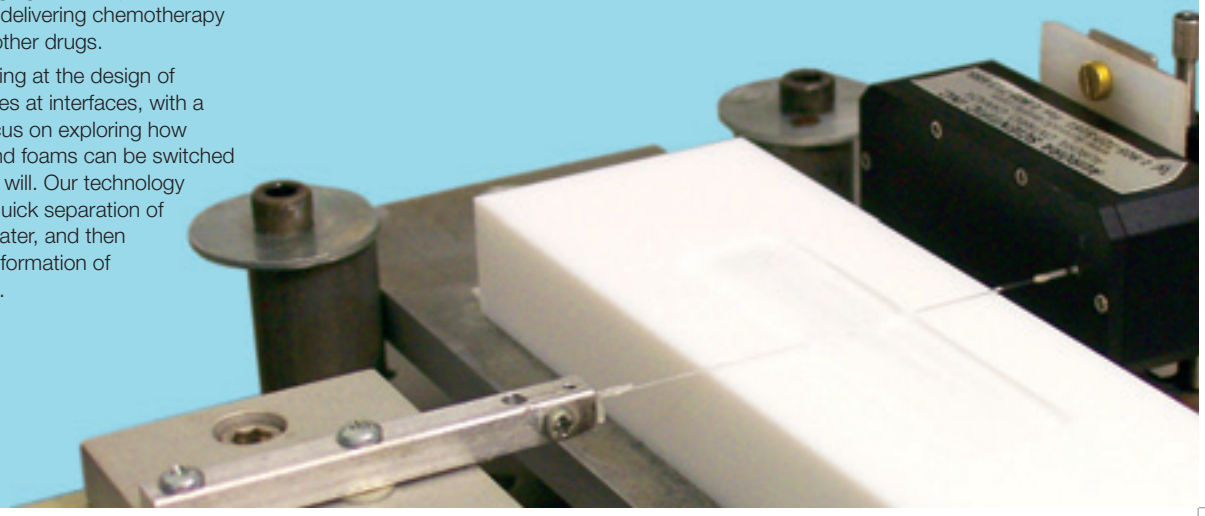
By engineering these structures to self-assemble, Professor Middelberg believes it will be possible to precisely control what is put in the particles, and to improve the way these particles are manufactured en masse.

"We will make a cheap and versatile tool that can help us understand how viruses behave, and how they induce an immune response. They can also be tailored to act as a trojan horse to deliver therapeutic payloads to carefully selected specific cell types" he said.

"Of course, none of this is possible without strong biotechnology skills such as biomolecular cloning, expression and purification.

"My research team has extensive expertise in downstream bioprocessing and in particular protein purification and analysis, and we work closely with UQ's Institute for Molecular Bioscience Protein Expression Facility.

"As well as answering fundamental questions regarding new technology, we also work on industrial bioprocessing questions including those related to protein aggregation, particularly during refolding, formulation and storage," he said.



Characteristics of products controlled by polymer formation

GROUP LEADER: DR MICHAEL MONTEIRO

NEW POLYMER STRUCTURES DESIGNED AT THE AIBN AND SUITABLE FOR USE IN DRUG AND GENE DELIVERY, AS WELL AS HIGH-STRENGTH COATINGS, WILL PROVIDE AUSTRALIAN PRODUCTS WITH ADVANCED FEATURES AND CAPABILITIES TO SIGNIFICANTLY IMPROVE PERFORMANCE.

This research, conducted by Dr Michael Monteiro, significantly advances the basic knowledge of polymer science and related fields through preparation of previously unavailable, novel and well-defined nanostructures.

Dr Monteiro said his group's research aimed to develop methodologies to synthesise complex polymer architectures in water with controlled particle size, molecular weight and morphology.

"From this we hope to gain an understanding of the structure-property relations of these novel nanomaterials so that targeted properties can be made for specific applications," he said.

Dr Monteiro believes one direct application of his research will be the development of polymer structures on the nanoscale with diverse chemical functionality throughout the structure for the attachment of various important biomolecules.

He said these nanostructures would be designed to protect and deliver biomolecules to specific cells and could be used in synthetic vaccines or to deliver drugs with controlled release.

"The knowledge obtained through this application will advance the development of synthetic vaccines and drug delivery devices more generally by providing an understanding of how these structures function in the body, he said.

"By using an environmentally friendly medium such as water we hope to use living radical polymerisation and its unique architectures such as block, branch and star polymers in a variety of applications such as speciality high-strength films in the coatings industry.

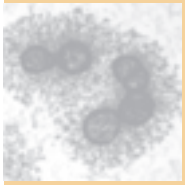
"To this end we are also trying to develop new living radical polymerisation techniques that allow a desired molecular weight distribution to be prepared with a single agent.

