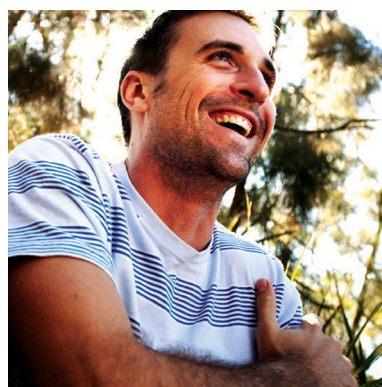




THE UNIVERSITY OF  
**NEWCASTLE**  
AUSTRALIA

**FACULTY OF SCIENCE &  
INFORMATION TECHNOLOGY**



**RESEARCH HIGHER DEGREE TOPICS**

**2012**

**RESEARCH**

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# School of Design, Communication & Information Technology

## COMMUNICATION

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### **Public Relations**

Public relations is both a professional practice and a subfield of communication with its own research and theory base. Public relations is relatively young as an academic field, having developed identifiable theory in only the last 30 years. The theoretical debates are far from settled and scholars from across the world, including scholars from this university, are contributing their research findings to further these debates in areas including the construction of meaning in contested spaces and the strategic management of communication. The field of public relations has developed into a theoretically based area of applied communication that has the potential to inform several areas of communication/mass communication and to offer theoretic and conceptual tools in many areas of communication industry practice. The advent of social media and new technologies potentially provides the field of public relations with huge challenges and opportunities, some of which are the focus of research being undertaken at the University of Newcastle. Projects are invited that explore aspects of the management of communication in public relations contexts, including from critical perspectives offered through discourse or semiotic approaches.

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### **Communication, media and consumption in the cultural sphere**

This contemporary area of study focuses on current and future trends in communication theory/practice created by digital media and the web. With the development of digital media and the online environment, the traditional lines between media and marketing/advertising products are increasingly blurred. The merging of marketing and media content has given rise to fresh concepts such as convergence, transmedia narrative, interactive advertising and a range of new theoretical perspectives. As marketing transforms into entertainment and media increasingly involves promotion, this new media-marketing terrain significantly impacts on

- the role of both media and marketing in the cultural sphere,
- how media and marketing function as cultural producers/intermediaries and
- how we consume these cultural products.

This area of study adopts an interdisciplinary approach from marketing, consumer research, media and cultural studies to investigate new theoretical and practical aspects of this exciting new world of possibilities for communication, consumers and culture.

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### **Creative Practitioner Research**

The research uses a Practitioner-Based Enquiry (PBE) approach in examining how form, format and an aesthetic style develops through the process of Media Practices. Any media project can be used for this research and theoretical approaches using Creativity are also suitable.

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*Research Group: Design, Information & Human Communication*

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### **Creativity and Innovation in Cultural Production**

Creativity is not, according to the latest research, a process of self-discovery in a freely expressive romantic process. Nor is it simply confined to the arts. In fact the latest research is showing that creativity and innovation involves an agent who necessarily engages with the social and cultural structures that both limit and enable their creative activity. It is a basic human activity that works across both the arts and sciences. It is multifactorial in origin. One of the confluence models developed from the current body of research, the systems model of creativity, is being tested at this University in a number of areas. These include journalism, children's literature, songwriting, video and documentary making, website construction, sound and radio production and so on. Projects are invited that explore similar areas of creative concern via an application of the systems model. Methodologies include quantitative and qualitative forms (experiments, surveys, ethnographies and case studies) as well as practitioner-based enquiry (PBE).

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### **Poetics, Aesthetics and Ethics**

Communication practices can be explored through a variety of creative and philosophical approaches. Poetics allows us to understand how we go about doing what it is we do. Poetics allows us to explore the how of what we do as we do it. The outcomes can be creative as well as philosophically novel. Aesthetics allows us to approach communication objects from the perspective of reception. What is the audience response, what do they perceive, how can media artists instruct intentions within objects? Ethics gets us to the why of the what of things. Media objects always raise ethical issues. Media effects is one of the short cuts to this question of why.

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### **Journalism and Public Affairs**

Research in the field of journalism encompasses a very broad area. For example, research can focus on journalists and their actions or journalism and society. Students can research and engage with texts or journalists or their audiences/readers/listeners. Honours research at UoN in journalism has included creative projects where students have combined an exegesis with a creative work. In 2009, one student undertaking journalism-related research created a radio series on "Coal and the Community", while another examined the impact of Web 2.0 technologies on the communication strategies of the major parties on the Australian political scene. Students interested in journalism related topics have a very open brief to develop a research question that will maintain their interest and academic staff work with them to focus that interest in a manner that will result in Honours research work that is focused, enjoyable and very achievable.

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### **How Religion, Media and Culture Intersect**

Projects could take an inter-disciplinary approach in seeking to examine the intersection of these spheres in particular the mediatization of religion and culture.

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### **Current student research projects include:**

- *Effect of Centralisation on Regional Radio: Case Study of the Super Radio Network (SRN) in Northern NSW and South East Queensland.*
- *The Journalist: A Secular Priest? How the News Criteria or Values of 'Secular' Journalistic Practice are Applied to Religious Issues in Contemporary Australia.*
- *The Creative Process and Journalism.*
- *Journalism and the creative process.*
- *Achieving Intended Outcomes: The strategic construction of meaning in public relations practice.*
- *Investigating the Production Process for a Producer/Writer/Director of Video Documentaries.*
- *The Creation of Australian Children's Literature.*
- *'I ♥ Mobile Phone' A Discursive Study of Identity Processes through Mobile Phone Communication.*
- *Wolfgang Iser and Literary Anthropology.*
- *Rock, this city: A history of 'pub rock' in Newcastle, Australia (1973-1987).*
- *The Effectiveness of Online Teaching and Learning on Service-Learning Education in Taiwan.*

### **Recently completed student research projects include:**

- *Global Media, Daily Life and Perceptions of Cultural Change in Bhutan.*
- *Communicating Community: Cultural Production, Habitus and the Construction of a City's Identity.*
- *The Australia-Indonesia Relations (A Study of the Opinion Among Indonesian Residents in Australia About Australia-Indonesia Relations).*
- *Creatures Comfort: An Examination of the Historical Bond Between NonHuman Animals and Human Lived Experiences.*

## DESIGN & NATURAL HISTORY ILLUSTRATION

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Staff within the Discipline of Design support a multi-disciplinary approach to research in the area of Visual Communication Design and Natural History Illustration. Students are encouraged to develop their own projects which will be reviewed before students are accepted into the program. In the past students have come from a variety of discipline areas and projects have covered a wide range of topics. Prospective students are encouraged to submit their proposed project outline for consideration.