"Our close collaboration with Professor Virgil Percec at the University of Pennsylvania in the US, has allowed us to explore such systems, and prepare novel polymer nanostructures," he said.

Tissue and metabolic engineering

GROUP LEADER: PROFESSOR LARS NIELSEN

CONTINUING ADVANCES IN THE ABILITY TO ENGINEER BIOLOGICAL SYSTEMS ARE REDEFINING BIOTECHNOLOGY AND MEDICINE AND WILL BROADLY IMPACT ON EXISTING INDUSTRIES, AS WELL AS CREATE TOTALLY NEW ONES.



Consequently new opportunities are constantly emerging in the pharmaceutical, food and biomedical areas.

AIBN's Professor Lars Nielsen is harnessing a combination of chemical engineering, biochemistry and molecular cell biology to develop new and innovative bioprocess applications.

Professor Nielsen and his team are advancing bioengineering principles and then applying them to specific problems ranging from production of blood cells for transfusion to the production of industrial biopolymers.

He said his two broad research areas were tissue and metabolic engineering; specifically haematotherapy, and polymer production in bacteria, animal cells, and sugarcane.

The group has several projects investigating the normal processes involved in replacing approximately 300 billion blood cells a human loses each day, and applying this knowledge to blood related disorders.

"The ability to grow blood cells in culture is an enabling technology with many potential applications in bone-marrow transplantation, gene therapy, immunotherapy, and the production of blood products," he said.

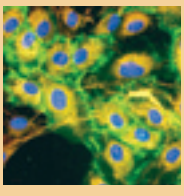
Professor Nielsen is also interested in metabolic engineering, the rational redesign of organisms using genetic engineering, to meet commercial objectives.

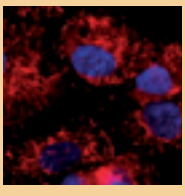
"I am interested in biopolymer production, in particular, new approaches to enhance production of monoclonal antibodies in mammalian cells, hyaluronic acid in bacteria and polyhydroxyalkanaotes (PHAs) in sugarcane.

"PHAs are the most promising form of biopolymer, and by using different bacteria and varying their carbon source, it is possible to produce biomaterials with properties ranging from stiff and brittle plastics to rubbery polymers.

"In Australia, production of PHAs and other bulk chemicals in sugarcane offers a potential for product diversification and reduced reliance on the price of sugar for Queensland's cane growing industry.

"To be successful, the new process must offer an economically viable alternative to current sources of PHAs and other bulk chemicals."





Biopesticides

GROUP LEADER: DR STEVE REID

INCREASED RESISTANCE TO CHEMICAL PESTICIDES AND CONCERN OVER THEIR USE HAS RESULTED IN RENEWED INTEREST IN THE APPLICATION OF BIOLOGICAL MEANS TO CONTROL PESTS OF COMMERCIAL IMPORTANCE.

Dr Steve Reid is advancing the technology necessary to reduce the cost of production of biological control agents, initially focusing on effective scale-up of insect viruses.

There are many wild type Baculoviruses that can specifically infect and kill key agricultural caterpillar pests. At 300 times smaller than a human hair Bacloviruses are the largest viruses known, because they wrap their genomes up in large protein coats known as occlusion bodies.

This enables the virus to be stable in the open environment and therefore deliverable to crops using conventional land and air based spraying procedures.

Dr Reid said his laboratory had a process patent on a procedure for producing Baculoviruses via fermentation.

"Our lead product is a Baculovirus which targets the Helicoverpa pest species, which accounts for a $US3.2 billion per annum market," he said.

"Baculoviruses are currently produced *in vivo* using caterpillar farms, but our intention is to produce such viruses *in vitro* using bioreactors.

"Current pilot work is conducted in 30-100 litre bioreactors and the virus product is simply harvested by cross-flow filtration, with the concentrated virus then being formulated such that it is ready for spraying onto fields. Final production, to be cost effective, would need to be conducted at the 20,000 litre scale."

He said at current yields the production costs would allow the team to target Helicoverpa pest species in areas where this pest is resistant to most low cost chemical options ($15/Ha), and where only more expensive chemicals are in use ($30-$50/Ha).

Dr Reid believes a two-fold improvement in yield would allow the product to compete on cost alone in all markets, including extensive markets in India and China.

Further process improvements to allow the product to progress to full-scale manufacture involves relatively straightforward biochemical engineering optimisation studies.

However, the major challenge limiting the full-scale manufacture of Baculoviruses *in vivo* is the development of Few Polyhedra Mutant (FPM) viruses during the extended passaging of the virus in cell culture.

"FPMs are caused by the mutation of key viral genes during scale-up," he said.

"In collaboration with scientists at UQ's Institute for Molecular Bioscience we will conduct basic biological studies of these mutation events, which will give insights into the cause of the yield-limiting mutations occurring during manufacture of this viral pesticide."

Computer power to simulate and visualise molecular systems

GROUP LEADER: PROFESSOR SEAN SMITH

A WORLD-LEADING PROGRAM AT THE CENTRE FOR COMPUTATIONAL MOLECULAR SCIENCE IS DEVELOPING NEW MOLECULAR AND COMPUTATIONAL METHODOLOGIES FOR APPLICATION-BASED MODELLING.

This interdisciplinary work focuses on molecular scale modelling in the areas of biological science, materials science, nanotechnology and environmental science.

Core research interests, according to AIBN Group Leader Professor Sean Smith, include computational studies of fluorescent proteins with a view to designing new proteins for use in cellular imaging applications, as well as hydrogen storage in carbon nanotubes as an alternative energy source.

"Quantum chemical studies, coupled with quantum and molecular dynamical calculations, reveal the key features that control the mechanistic and functional properties we wish to design into new engineered fluorescent proteins," Professor Smith said.

"Such mechanistic information is presently patchy, and substantial developments in this area of theoretical modelling will greatly facilitate attempts to develop new fluorescent proteins for a wide range of biotechnology applications.

"Meanwhile, our computational study on hydrogen storage, a research area of enormous economic significance, is performed in close collaboration with experimental studies."

He said hydrogen was both renewable and environmentally friendly with nearly three times the energy content of gasoline; however, the lack of practical storage methods had hindered the widespread use of this fuel.

"This research concentrates on the interactions of molecular and atomic hydrogen with a range of novel nanomaterials being specifically designed for hydrogen storage.

"These new materials are based on carbon nanotubes and magnesium, where small amounts of heavy metals have been incorporated to form impurities which will assist in catalysing the adsorption and release of hydrogen."

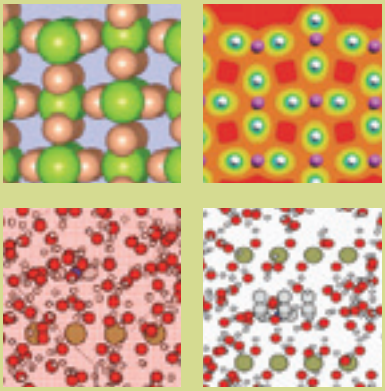
"Another research project in the area of drug delivery computationally investigates the mechanistic action of a number of new nanoparticles designed for effective DNA delivery across cell membranes.

"These new technologies have far reaching consequences for medical applications and the mechanism by which they operate is presently unknown and speculative."

Professor Smith said these projects were generally computationally intensive and expensive in terms of processing time.

The research is therefore greatly aided by in-house computational facilities, incorporating both large distributed memory clusters (Intel, Xeon and AMD Opteron) and shared-memory computers.

"Parallel computing strategies often facilitate the most difficult and extensive calculations, or indeed enable them when they would otherwise be infeasible," he said.



Nanotechnology and biomaterials

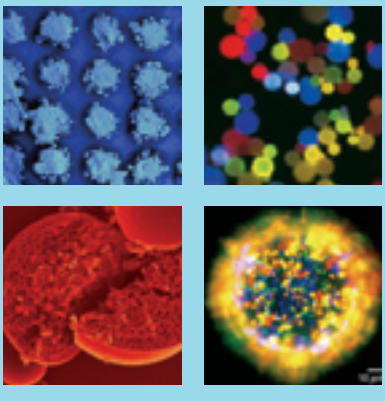
GROUP LEADER: PROFESSOR MATT TRAU

IMPROVING HUMAN HEALTH BY DEVELOPING NANO-SCALED BIOLOGICALLY RELATED MATERIALS AND DEVICES IS THE OVERALL GOAL OF PROFESSOR MATT TRAU'S GROUP.

The work conducted at the Nanotechnology and Biomaterials Centre focuses on two main areas: nano-scaled molecular diagnostics and artificial tissue matrices for implantation in the human body.

Both of these research areas require creation of novel materials and devices, usually microscopic or colloidal in nature, which have been fashioned to contain designed nanostructures.

Professor Trau explained that colloidal systems comprise finely divided, pieces of matter, typically particles of approximately 10 to 10,000 angstroms in size, dispersed within a continuous medium.



"These provide a wonderful set of 'nano-sized lego blocks' which can be used to construct complicated materials," he said.

"This 'bottom-up' approach to materials and device design is the way biology builds a vast array of nanoscaled materials and devices.

"By learning from and imitating such biological processes, we have the best chance to produce materials with similar properties to those of living systems."