### **Current student research projects include:**

- *The Application of Hand-Rendered Techniques in Modern Day Visual Communication.*
- *A Tryptic exploring the design process.*
- *The Australian Wine Label, an Analysis of the Graphic Design and Impact of Visual Communication Strategies in the Wine Industry.*
- *Studies in Visual Anatomy Transported through Digital Media and Three-Dimensional Modelling to Arrive at Two-Dimensional Outcomes in Illustration.*
- *A Visual Interpretation of the Effects of Light within the Natural World.*
- *Bringing to Light the Ghassulian Wall Paintings: Uncovering, Reconstructing and Analysing the Wall Paintings and Corresponding Architectural Landscape of Neolithic/Chalcolithic Teleilat Ghassul, Jordan.*
- *Using NHI to as an Educational Tool to Increase Conservation of Urban Australian Wildlife: Studying Human/Wildlife Conflict and Wildlife Anatomy.*
- *Floral Language or Mapping the Floral.*
- *Red Fox - A Visual Journey into the History of a Creature That is Both Revered and Reviled.*
- *The Psychology of the Gaze.*
- *Just Frogging About: A Frog Field Guide Book of NSW Frogs, Illustrated.*
- *Drawing Now: The Relevance of Drawing, New Directions in the 21st Century.*
- *In Motion: Illustrating the Moment of Motion: a Comparative Approach to Birds and Fish.*
- *Captive Asian Elephants – Conservation Through Art and Science.*
- *Collection and obsession - a case study in creative methodology: the PINcard.*
- *Visualising the Dreamtime: Bringing the Dreamtime Alive Through Words and Pictures.*
- *Adapting Advanced Manufacturing Technology Used in Engineering for Use by Artists Producing Sculpture.*
- *Wild Visions: An Artistic Investigation into Animal Vision and related Natural Environments.*

### **Recently completed student topics include:**

- *Navigational System and Desktop Environment Design Within the Virtual Space.*
- *Illuminating the Scrolls: Illustrating Australian Nature in Response to the Biblical Texts of Lamentations, Ruth, Ecclesiastes and Esther.*
- *Is There Method in the Madness? The Development of an Innovative Field-based Methodology That Can Be Applied to Contemporary Natural History Illustration.*

## **Natural History Illustration**

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*Wildlife Representation Group*

## **Visual Communication Design**

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## **INFORMATION TECHNOLOGY**

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### **Data Mining on Health Research Data**

Data Mining (DM) provides a means for exploratory analysis of large data sets. A number of IT tools and techniques are available for exploratory data analysis. This project aims to explore health research data collected on pregnancies using Data Mining techniques. The project entails working with both IT and Health researchers to analyse the data with the goal of developing a model to characterise status of a pregnancy based on the different characteristics of the data set. The student will use both statistical and DM IT tools to analyse the data and interact with IT and health researchers in interpreting/visualising them.

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### **Atlas-assisted Diagnosis and Assessment of Alzheimer's Disease from Neuroimages**

Despite the intensive research on the brain, it still remains a great mystery. Alzheimer's disease (AD), a major form of dementia, is one of common neurological diseases. Currently, it is still a big challenge to diagnose this degenerative human brain disease. Neuroimaging techniques provide the possibility to investigate the human brains in vivo subjects. However, processing of neuroimages is a challenging problem due to complicated brain anatomy and function and a variety of techniques for brain imaging. Atlas-assisted brain image processing is one of major approaches for medical image analysis, and shows its clinical values in the applications in stroke. The target of this research is to build an approach for AD early diagnosis and severity assessment in a way of processing neuroimages, based on a digital atlas with labels of AD-specific structures. The proposed approach will be designed and efficiently implemented and, subsequently, dedicated algorithms for analysis of AD will be developed.

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### **Security of Remote Transactions**

The research area involves aspects of security in the electronic commerce and online payment systems. It will provide a new practical mechanism to simplify the payment procedure, reduce risk, and protect customer data, as well as enhancing customer's trust. It is based on mobile device technology which based on mobile code that is an intermediary between the customer and the other parties involved in the transaction. Thus, customers will send their information without the worry of disclosure or misuse of their confidential personal information. The results, which will be collected from evaluating the simulation processes, will be analysed by quantitative and qualitative approach in order to support the approach.

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### **Video Content Analysis for Video Adaptation**

The research focuses mainly on video content analysis to achieve personalized video adaptation. Machine learning algorithms are used to map low-level multimodal features to affective and cognitive content. Affective content causes audiences' strong reactions, such as horror content in movies. Cognitive content refers to those semantic events in specific video domains, such as interesting events in sport videos. The detected video content is further used to generate useful meta-data for MPEG-21 Digital Item Adaptation.

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### **An agent-based model of emotion**

The aim of this project is to develop a new model of conflicting emotion which can be integrated into non-playing computer game characters. It will examine current models of emotion and develop a new modelling approach. It will then use agent-based simulation techniques to test outcomes from the model.

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### **Designing sound in computer games**

The aim of this project is to evaluate the performance of players in computer games that provide sound in the interface. Some questions to be looked at include: How is sound currently used in computer games? Does sound actually improve player performance? Can sound displays be better designed to increase (or decrease) the players ability to overcome game challenges.

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### **Visualising patterns in changing information**

The aim of this project is to develop and evaluate some new techniques for visualising dynamic data (e.g. stock market). A generic 3D tool will be developed and applied to a specific application domain (stock market, sport, neurophysiology, etc). The display will be evaluated in the chosen domain.

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### **Pharmaceuticals and the Interactive Human**

This project aims to develop a 3D virtual human that allows pharmacists to train in the complex tasks relate to patient management. The project will leverage off existing work in this area. New styles of interfaces from virtual reality and computer games, such as 3D stereoscopic benchtop displays, multisensory feedback (sound and haptics) and novel interaction devices such as the Wii and Kinect will be considered in the project. The outcomes are expected to be evaluated heuristically in usability trials and more formally using traditional experimental methods. A good appreciation of computer graphics and interface design is recommended for students considering this project. Experience in the problem domain will be provided by Rohan Rasiah from the School of Biomedical Science and Pharmacy.

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### **Facilitating Collaborative Intelligence Analysis Using Computational Methods**

The key question of this research area is: "How can the intelligence analysis process be improved through the utilisation of Digital Collaborative Environment technologies?". Collaboration within and between allied intelligence organisations is vital for effective national and international security. The review of available literature shows that there is a fundamental lack of collaboration within and between intelligence organisations. This lack of collaboration has been blamed for the failure to prevent of more than one terrorist attack, including the September 11th attacks. This research project aims to address some of these issues by investigating, designing, and developing digital collaborative solutions to facilitate Collaborative Intelligence Analysis.

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*Visual Information Processing (VIP) Group*

### **Current student research projects include:**

- *DWT Method on Multimedia Data Mining.*
- *Agent-based simulation of a multi-queue emergency services call centre to evaluate resource allocation.*
- *Improvement to an Image Search Engine Based on Image Parsing.*
- *Customer Trust Satisfaction to Enhance the Security of Remote Transactions.*
- *Ubiquitous Robotics Incorporating Mobile Robots, Sensor Networks and Agents.*
- *Pattern Recognition and Automatic Detection.*
- *How to Create a Prototype for an Aboriginal Website.*
- *An Investigation on Automatic Access Control, Trust Relationship and Privacy Protection in a Digital Ecosystem Environment.*
- *TV Content Analysis, Advertisement Detection and Auto Recognition.*
- *Morphological Analysis of Brain Structures based on Magnetic Resonance Imaging in the Elderly.*
- *Authentication of Computer Users with RFID.*
- *A Grid Resource Allocation Mechanism for Heterogeneous E-Waste Resources.*
- *Atlas-Assisted Assessment and Diagnosis of Alzheimer's Disease from Neuroimages.*

**Recently completed student research projects include:**

- *Content Analysis for Personalised Video Adaptation.*
- *Generalised, Parsimonious, Individual-based Computer Models of Ecological Systems.*
- *Interoperability and Information System Replacement in the Health Sector.*
- *Multimodal Mid-Level Representations for Semantic Analysis of Broadcast Video.*
- *Visualising the Minority Game Using Space-Filling Techniques.*

# School of Environmental & Life Sciences

## APPLIED SCIENCE (OURIMBAH CAMPUS)

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### **Influence of external factors on peripheral blood flow**

Near infrared spectroscopy is a new non-invasive technique that is used to monitor both oxygenated and deoxygenated haemoglobin through muscles. There is little evidence as to the effect that a number of external factors, such as the environment, posture or training has on the validity of its measures. This area of research would target closing these gaps and work towards more advanced applications of the technology.

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Exercise & Sport Science Group

### **Physiology of compression garments**

Compression garments are increasingly popular amongst athletes, though there is very little scientific evidence to support their use. There is an opportunity for students to continue on from several previous studies looking at the benefits and effects of wearing compression garments both during and following exercise.