Further development of this approach presents exciting opportunities in the fields of tissue engineering and regeneration, as well as genomics, proteomics, drug discovery, human diagnostics and personalised medicine.

Proessor Trau said the recent completion of the human genome project had heralded a new era of molecular and genetic based medicine.

"Major opportunities include a plethora of new personalised treatments and early diagnoses for individuals affected by a wide variety of illnesses such as cancer, diabetes, heart disease, autoimmune disease, as well as a many infectious diseases like SARS, West Nile virus, Dengue Fever and Bird Flu.

"A major stumbling block inhibiting the full utilisation of genomic data generated from the human genome project is our current inability to conveniently and accurately read the large amounts of biomolecular information present within the cell.

"We are currently developing nanoscaled devices to be used for rapid DNA sequencing, genetic screening, proteomic, early diagnostic and drug discovery applications.

"Additionally, many human ailments arise as a result of the body's inability to fully regenerate damaged tissue such as bone, liver and pancreas."

The ARC Federation Fellow said current medical therapies in these cases involved the use of autografts – implants from one's own body, allografts – implants from cadavers, or other non-biological materials each of which had their associated problems.

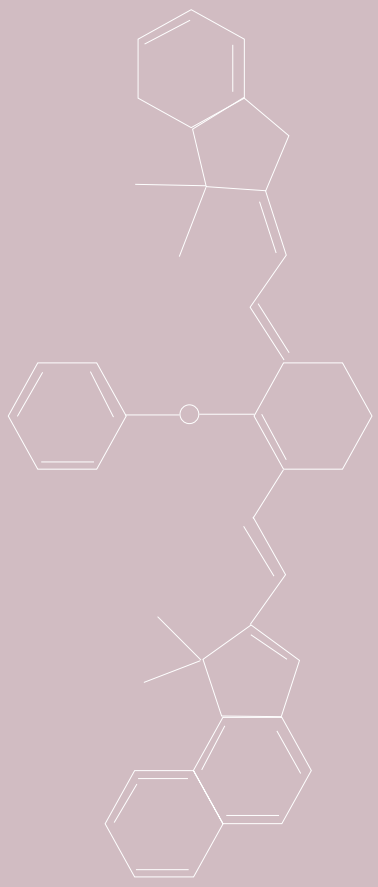
"Our research focuses on developing novel biological, degradable and 'living' implants for the human body," he said.

"A variety of nanostructured materials are being developed for applications in cell immobilisation, tissue regeneration, cell transplantation, and *in vitro* cell culture."

Polymer physical chemistry and NMR imaging

GROUP LEADER: PROFESSOR ANDREW WHITTAKER

IDENTICAL, SMALL MOLECULES BONDED TOGETHER FORM POLYMERS. THEIR APPLICATION TO BIOMATERIALS AND MICROELECTRONICS OFFERS EXCITING POSSIBILITIES IN DRUG DELIVERY AND TISSUE REGENERATION.



Headed by Professor Andrew Whittaker, the group is concerned with the manufacture of novel polymeric materials and understanding how the structure of these materials can be manipulated to provide key materials properties.

Biomaterials are synthetic polymers for use in the human body. They can be used for imaging cell types and tissue function, delivery of drugs and growth factors, and support for tissue regeneration and cell expansion.

Professor Whittaker said they had research programs in these three areas and collaborated extensively with other groups from AIBN.

"Polymers with Magnetic Resonance Imaging (MRI) or Positron Emission Tomography (PET)-imaging labels are injected into the body, to enable the study of blood flow, and if conjugated with a suitable targeting moiety, to provide images of specific tissue types, such as tumour cells," he said.

"Polymers are also used as tissue scaffolds; biodegradable polymers provide mechanical support to allow regeneration of many different tissue types.

"The ability to control polymer chemistry and network structure allows the delivery of biological agents (drugs and growth factors) at a defined extent and rate.

"We are also interested in preparing polymer-gold nanoparticles for application as high-sensitivity biosensors."

Polymers are also an essential element of the manufacture of integrated circuits with increased processor speed depending on ever-decreasing feature size on the silicon wafer.

This decrease in feature size is achieved by new chemistry, specifically polymers with high-refractive indices.

The team is developing novel materials to be used in the manufacture of the next generation of computer chips.

"Towards the end of the decade an entirely new polymer technology will be required if computer technology is to advance any further," he said.

"We are working to develop new polymers for this technology known as extreme ultraviolet lithography."

Underpinning these research efforts is the development of modern methods of analysis by magnetic resonance spectroscopy and imaging. The team has strong links to the Centre for Magnetic Resonance, and is interested in new high-pressure nuclear magnetic resonance (NMR) methods, hyperpolarised gas-phase NMR and solid-state NMR.