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### **Adaptation of resistance training methods to female steroid hormone fluctuations**

The female steroid hormone oestrogen is known for its anabolic effects. It would therefore be expected that conditions for muscle growth are better when oestrogen is elevated. Thus the variability in oestrogen levels due to the menstrual cycle may affect the ability of skeletal muscle to respond to training. The aim of this research is to establish if adaptations of resistance training programs to fluctuations in oestrogen will result in greater strength gains than traditional training programs. Significant improvements with the oestrogen adapted training would revolutionize training regimes for female athletes and assist in improving musculoskeletal rehabilitation programs for females.

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### **Applied Sport Science research in Soccer**

There are opportunities for applied sport science research working with a professional soccer team. Details of the project will be determined in consultation with the soccer team's sport science staff.

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### **The effects of nutritional supplementation and resistance training on muscle strength and hypertrophy**

There are opportunities for research analysing the effects of resistance training in conjunction with a range of nutritional supplements on muscle strength and hypertrophy in trained and/or untrained individuals. Details of the project will be determined in consultation with sport science academics.

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Exercise & Sport Science Group

### **Exercise and prostate cancer**

Androgen deprivation therapy (ADT) in men with prostate cancer is associated with a number of adverse effects, including reduced muscle mass and strength. The goal of this project is to characterise the effects of ADT on the fatty infiltration of muscle (myosteatosis) and the role that exercise may play in preventing this change in muscle composition as well as in enhancing physical function.

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### **Exercise and surgical outcomes**

Exercise has been shown to be beneficial in a number of disease states. However, little work has been undertaken in the role of exercise as a form of prehabilitation to enhance the recovery of patients following surgery. This is especially important for older persons who due to their deconditioned state may fall below the strength/functional thresholds for performing daily activities following surgery and the associated recovery period. This project will examine the effects of pre-surgical exercise on patient outcomes, including recovery time and functional status.

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### **Exercise and sarcopenia: is the message getting out?**

For the past two decades exercise has been shown to be an effective countermeasure against sarcopenia and the associated decline in physical function. However, how well this is recognised by physicians remains unclear, especially given the relatively low uptake of resistance training by older adults. The goal of this project is to ascertain the perception by physicians of resistance exercise as a training mode for older persons and develop strategies to enhance the promotion of this exercise mode.

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### **Exercise prescription and programming preferences for people with Multiple Sclerosis (MS)**

Physical exercise is beneficial for MS patients, improving health outcomes and quality of life. However, many people with MS remain sedentary. Understanding exercise programming and counselling preferences may represent an effective method for enhancing exercise participation and adherence in this patient group. The purpose of this project will be to investigate the exercise programming and counselling preferences for persons with MS with the goal to enhance physical activity/exercise participation.

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### **Reproduction, age and growth of the common stingaree, *Trygonoptera testacea***

*T. testacea* is a significant bycatch species in Australian fisheries, including those operating off the NSW coast. Despite this, little is known of their basic biology which significantly limits our understanding of their ecological role and hinders management actions. The aim of this project is to determine key aspects of their reproductive biology, including age/size at sexual maturity, maternity rates, fecundity, reproductive periodicity, litter size, size-at-birth and others, as well as growth and ageing using vertebrae and caudal spines. The potential exists for additional investigations that would allow the development of demographic models for this species.

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Sustainable Use of Coasts & Catchments Group

## **BIOLOGICAL SCIENCES**

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### **Plant and Cell Development, Functional Genomics and Plant Biotechnology**

#### **i) Key signalling events that induce embryo formation from stem cells in the model legume *Medicago truncatula***

The development hormones auxin and cytokinin and the stress hormone ethylene initiate signalling events that activate key genes that produce stem cells and subsequently embryos. How the key signals are integrated is the subject of this project. In addition to improving the understanding of the regulation of plant development, this work has the potential to enable genetic transformation in all species and provide new plant breeding strategies.

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ARC Centre of Excellence for Integrative Legume Research

#### **ii) The regulation of the development of oil and protein bodies in legume embryos and seeds for improving nutrition and use in biodiesel.**

A third of flowering plants are legumes and different species can make a major contribution to human nutrition and as well as for biodiesel stock. The project examines the cellular and genetic mechanisms by which oil and protein are assembled and stored in special cellular compartments in the embryo of the seed. This work has the potential to modify the protein: oil ratio as required.

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ARC Centre of Excellence for Integrative Legume Research

#### **iii) Epigenetics and plant development**

Epigenetics examines genetic changes that are not due to changes in DNA sequence but changes due to DNA methylation and/or histone modification. This project examines the epigenetics of two *Medicago truncatula* strains that have the same DNA sequence but differ in DNA methylation patterns and have developmental differences. This work will help unravel the phenomenon of genetic change due to DNA methylation.

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**iv) Organelle interconnection in cells**

All too often, cells are conveyed as static assemblages of organelles within a bag of cytoplasm. Nothing could be further from the truth, however, and inside live cells exists a highly dynamic environment where organelles undergo continual changes in number, shape and position in response to external cues and intracellular demands. Organelles such as mitochondria, peroxisomes and chloroplasts have all been shown to produce long tubular extensions, respectively called matrixules, peroxules and stromules. The function of these highly dynamic tubular extensions is unknown. This project aims to investigate the function of peroxules and stromules in plant cells, particularly those undergoing dedifferentiation. Findings from this work will potentially revolutionise our understanding of subcellular interactions and how organelle dynamics impinges on cell function.

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**v) Plant mitochondrial fusion proteins**

Mitochondria are critical for the function of eukaryotic cells. Although most genes for mitochondrial proteins are encoded by the nucleus, a number of critical genes exist in the mitochondrial genome. Free radicals produced in mitochondria can damage these genes, causing aberrant gene products to be produced and ultimately leading to non-functional mitochondria. Fusion between individual mitochondria enables them to share genomes and 'dilute-out' aberrant coding sequences, thereby ensuring functionality of the mitochondrial population as a whole. However, little is known about the mechanism of mitochondrial fusion in plants. We have a system in which we can induce massive levels of mitochondrial fusion. By comparing cells undergoing massive mitochondrial fusion with cells in a non-fusing state we hope to identify the proteins that mediate plant mitochondrial fusion. This project has the potential to provide knowledge that may aid treatment of neuropathies such as CMT disease and provide novel ways to breed plants.

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ARC Centre of Excellence for Integrative Legume Research

**vi) Mechanisms of chloroplast repositioning in dedifferentiating plant cells**

Organelles, such as chloroplasts comprise an essential component of plant cells. Ensuring their faithful inheritance at cell division is therefore crucial to the viability of daughter cell generations. Plants possess ordered mechanisms to ensure faithful partitioning of chloroplasts at cell division. Although we know chloroplast partitioning is an ordered and actin filament dependent process, we lack knowledge of the molecular machinery that mediates the interaction of chloroplasts with actin and the components that regulate the coordination of chloroplast repositioning with the cell cycle. This project would use forward and reverse genetic screening to identify genes involved in chloroplast repositioning and has the potential to enhance plant transformation strategies and increase our understanding of mechanisms that drive organelle dynamics in plant cells.

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### vii) **Organelle genome inheritance in dividing cells**

Most genes in plant cells are contained within the nuclear genome and we know a great deal about how genes in the nucleus are partitioned and inherited at cell division. However, many genes critical to plant function reside in the mitochondrial and chloroplast genomes. Inheritance of these genomes during both organelle and cell division is therefore critical to cell function. This project would investigate the replication and dynamics of organelle genomes in dividing cells using a novel fluorescent protein labelling strategy. Project outcomes will improve our understanding of genetic inheritance mechanisms and lead to enhanced strategies for generating transgenic plants.