Innovation
and Commercial Development

AN INSTITUTION WITH THE RESEARCH BREADTH AND DEPTH OF THE AIBN PRODUCES A COMPREHENSIVE RANGE OF INTELLECTUAL PROPERTY, MUCH OF WHICH HAS COMMERCIAL POTENTIAL.

The AIBN's Innovation and Commercial Development (I&CD) team focuses on the intellectual property (IP) management and commercialisation of the Institute's research and development activities, as well as fostering industry-led collaborations and contract research.

The AIBN has a strong commercial focus. To support and rapidly build the Institute's commercialisation activity, AIBN has a strategic relationship with UniQuest Pty Limited providing access to commercialisation expertise, processes and resources. UniQuest is recognised as an Australian leader in research commercialisation and is the main commercialisation company of The University of Queensland.

I&CD strategy

The commercial objective of the Institute is to produce innovations assisting in the growth of industries; the development of new products, processes and technologies; and play a major role in developing the Australian nanotechnology and biotechnology industries. This objective will be met through a dual commercialisation strategy.

The 'inside-out' strategy provides for the development of AIBN's IP through market-led R&D, funded from public and private sources as appropriate and commercialised via a license agreement or forming a start-up company to further develop the technology into a product.

In contrast the 'outside-in' strategy aims to capitalise on AIBN's capabilities, infrastructure and intellectual capital by working closely for or with industry. I&CD engages with key figures in the bioengineering and nanotechnology industries, to determine their various needs, which often results in commercial discussions leading to consultancy and collaborative research arrangements, contract research and license agreements.

IP management and commercialisation

In line with the 'inside-out' strategy, typical commercial activities include:

- development and implementation of IP-related policies;
- continual IP capture through research and IP census activities;
- IP and commercial assessment of new discoveries;
- filing and maintaining patents;
- protecting the AIBN's intellectual property through confidentiality and material transfer agreements;
- sourcing funding from federal and state government granting schemes in partnership with external companies for collaborative research; and
- packaging IP in preparation for out-licensing and the formation of start-up companies.


Opportunities for industry

The AIBN is an IP-rich environment with innovative technologies, cutting edge capabilities, acknowledged research leaders and a culture of collaboration. It adds value through the research and development of new processes, technologies, materials and devices in the following areas:

- Nanotechnology-based imaging and drug delivery for therapeutic products;
- Regenerative medicine: biology, stem cells, micro-bioreactors and novel scaffolds;
- Nanotechnology enabled commodity products for industrial application;
- Novel protein expression utilising metabolomics and systems biotechnology; and
- Nanotechnology for energy and environmental applications.

AIBN is ready, willing and able to work for, or with, industry. The Institute can undertake R&D with flexible arrangements to meet partner's needs, including:

- Consulting;
- Partnering;
- Contract research;
- Licensing; or
- Investment in the formation of a start-up company.

For speculative, strategic or long-term corporate initiatives, it is also possible to sponsor postgraduate research students to explore new areas of research.

Commercial Affiliates Program

The Commercial Affiliates Program is an industry linkage program. It is a network of invited individuals and commercial organisations joining the AIBN to serve as a two-way conduit with industry.

The Program aims to increase industry awareness of the AIBN, its IP, capabilities and expertise, as well as providing a commercial touchstone and industry perspective of its technology and market opportunities.

A preliminary research and IP census of AIBN Group Leaders was conducted during 2005. This on-going process enables the protection and management of the Institute's IP and ensures the identification of new discoveries with intellectual property protection and commercial potential.

Where a discovery proceeds to a provisional patent application, I&CD works closely with the AIBN researchers to establish an IP and commercial strategy, and identify potential sources of R&D funding, from both traditional and non-traditional sources.

To support this growing activity, Ms Sharon York joined the Institute in the role of Innovation and Commercial Development Associate. Ms York is responsible for IP management across the Institute, filing and maintaining patents, protecting the Institute's IP through confidentiality and material transfer agreements, and assisting in the commercial development of AIBN's projects. In addition to her strong chemistry and materials science background, Ms York has over ten years experience in intellectual property protection and is a registered patent attorney in Australia.

Scientific and Commercialisation Committee

The AIBN's Scientific and Commercialisation Committee (SACC), with responsibility for providing advice to the Board and Director on research direction and strategies, met for the first time in 2005.

The members of the Committee are:

- Professor Peter Gray, AIBN Director and Chair;
- Professor Barry Buckland, Vice-President, Bioprocess R&D, Merck & Co; USA;
- Professor Chris Lowe, Director, Institute of Biotechnology, University of Cambridge
- Dr Daniel Syrdal, Attorney, Heller Ehrman Attorneys, USA;
- Professor Craig Hawker, Director, Materials Research Laboratory, University of California, Santa Barbara;
- Professor Chunli Bai, Key Laboratory of Molecular Nanostructure and Nanotechnoloy, Institute of Chemistry, The Chinese Academy of Sciences.