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### **Metabolomics of bacterial responses to environmental stresses**

Staphylococci represent a clinically significant group of bacteria that cause serious infections. The coagulase positive *Staphylococcus aureus* or “golden staph” is responsible for many life-threatening hospital-acquired (nosocomial) infections and can have multiple antibiotic resistances. The coagulase negative staphylococci, such as *S. epidermidis* and *S. lugdunensis*, can also cause nosocomial infections and are often associated with chronic infections with prosthetic joint implants and associated drug resistance. These staphylococci are all natural inhabitants of the skin surfaces in healthy individuals. The bacteria can respond to the environment to make the most of infection opportunities and change their mode of existence to a virulent form or survival form as appropriate. These phenotypic variations represent obvious responses to environmental challenge and can invade intra-cellularly. This project will explore the metabolic changes associated with ultra-structural and colony changes in SCV formation. Gas chromatography-mass spectrometry will be used to measure biochemical profiles of cytoplasmic composition before and after stresses.

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### **Research within the Plant Science Group is centred around two key themes:**

- 1) **Nutrient allocation** impacting upon crop yield and quality using molecular and cellular approaches;
- 2) **Reconstructing sustainable ecosystems** with native vegetation.

Projects within theme 1 are listed under i) Nutriomics, ii) Transfer cell development, iii) Cotton fibre development, iv) Improving drought tolerance of crops and v) Biofuels. Projects within theme 2 are listed under i) Rebuilding soils, ii) Reconstructing Ecologically Endangered Communities and iii) Restoration potential.

### **Nutrient Allocation in Plant Biology**

- i) **Nutriomics.** Nutrient (especially sugars) transport and metabolism within organs of agronomic significance (e.g. fruit and seed).

#### **Novel membrane transporters**

As membrane transport of sucrose is a key determinant of crop yield, a detailed understanding of genes encoding sucrose transporters provides fundamental knowledge towards increasing crop yield. This

project aims to identify and functionally characterise novel sucrose transporters utilising a yeast mutant as an innovative positive selection tool.

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#### **Enhancing sugar accumulation in tomato fruit**

Fruit sugar levels are a significant agronomic trait, especially in the tomato industry. Sugar transporters have been shown to regulate this trait. The project will develop biotechnological innovations to enhance sugar levels in tomato fruit based around genetically manipulating transporter activities.

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#### **Food security: Improvement of seed and fruit development using gene technology**

Seed and fruit are organs of major agronomical importance. We recently identified a key regulatory gene, *INVINH1*, which controls seed size and fruit sugar level by repressing activity of invertase (INV) in tomato and *Arabidopsis* (Jin et al 2009 *Plant Cell*). Further work aims to elucidate the molecular mechanisms and signalling pathways that controls the co-expression and interaction of the *INVINH1* and its target, INV. The questions will be addressed by using contemporary molecular, cellular and biochemical approaches. Research outcomes may include better understanding of carbon allocation in plants and improvement of seed and fruit yield and quality.

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- ii) **Transfer cell development.** Specialised cells that play a vital role in nutrient allocation in plants.

#### **Building transfer cell wall ingrowths**

Transfer cells have intricately-invaginated wall ingrowth labyrinths that greatly amplify their plasma membranes which in turn contain high densities of nutrient transporters. We can induce epidermal cells of Faba bean seed to form large numbers of transfer cells. This project will use this novel culture system together with contemporary cell imaging techniques and immunolocalization of key regulatory wall building proteins to establish the mechanistic processes involved in forming wall ingrowths.

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#### **Feeding a Hungry World: Manipulating Transfer Cell Development**

This project will use the model species *Arabidopsis thaliana* to investigate genetic control of transfer cell development. Identifying key transcription factors responsible for initiating transfer cell development will provide new avenues for improving yield in important crops. The project will involve gene expression analysis, confocal fluorescence microscopy, and genetic analysis of selected mutants.

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iii) **Control of cell wall biosynthesis for high bio-energy production and crop yield**

This project will use cotton fibre cell and transfer cell as two models to identify genes for modification of plant cell wall composition to increase efficiency of bioenergy production and cotton fibre yield. Contemporary molecular, cellular and biochemical approaches will be utilized to address a set of hypotheses.

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iv) **Manipulating water channel genes for improving drought tolerance of crops**

This project will study water channel genes in the control of water movement in plant cells and design innovative approaches to increase drought tolerance of crops. A combination of molecular, cellular and physiological approaches will be utilized to address relevant questions.

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v) **Biofuels.** Maximising carbon capture by key crops as a biofuel feedstock.

**Sorghum, a biofuel feedstock for arid environments.**

Increasing fuel costs, finite resources and the need to develop more carbon neutral and cleaner fuels have created a need for renewable resources. *Sorghum bicolor* (Sorghum) is a crop plant adapted to the hot water limited environments of northern Australia, both as a grain and forage crop. As a result of its rapid growth rate, sorghum is an ideal crop for biofuel production from grain, sugar and biomass accumulation.

**The TILLING project** (*Targeting Induced Local Lesions in Genomes*):

The overall strategy will be to carry out a survey of natural allelic variation in a broad range of sorghum accessions for candidate genes that may be associated with sugar/starch metabolism or deposition. We will then associate any variants with phenotypic traits including growth rates, biomass, grain quality traits, fibre and sugar content. The correlated specific allelic differences will subsequently be used as 'markers' in screening the populations produced during the course of a larger ARC-LP project.

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vi) **Setaria, an ideal model for dissecting biomass quality traits**

Lignocellulosic bioethanol derived from plant biomass will provide a cost effective contribution to environmental sustainability and energy security. *Setaria italica* (foxtail millet) is an ideal genetic model to dissect biomass quality traits. A large number of plant lines exhibiting broad genetic diversity will be screened using Fourier Transform Infra-Red (FTIR) spectral analysis to identify those ecotypes with differing cell wall composition. Quantitative expression analysis of key genes using RT-qPCR, will be undertaken on the most divergent ecotypes as a platform to unravel the pathways and mechanisms contributing to variation in cell wall composition. Outcomes of this project will contribute significantly to our understanding of the capacity to tailor cell wall attributes to maximise digestibility of plant biomass.

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## Reconstructing Sustainable Ecosystems

i) **Rebuilding soils.** Use of plant-microbe associations to re-establish nutrient cycling.

In badly disturbed ecosystems such as where logging, grazing and mining have occurred, soil function has largely been lost or restricted by erosion, compaction, and physical disturbance. Our principal aims are to capture remaining components of soil biota, determine their role in functional soil, culture them, and return them to reconstructed forest and woodland using experimental methods. Manipulation of the physical characteristics of a site can promote these interactions. The effects of site amelioration, including decompaction, scarification, adding organic materials and inoculation on plant and microbe survival and health is also being investigated.

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ii) **Reconstructing Ecologically Endangered Communities (EECs)**

A number of vegetation communities are particularly threatened by development and have therefore been classified as "Ecologically Endangered Communities" or EECs. These are of particular interest when it comes to reconstructing communities on disturbed land. Experimental testing of techniques such as scalping or ripping the land prior to seeding and planting with a wide range of species are being investigated to determine the best methods of restoring these communities. The cost-benefit relationship of particular reconstruction strategies is also being undertaken. Some species may be difficult to re-establish and research into factors contributing to this including mycorrhizal associations, seed dormancy and site conditions is being developed.

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iii) **Restoration Potential.** Addressing ecological bottlenecks by modifying, monitoring and modelling native vegetation communities.

Ecosystems that have suffered loss of structure and function due to disturbances such as logging and grazing can have bottlenecks preventing pollination, dispersal and the development of regeneration potential. We are using remnant forest and developing dispersal sources to enable understanding of future limitations to regeneration potential and modelling of forest composition. As part of this research we are building and calibrating models of sustainability and resilience. The ecological conductance model seeks to explain the ease or difficulty that organisms confront in completing their life cycles and building restoration potential. Current research is focussed on quantifying the resistances to life cycle completion, including pollination success; seed production and viability; the ability to be recruited into a sustainable population; to form associations with soil microbes; and the development of both spatial and temporal dispersal vectors.

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## SPERMATOGENESIS AND STEM CELL BIOLOGY

### Male germ cells:

#### i) **Germ cell homing to the Stem Cell Niche**

##### *Chemokines and spermatogenesis: roles of SDF-1 and CXCR-4*

In the mammalian testes, numerous spermatozoa are continuously produced throughout adult reproductive life. This process, known as spermatogenesis, is dependent on the establishment early in neonatal development, of a population of self renewing germ line stem cells known as GSC's, from which the highly differentiated haploid spermatozoa are produced. Little is known about the molecular and cellular mechanisms underlying the creation of GSC's from their immediate progenitors, the gonocytes, and how the stem cell niche in which they reside in the testes is defined. Recent evidence from our laboratory suggests that a chemokine SDF-1 and its receptor CXCR-4 are intimately involved in the processes of gonocyte survival and differentiation in the fetal testes and the eventual migration of the GSC population to the stem cell "niche" located in the basement membrane in the post natal testes. The aims of this proposal are: to elucidate the mechanism of maintenance and migration of male germ cells in the developing testis and the role of SDF-1/CXCR-4 interaction in the establishment of stem cell populations in the germ cell niche, to characterize the signalling pathways activated by CXCR-4 and their role in germ cell differentiation and to investigate the use of knockdown and overexpression technologies in vivo and in vitro to manipulate germ cell survival and differentiation.

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#### ii) **Retention of Spermatogonial Stem cell phenotype**

Crucial to spermatogenesis are a number of RNA binding proteins, which are expressed in germ cells. These proteins are responsible for the control of post-transcriptional regulation of the multitude of mRNAs coding for proteins essential for latter stages of germ cell and spermatozoal development. Musashi (Msi) is an RNA binding protein family and we recently investigated the role of Musashi family in the Drosophila and mouse testes and showed that Drosophila Msi is both expressed and required in spermatogonial stem cells for maintenance of stem cell fate. We also found that cell-autonomous loss of Msi in the Drosophila testis results in the premature differentiation of spermatogonial stem cells, indicating an intrinsic requirement for Msi for regulation of stem cell maintenance – we have produced a transgenic msi1 mouse for overexpression studies and this project aims to characterise this mouse.

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iii) **Molecular Pathways of Germ Cell Differentiation**

We are seeking to understand the transition from spermatogonia to spermatocyte at the molecular level. We have identified 2 signalling pathways that interact during spermatogonial differentiation: the BMP4 and retinoid pathways. Previously, we have found that the metabolites of vitamin A, known as retinoids, regulate BMP4 gene expression. The major metabolite of vitamin A is not the active molecule in this case. This challenges a dogma. Testis and germ cells will be examined for vitamin A metabolites. Retinoids, both extracted and commercially available, will be tested by assessing their affects on BMP4 gene expression in isolated cells. Using array technology we have previously identified a number of other genes also regulated by retinoids in the testis. We now intend to determine which of these regulated genes are expressed in spermatogonia. A separate array approach has suggested some candidates.

One project involves confirming the expression and regulation of candidates in spermatogonia treated with a number of retinoids with a focus on the regulation of BMP4 gene expression. Another project involves further analysis of the two sets of array data in combination with published data sets relating to stem cells from other populations. We are also developing a number of models of BMP4 signalling in the germline. These will allow us to determine the role of BMP4 in spermatogonial differentiation. A project exists in characterising the molecular response of the germ line to BMP4.

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iv) **DNA damage in the Germline**

DNA damage in the male germline is associated with poor fertilization rates following IVF, defective preimplantation embryonic development, and high rates of miscarriage and morbidity in the offspring, including childhood cancer. This damage is poorly characterized, but is known to involve hypomethylation of key genes, oxidative base damage, endonuclease mediated cleavage and the formation of adducts with xenobiotics and the products of lipid peroxidation. There are many possible causes of such DNA damage, including abortive apoptosis, the oxidative stress associated with male genital tract infection, exposure to redox cycling chemicals, and defects of spermiogenesis associated with the retention of excess residual cytoplasm. Physical factors such as exposure to radiofrequency electromagnetic radiation or mild scrotal heating can also induce DNA damage in mammalian spermatozoa, although the underlying mechanisms are unclear. Ultimately, resolving the precise nature of the DNA lesions present in the spermatozoa of infertile men will be an important step towards uncovering the aetiology of this damage and developing strategies for its clinical management.

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v) **Transgenerational toxicity**

We are interested in the response of the male germ line to exposure with foreign compounds (xenobiotics). Such exposure can lead to defects in the offspring indicating damage at the level of DNA. We are trying to elucidate the mechanism of damage generation. Using microarray technology we established the cyp gene profile in the male germ line. Cyp genes encode for the phase I detoxifying enzymes; the cytochrome P450s. Further studies on gene expression and toxicology in germ cells are required. In particular we are interested in assessing changes in cyp expression in response to toxicant treatment. We are also looking to measure the formation toxicant-DNA adducts. Currently we are

establishing a DNA damage assay based on real time PCR. This work has been carried out on human DNA. We are interested in establishing this assay in mouse germ cells with a view to high throughput testing of the germ cell response to xenobiotic compounds.

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## MAMMALIAN SPERMATOZOAL BIOLOGY

### Sperm Function:

#### i) ***Epididymal Transit and Maturation***

Upon leaving the testis, spermatozoa are incapable of progressive movement or the cascade of cellular events that result in fertilization of the oocyte. These functional characteristics are only acquired as spermatozoa undergo maturation during epididymal transit. Given the absolute importance of epididymal maturation for the generation of fertile spermatozoa, it is clearly important that the molecular mechanisms supporting this functional transformation be elucidated. Success in this area will have implications both for development of reversible male contraceptive agents and the aetiology of male infertility. This project aims to characterise changes in tyrosine phosphorylation and mitochondrial activation which appear to be particularly important parts of epididymal maturation.

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#### ii) ***Capacitation and Development of Fertilizing Ability***

Transcriptionally inactive spermatozoa rely totally on Post-translational modifications in order to acquire functional competence. These processes occur in two distinct phases; firstly, spermatozoa pass through the epididymal lumen, and secondly, inside the female reproductive tract as sperm capacitate. Both events are essential for fertility, however, the biochemical mechanisms behind the maturation of these cells is unclear. This project aims to characterise the entire gamete of proteins present in spermatozoa. It will also decipher which proteins (peptides) are up/down regulated, or completely new/lost during both maturation procedures. Changes in tyrosine phosphorylation and mitochondrial activation which appear to be particularly important parts of epididymal maturation.

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#### iii) ***Mitochondrial Function and Reactive Oxygen Species***

Reactive oxygen species (ROS) are conventionally considered as detrimental by-products of cellular metabolism, which generate a state of oxidative stress in susceptible cells. Despite the pathophysiological significance of ROS generation in the male germ line, neither the sub-cellular origin nor the biochemical basis for this activity has been established. The major source of ROS generation in somatic cells is postulated to involve electron leakage from the mitochondrial electron transport chain during cellular respiration. In view of our poor understanding of mitochondrial function in spermatozoa, and the potential importance of these organelles as a potential source of oxidative stress in the male germ line in particular, this project is an analysis of the potential competence of human sperm mitochondria to generate ROS and to characterise the significance of this activity in the aetiology of defective sperm function.