Also attending the SACC meeting were:

- Ms Donna Hannan, AIBN Executive Officer and Secretary
- Dr Craig Belcher, Manager, Innovation and Commercial Development

The inaugural meeting provided SACC members with an appreciation of the Institute's portfolio of research activities and commercial opportunities. All were excited by the scientific prospects of the AIBN and have begun contributing to the research and commercialisation activities of the Institute.

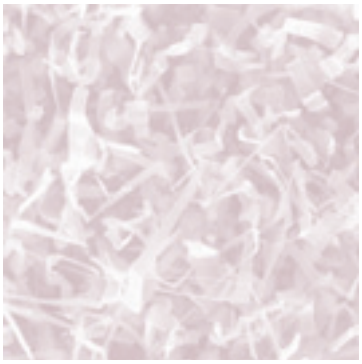
Please contact the AIBN to discuss innovation and commercial opportunities.

Dr Craig Belcher

MANAGER, INNOVATION AND COMMERCIAL DEVELOPMENT

Graduate Program

AS A RESULT OF BEING GRANTED THE ABILITY TO ENROL ITS OWN STUDENTS IN LATE 2004, THE AIBN APPOINTED PROFESSOR LARS NIELSEN AS THE INSTITUTE'S INAUGURAL POSTGRADUATE COORDINATOR.



This important position acts as a delegate of the Institute's Director in making academic, administrative and, in some instances, resource decisions as they pertain to research higher degree (RHD) students and the AIBN's Graduate Program.

AIBN is acutely aware of the important contributions research students make to the success of a research organisation and, as a result, is committed to providing students with a comprehensive set of research skills that will be the foundation of a successful scientific career.

The Institute has implemented policies and procedure ensuring its students will benefit from an intellectually supportive and stimulating environment enhanced by access to state-of-the-art equipment as well as the world-leading researchers found at the AIBN.

Professor Nielsen has been instrumental in developing and promoting the Institute's postgraduate profile as a unique environment in which to undertake a research higher degree. Additionally he was the instigator of the AIBN's Postgraduate Policy and established appropriate procedures for monitoring student progress, and advising on facilities.

Consequently AIBN has now formalised its Graduate Program and implemented various elements to enhance the research experience for its students. These include AIBN's Confirmation Procedure, and the appointment of a Thesis Committee that 'travels' with the student through the course of their research higher degree.

AIBN has established a yearly induction program for new students, and identified areas in which interested students may undertake additional studies concurrent with their higher degree qualification. These elements are enhanced by the resources and training already provided by The University of Queensland's Graduate School.

As a result, AIBN graduates will be recognisable by their high degree of research expertise as well as a variety of complementary skills, with innovation management being one just example.

What's more, 2005 was a very successful year in terms of growing our student population. AIBN had five students enrolled by June, with a further seven joining the program during semester two.

Student	Topic	Supervisor
Ian Aird	*Ex vivo* expansion of neutrophils and neutrophil precursors from cord blood stem cells for treatment of neutropenia	Lars Nielsen
Wendy Chen	Effect of gene dose on hyaluronic acid metabolism	Lars Nielsen
Kwok Cheung	Fuel cell optimisation through data integration and model harmonisation	John Drennan
Yap Pang Chuan	Chemical self-assembly processing: model-based strategies and novel process routes underpinned by fundamental biophysics	Anton Middelberg
Natalie Connors	Identification of properties that affect *in vitro* virus-like particle assembly	Anton Middelberg
Sani Jahnke	Myofibroblast differentiation in models of wound healing	Julie Campbell
Esteban Marcellin	Structured bio-reaction kinetic model of microbial hyaluronic acid production for molecular weight control	Lars Nielsen
Wadcharawadee Noohom	Nano-Hydroxyapatite composite scaffolds for tissue engineering	Kevin Jack
Katharina Porazik	Nanoparticle with application in the delivery of DNA to mammalian cell lines for the production of recombinant DNA-derived proteins	Max Lu & Peter Gray
Andrew Rolands	Conducting porous scaffolds for muscle engineering	Justin Cooper-White
Akshat Tanksale	Nanostructured catalysts for hydrogen production by aqueous phase reforming of biomass	Max Lu
Kylie Varcoe	The development of hyperpolarized (HP) 129 Xenon NMR methods for the study of polymer structure and dynamics	Andrew Whittaker