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iv) **Monotreme sperm biology**

As iconic symbols of Australia's unique fauna the platypus and echidna generate considerable interest from tourists and the Australian public, thus ensuring that their display in zoos is of significant commercial value. Nevertheless, the record of breeding the 3 extant monotremes in captivity is poor, and the New Guinea echidna faces extinction in the wild. Consequently, knowledge of monotreme reproductive biology is important for conservation practices. This project focuses on elucidation of the molecular processes leading to fertilization in monotremes, including: the proteins which form sperm into bundles to greatly enhance their motility (a unique sperm competition strategy) and the mechanisms involved in sperm bundle formation. The work will provide an understanding of the biological significance of adaptations unique to mammals, the need for maturation of sperm in the epididymis and a subsequent period of capacitation before they are capable of fertilizing an ovum.

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## OVARIAN BIOLOGY

### Oocytes and Folliculogenesis:

i) **RNA binding proteins and oocyte development**

**Musashi 1 and 2**

There is major interest in the molecular mechanisms regulating the maintenance and development of oocytes in the mammalian ovary. Exhaustion of the supply of oocytes results in menopause. The deterioration of oocyte quality with age has significant impacts on female fertility, meiotic defects in the embryo, particularly trisomy 21, and long term susceptibility to conditions such as cardiac disease, diabetes and obesity. Crucial to ovarian function are RNA binding proteins, which control post-transcriptional regulation of mRNAs coding for proteins essential for germ cell and follicle development. We have localised Musashi 1 and Musashi 2, RNA binding proteins with known roles in stem cell specification and meiotic segregation, to the mouse oocyte. This project aims to characterise the expression of Musashi 1 and 2 throughout oogenesis and folliculogenesis and to identify the mRNA target(s) of Musashi 1 and 2 for translational repression in the oocyte, delivering possible therapeutic options for improving human oocyte health.

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ii) **Cytokine signalling and primordial follicle activation**

**Cytokines and ovarian folliculogenesis**

Female germ cells or oocytes are sequestered in primordial follicles before birth and remain quiescent in the ovary until recruited into the growing pool throughout the reproductive years. Programmed follicular cell death continues throughout a woman's reproductive lifetime and ultimately 99.9% of all oocytes are lost prior to ovulation with no opportunity to be fertilised. Very little is known about what triggers follicle

activation, nor the intracellular mechanism by which the coordinated differentiation of somatic cells is harmonized with oocyte growth yet this holds the key to female germ cell maintenance as well as optimising oocyte cell health and development. Studies of pleiotrophic cytokines have suggested that the mechanisms behind follicle activation involve a complex network of bidirectional signalling between cellular components of the ovarian follicle. However little is known about the intracellular signaling pathways activated by these pleiotrophic cytokines. In our pilot microarray gene expression surveys and confirmed by our protein localisation studies, we have identified that two key intracellular signaling molecules Signal Transducers and Activators of Transcription 3 (STAT3) and Suppressor of Cytokine Signalling 4 (SOCS-4) are induced on activation of the murine primordial follicle. The overall goal of our proposed project is to characterise the intracellular cytokine signalling pathways regulating activation and maintenance of mammalian ovarian primordial follicles.

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### iii) **Xenobiotics and folliculogenesis**

#### **Cytokines and ovarian folliculogenesis**

All mammalian ovaries contain a finite pool of primordial follicles from which mature oocytes and ultimately embryos are derived. Recently it has become apparent that synthetic chemical compounds (Xenobiotics), are capable of interfering with normal female reproductive function. Some xenobiotics such as 4-vinylcyclohexane that are prevalent in the environment have been shown to target primordial follicles and trigger atretic oocyte depletion of the ovary leading to premature menopause. Studies of cells other than ovaries have demonstrated that mammalian cells generally have two defence mechanisms (termed Phase I and Phase II enzymes) for the elimination of xenobiotics. Preliminary findings suggest that activation of the Phase I enzymes in the ovary by xenobiotic exposure may have undesirable consequences such as the generation of free oxygen radicals and subsequent DNA damage. With many Australian women opting to delay childbirth, then life long exposure of ovarian oocytes to xenobiotics has repercussions both for the fertility of these women and the welfare of their offspring.

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## FERTILISATION AND CONTRACEPTION

### Sperm Oocyte Interaction:

#### i) **Formation of Sperm Zona Receptor Complex**

Mammalian sperm-egg interaction is arguably one of the most remarkable processes in biological science. This exquisitely specific cell recognition event depends upon a complex cascade of interactions between free-swimming sperm and ovulated eggs. Elucidating the nature of these interactions has been the subject of intense investigation by many laboratories. Although this has led to extensive characterization of the respective gametes, such studies have failed to elucidate the molecular basis of this event. In our considered judgement this lack of success stems from the incorrect assumption that the sperm receptor is a single molecular entity that is constitutively expressed on the cell surface. In contrast, recent research from our laboratory has provided support for a novel hypothesis that sperm-egg interaction is mediated by a multimeric sperm receptor complex. Furthermore, we have compelling evidence that this complex is assembled on the sperm surface through the concerted action of a family of molecular chaperone proteins that reside within specialised membrane domains, known as lipid rafts. In this project we aim to confirm the validity of this model, establish the molecular composition of the sperm surface receptor complexes and characterise the downstream signalling cascades that culminate in fertilisation.

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#### ii) **Oolemma sperm receptors**

Post-coitus, sperm encounter the ovulated oocyte within the fallopian tube, which serves as the site of fertilisation. By the time sperm reach the site of fertilisation they have undergone the prerequisite series of capacitation-associated changes necessary for ultimately achieving fertilisation. Upon penetrating the Zona pellucida, sperm must then recognise and bind to the oocyte plasma membrane. Together, the molecular machinery present in both cell membranes must then interact in a precise manner necessary to facilitate the energetically costly event that is the merger of sperm and egg membranes.

This research aims to identify and characterise egg surface proteins implicated in sperm-egg interaction, by identifying the important GPI-anchored protein(s) as well characterising the role of the tetraspanins and their interacting web partners. In vitro binding and fusion experiments will be used as functional bioassays and mass spectrometry (MS)-based proteomics and bioinformatics-based analyses will be employed to compile oocyte protein databases and to identify candidate proteins responsible for mediating sperm-egg interaction, such as newly identified candidate GPI-anchored proteins.

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iii) **Spermicides and microbicides**

There is an urgent clinical need to research novel methods of fertility control that are also protective against sexually transmitted diseases (STDs) such as the human immunodeficiency virus (HIV) or Chlamydia. The most obvious way to generate such a dual-purpose contraceptive method would be to develop safe, effective spermicides that were also active against a wide range of pathogenic organisms. The currently available formulations such as nonoxynol-9, gramicidin and benzalkonium chloride are effective spermicides but are toxic to the vaginal epithelium and do not provide protection against STDs. Over 60 agents are in clinical trials as potentially safer topical spermicides and/or microbicides. Compounds that have reached this stage of development include acid buffers, detergents, dendrimers, non-nucleoside reverse transcriptase inhibitors and anionic polymers. In addition, a number of potential spermicides/microbicides are the subject of preclinical investigation, including beta-cyclodextrin, cyanovirin, porphyrins, cyclotriazadisulfonamides, dermaseptins, short-interfering RNA (siRNA) and HIV antibodies. This project aims using to characterise the biological activities and mode of action of newly developed target specific compounds as novel dual spermicides/microbicides.

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iv) **Environmental Impacts on Female Fertility**

All female mammalian ovaries contain a limited supply of primordial follicles which are present from birth. Recently it has become apparent that xenobiotics, such as organochlorine pesticides, polychlorinated biphenyls, dioxins, alkyl phenolic chemicals, phthalates and synthetic oestrogens are capable of interfering with normal female reproductive function in both humans and animals. Some xenobiotics that are prevalent in the environment including 4-vinylcyclohexane and benzo[a]pyrene, have been shown to target primordial follicles and trigger atretic oocyte depletion of the ovary leading to premature menopause. Our recent studies of the effects of xenobiotic exposure in the ovary have demonstrated that environmental agents can cause significant primordial follicle loss and oocyte damage through oxidative stress. Our proposed model is based on preliminary findings which indicate that xenobiotic exposure has direct consequences on ovarian function. The aims of this project are: To elucidate the action of xenobiotics in the developing ovary and in particular the role of the Phase I enzymes (Cytochrome p450's) in the generation of reactive oxygen species. To quantify the role of xenobiotic derived oxidative stress on mitochondrial function, plasma membrane fluidity and oocyte dysfunction. To characterize the ovarian follicle signalling pathways activated by xenobiotics and their role in oocyte growth, follicle differentiation and survival. Insight into these processes will illuminate the origins of primordial follicle loss and oocyte dysfunction leading to subsequent ovarian failure and infertility in human females.

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v) **What Makes a Good Egg?**

There is major interest in the molecular mechanisms regulating the maintenance and development of oocytes in the mammalian ovary. Exhaustion of the supply of oocytes results in menopause. The deterioration of oocyte quality with age has significant impacts on female fertility, meiotic defects in the embryo, particularly trisomy 21, and long term susceptibility to conditions such as cardiac disease, diabetes and obesity. Crucial to ovarian function are RNA binding proteins, which control post-transcriptional regulation of mRNAs coding for proteins essential for germ cell and follicle development. We have localised Musashi 1 and Musashi 2, RNA binding proteins with known roles in stem cell specification and meiotic segregation, to the mouse oocyte. This project aims to characterise the expression of Musashi 1 and 2 throughout oogenesis and folliculogenesis and to identify the mRNA target(s) of Musashi 1 and 2 for translational repression in the oocyte, delivering possible therapeutic options for improving human oocyte health.

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vi) **Identification and validation of targets for fertility regulation**

There have been no significant advances in planned fertility regulation since the introduction of the oral contraceptive pill in the 1960s. The purpose of this project is to use our advanced proteomics platform to identify targets for male and female fertility regulation on the basis of their specificity, functional significance and druggability.

The current focus is on the identification of phosphoproteins that are critical to the process of fertilization and then through a knowledge of the kinases and phosphatases that regulate their phosphorylation status to select contraceptive targets that can then be validated by functional genomics in vivo and in vitro.

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## ASSISTED CONCEPTION AND EARLY DEVELOPMENT

The overall purpose of the studies grouped under this heading is to improve the management of human infertility by evaluating the causes of diminished gamete quality and resolving the impact of this damage on the developmental potential of the embryo.

### i) ***Proteomic and Metabolomic Analyses of Gamete and Embryo quality***

This clinically-orientated project research project involves the development of a close interface with collaborators in assisted conception clinics to refine our understanding of gamete and embryo quality. This project will use state-of-the-art techniques in metabolomics and proteomics to define the molecular basis of impaired gamete function and to identify markers for the assessment of embryo quality. Current emphasis is on resolving the molecular basis of impaired gamete interaction at fertilization and the role of oxidative stress in the disruption of fertilization and impaired embryonic development. This project would provide training in advanced mass spectrometry as well as insights into the assisted conception industry.

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### ii) **Epigenetic Defects**

Preliminary clinical data is available to suggest that infertile males generate gametes that possess methylation defects that might have an impact on the developmental potential of the embryo and the health and well being of the subsequent offspring. These defects are characterized by hypomethylation of key sites, which we have hypothesised is due to oxidative damage to the corresponding CpG islands. High-throughput DNA methylation profiling will be used to screen for genome wide methylation defects in the gametes of infertile men. These profiles will subsequently be correlated with presence of oxidative base damage to the sperm DNA. In addition we shall correlate any defects seen in the methylation profiles with the developmental potential of the embryo and the normality of DNA methylation in the offspring.

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## CHEMISTRY

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### **Characterisation of Solid – Liquid Interfaces in Dye Solar Cells (DSC).**

It is clear that burning fossil fuels is not sustainable in the long term. The DSC is a cheap and versatile technology for large scale production of solar cells. The basic element of a DSC is an assembly of titanium dioxide nanoparticles about 20 nm diameter, well connected to their neighbours. As TiO<sub>2</sub> only absorbs a small fraction of the solar energy, dye molecules are attached to the TiO<sub>2</sub> surface to harvest a greater portion of solar light. This project will characterise the structure of the solid – liquid interfaces within the DSC, which will lead to the new DSC designs with increased energy conversion efficiencies.

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### **Effect of Electrode potential on Ionic Liquid Interfacial Structure**

Interest in ionic liquid (IL) based electrochemistry increased markedly around the year 2000, primarily as a consequence of ILs often wide electrochemical windows. Until now atomic force microscope (AFM) experiments have only been conducted at the open circuit potential (OCP), but we have recently modified our AFM cell to allow force curves to be obtained as a function of potential. As the magnitude of the potential is increased the strength with which IL ions are bound to the surface also increases, which will affect a variety of electrochemical processes, including electrodeposition, batteries and capacitors. Experiments planned for this topic will examine interfacial forces as a function of potential across the whole electrochemical window, which will reveal how IL interfacial structure evolves with potential. The effect of dissolved solutes (particularly ions) on interfacial properties will also be examined, allowing mechanisms for tuning interfacial structure to optimise electrochemical performance to be determined.

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### **Ionic Liquid Lubricants**

The use of ILs as lubricants was first proposed in 2001 and since then about 80 articles have appeared on the topic, the majority describing macroscopic measurements. Strong ion adsorption at solid surfaces and robust physicochemical properties, in particular negligible vapour pressure, could lead to high end lubrication applications, such as in electronics or high vacuum environments where ILs could be used without significant product loss. The tendency for ILs to adsorb and spontaneously arrange into interfacial layers results in a coating of ions at the solid interface. In an article published last year we reported that particles suspended in a protic IL were stable to aggregation but settled six times faster than predicted by the Stokes equation, and suggested that the same interfacial IL structure that imparts stability could have a lubricating effect. This project will measure friction as a function of cation alkyl chain length, after which the cation and anion species will be varied.

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### **Nanostructures in Ionic Liquids**

Ionic liquids are molten salts, which means they are salts in a liquid phase, not simply salts dissolved in water. Surfactant molecules dissolve in ionic liquids and can self assemble into nanostructures like micelles, liquid crystals and microemulsions, just like they do in water. This project will examine various surfactant structures in ionic liquids. Our aim is to use surfactant templating of glass-forming ionic liquids as a way of designing and

creating permanent high surface area structures from microemulsions and liquid crystals. These materials could be used in catalytic or separation technologies.

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**Catalytic Oxygen Transfer Reactions to Unsaturated (Allylic) Alcohols from H<sub>2</sub>O<sub>2</sub> using sandwich-type Transition Metal-Substituted species [WZn{M(L)}<sub>2</sub>(ZnW<sub>9</sub>O<sub>34</sub>)<sub>2</sub>]<sup>n-</sup>, where M = M(III) or M(II) transition metal ions and L = H<sub>2</sub>O.**

The catalytic oxidation of organic substrates, whether in the laboratory or as used by industry, requires a catalyst and a source of oxygen. Under homogeneous conditions, polyoxometalate ions can act as efficient oxygen transfer agents for a range of oxygen donors. Arguably, other than O<sub>2</sub> itself, which mostly reacts by radical processes, H<sub>2</sub>O<sub>2</sub> is the most cost-effective oxygen donor (with 47% active oxygen). In addition to the synthesis of the sandwich-type polyoxometalate ions [WZn{M(H<sub>2</sub>O)}<sub>2</sub>(ZnW<sub>9</sub>O<sub>34</sub>)<sub>2</sub>]<sup>n-</sup>, where M = Mn<sup>3+</sup> (n = 10), and Zn<sup>2+</sup>, Co<sup>2+</sup> and Pd<sup>2+</sup> (n = 12), this project will explore the kinetics of oxygen-transfer reactions using these sandwich compounds as catalysts in selected reactions with allylic alcohols. Studies will be made under biphasic and homogeneous conditions, including the use of ionic liquids.