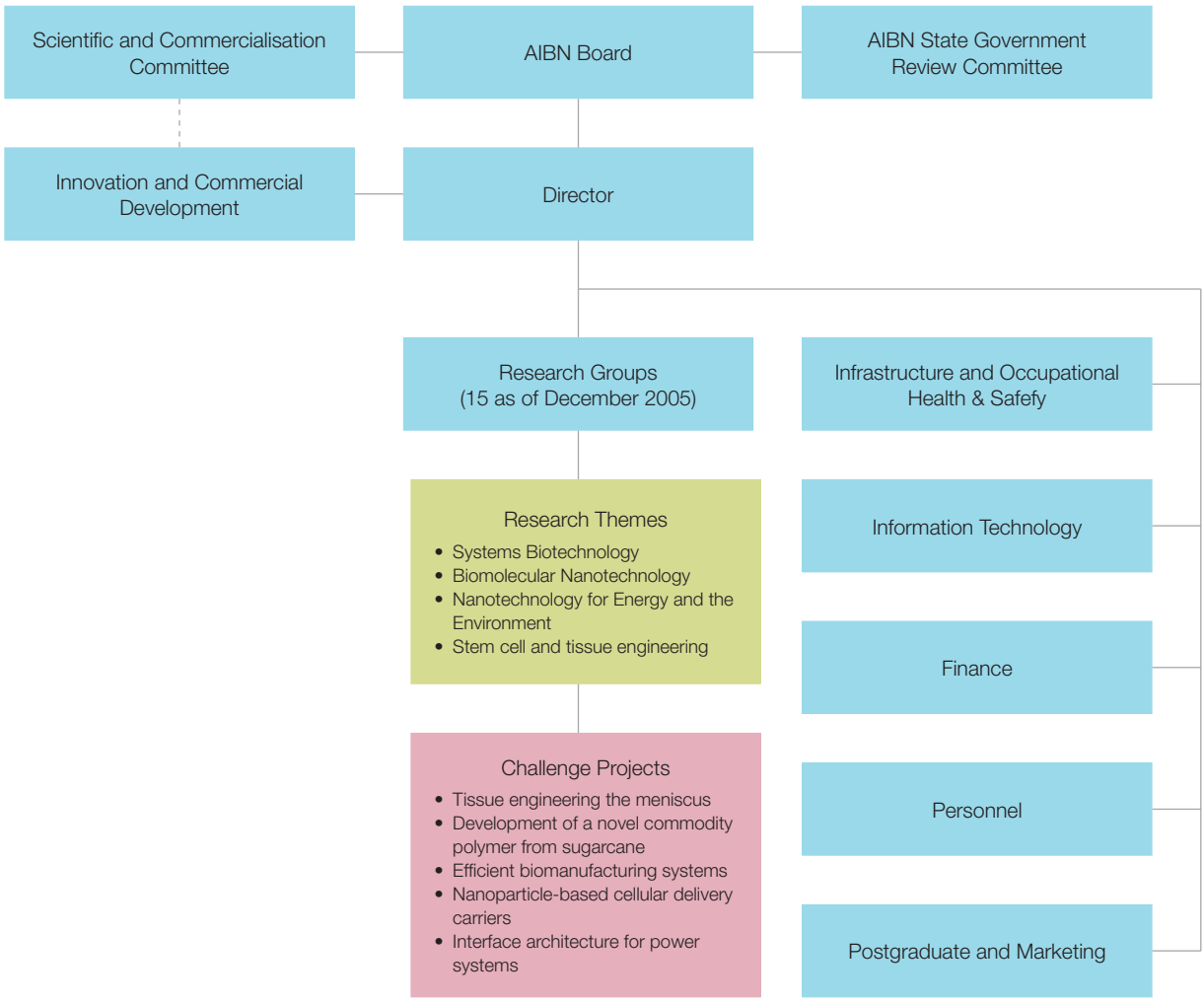
Four of the initial five students were recipients of AIBN Scholarships, which were advertised in November 2004 and designed to immediately attract high-quality students to the Institute. Importantly, several of these students were awarded Australian Postgraduate Awards (APA) scholarships in 2005 and took AIBN's total of successful APA applicants to five.

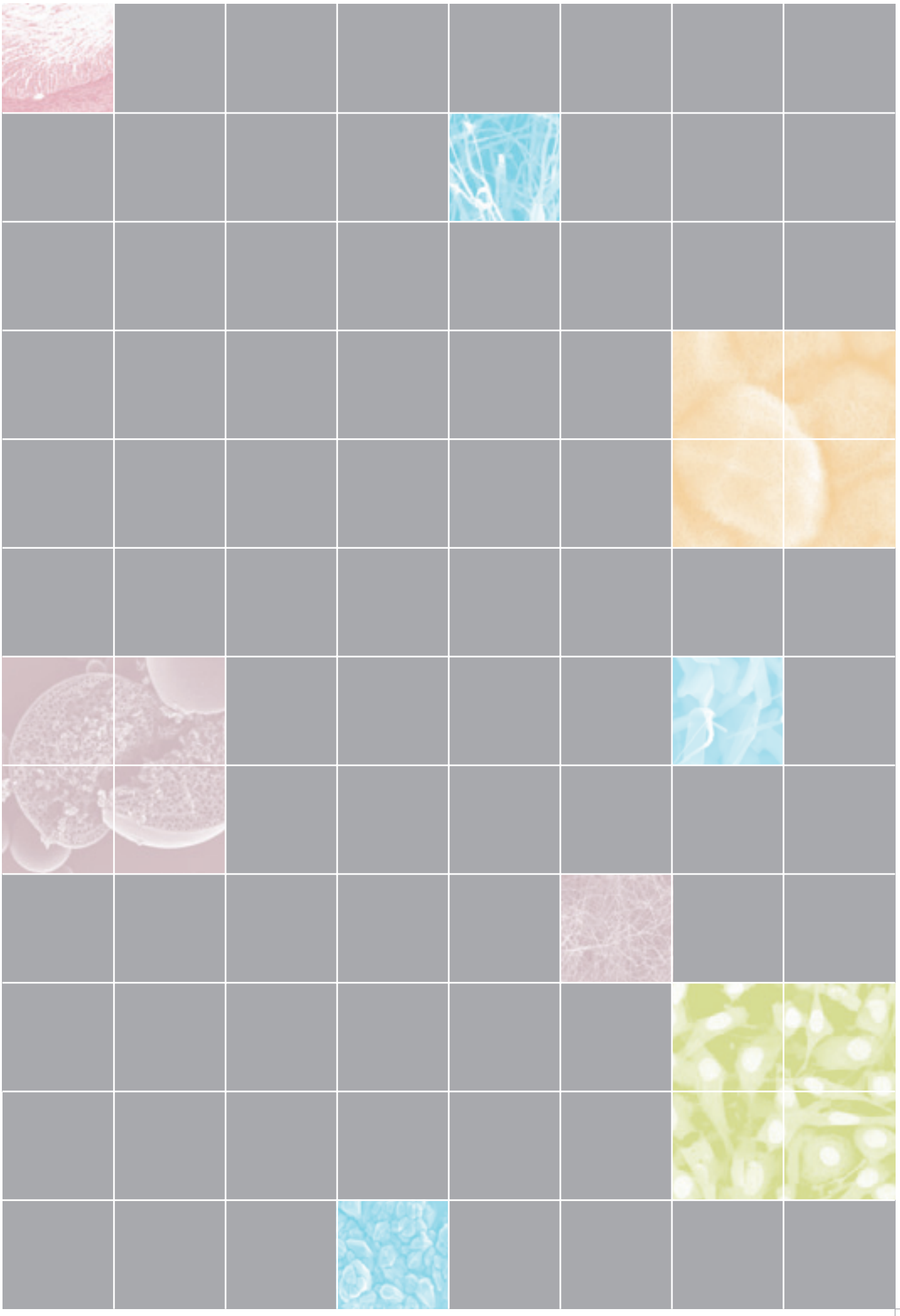
AIBN was also able to nominate, for the first time, two students for the extremely competitive Endeavour Foundation International Postgraduate Research Scholarships (IPRS). Both AIBN-nominated students received funding under this scheme and are expected to commence in early 2006.

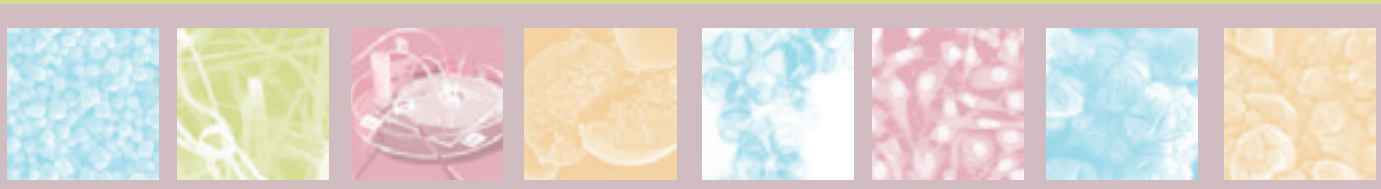
These scholarship successes and growth of the Graduate Program illustrate that high-quality students already recognise the exciting research and commercialisation opportunities available at the AIBN.

Finally, one of our PhD students, Mr Andrew Rowlands, should be congratulated on his recent election as a student representative to the Australasian Society for Biomaterials.

AIBN Organisation Structure







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