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**The selective oxidation of small alkanes by new generation catalysts – green heterogeneous catalysis**

This project deals with the study of new solid-state catalysts for the oxidation of isobutane to methacrolein and methacrylic acid, which lead to the commercially important Perspex. The catalysts are heteropolyoxometalates and related oxide-based materials. Studies will involve the design, synthesis, characterisation and application of the catalysts, and there are many aspects of this work applicable to both PhD and Honours projects.

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**Advanced Supercapacitors**

Modern electronic devices (e.g., consumer electronics and electric/hybrid vehicles) place considerable demands on their respective power sources, to the point where device efficiency is compromised. The inclusion of a supercapacitor has the potential to improve the specific power density and also cycle efficiency of all types of power source. We have recently made considerable advances in improving supercapacitor performance (e.g., 800 F/g for existing systems compared to >2000 F/g in our advanced materials). Projects in this area will be focus on both understanding the origin of this improved performance, as well as implementing these materials into prototype supercapacitors. This work is funded by CSIRO Division of Energy Technology and CAP-XX, and is also in collaboration with the Ecole Polytechnique de la Universit e de Nantes and National Taiwan University.

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### **Catalysts for Fuel Cells**

Energy can be stored in many chemical forms, and hence used in many different ways. One way is in a fuel cell, of which there are numerous varieties. The cathodic reaction in all though involves reduction of  $O_2$  to  $H_2O$  on the surface of a suitable catalyst. This is currently the limiting performance feature of all fuel cell technologies because of its slow reaction kinetics. This focus of projects in this area is to examine the factors that cause slow  $O_2$  reduction kinetics, and to then address these limitations with novel solutions. One particularly important aspect is to examine the role that adsorption plays in determining  $O_2$  reduction kinetics. This work is in collaboration with the Massachusetts Institute of Technology.

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### **Corrosion Phenomena in Electrode Materials**

Corrosion is an electrochemical phenomenon that can have a devastating effect on all forms of infrastructure if it is not properly monitored and controlled. Projects in this area are focussed on understanding the corrosion phenomena that metals such as titanium and copper undergo, and then developing strategies to minimize their corrosion. Titanium, for example is used as the anode substrate in many modern high volume electrolysis processes, yet it is subject to corrosion and passivation which effectively destroys its performance. Similarly, copper is used as an earthing electrode in modern power infrastructure, in which case its corrosion and failure lessens the safety of such a network. Support for these projects comes from Energy Australia.

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Priority Research Centre for Energy

### **High Performance Battery Systems**

The backbone of energy storage in modern society is the battery. Of course many systems are commercially available, each having been developed to power a specific type of electronic device. The importance and extent of efficient energy storage will increase in the future due to the required move away from fossil fuel powered energy. Projects in this area will focus on the development of advanced materials, and improving our fundamental understanding of the charge storage mechanisms various materials possess. Funding in this area comes from the CSIRO Division of Energy Technology (Li-ion systems), Duracell (advanced  $MnO_2$ ), Pure Energy Battery Systems (rechargeable  $MnO_2$ ), and Litronik Batterietechnologie (battery systems for implantable pacemakers).

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### **Hydrogen Production**

Hydrogen has been variously described as the perfect fuel. It is abundant, chemically non-toxic, and it burns to produce non-toxic species. However, its main limitation to commercial uptake is its synthesis, since it requires more energy to produce hydrogen than what is returned upon its combustion. Projects in this area revolve around the use of the Hybrid Sulfur (HyS) Cycle for the large scale production of hydrogen. Using renewable energy inputs water can be split into its components through the use of a sulphur-based intermediate. Part of the HyS cycle involves an electrolysis step ( $SO_2$  oxidation to  $H_2SO_4$ ), the efficiency of which is a significant limitation to the overall process. Therefore, our focus will be on developing an understanding of the oxidation mechanism, and developing new catalysts to facilitate its improvement. This work is in collaboration with the CSIRO Division of Energy technology.

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### **Molecularly Imprinted Polymers (MIPs)**

Molecular imprinting is an effective method of imparting highly specific and selective recognition sites in synthetic polymers. First, a molecule of interest (target) is used as the template and allowed to pre-associate with polymerisable (a molecule with a double bond) molecules (*in situ* imprinting) called the functional monomers. The degree of association between the monomer and the template (T) depends on their functionalities but mostly based on simple molecular interactions such as hydrogen-bonding. Secondly, the association between the template and monomer can be fixed in place by polymerisation in the presence of a huge amount non-interacting monomer (e.g. crosslinker), which can impart the robustness required for the polymer. Thirdly, the template is extracted from the monolithic or particulate polymer to leave behind a cavity containing binding sites that are oriented to compliment the functional groups of the template molecule and capable of rebinding the target. Molecular imprinting can also be achieved by *post*-polymerisation imprinting on a pre-prepared polymer, a technique that is very useful for the preparation of MIP films.

#### **i) PNIPAAm-Based Molecularly Imprinted Polymers**

Poly(N-isopropylacrylamide) (PNIPAAm) is a thermoresponsive polymer and is characterised by a lower critical solution temperature (LCST). Below its LCST, PNIPAAm is water-soluble; above its LCST, it is water-insoluble. The LCST of PNIPAAm can be tuned by copolymerisation. For example, its LCST can be lowered to 10°C in the presence of the hydrophobic monomer styrene. Thus, by choosing comonomers that can interact with a target molecule of interest, it is possible to use PNIPAAm copolymers to create molecular moulds. Simply by using the target molecule as template at temperatures below the LCST and preserving the target imprints at temperatures higher than the LCST, PNIPAAm copolymers can be imparted with molecular recognition sites which can be capable of selectively binding the target molecule in the presence of other analytes. This project will focus on the evaluation of the molecular imprinting capability of PNIPAAm copolymers and will involve (a) synthesis of NIPAAm polymers, (b) preparation of PNIPAAm MIPs (c) evaluation of PNIPAAm MIP binding capability (d) characterisation of PNIPAAm polymers and MIPs.

#### **ii) MIP as Reaction Catalyst**

The ability of a MIP to recognise and trap a template/target molecule makes it an attractive alternative catalytic system. Considering the hypothetical synthetic reaction,  $R1 + R2 \rightarrow DP + BP$ , this project will involve (a) the generation of a MIP selective to either DP or BP, (b) evaluation of the selectivity of the MIP with respect to the other substances involved in the reaction – R1, R2 and DP or BP (c) testing the catalytic effect of the MIP by evaluating reaction yields.

#### **iii) Investigation of the Mechanism of Imprinting: Kinetics of the Formation of Imprints**

Recent studies have shown that the formation of molecular imprints is affected by temperature, solvents and polymer composition, and that the imprinting effect can sometimes be missed due to the high binding capacity (though superficial) of its non-imprinted equivalent (NIP). Most of the reported evidence deals with the beginning - presynthetic studies (i.e. molecular modelling and spectroscopic studies) and the end - binding performance of the MIPs and NIPs, but no evidence has been gathered during the early stages of the formation of imprints (i.e. within 12 hours of polymerisation). This study proposes to investigate the early stages of MIP formation with the aim to understand the effect of the template on the polymer structure and the kinetics of template-monomer association and will involve: (a) molecular modelling using Spartan, (b) NMR experiments, (c) free radical polymerisation and (d) quantitation and species identification by GC or LC MS.

#### **iv) Preparation of Clickable Molecularly Imprinted Nanoparticles (MINPs)**

The project will involve the synthesis and characterisation of MIP nanoparticles that are functionalised so it can be covalently attached ('clickable') to a functionalised substrate of interest (e.g. optical fiber) for sensing application. The so-called 'click' chemistry makes use of the copper-catalysed azide-alkyne cycloaddition reaction. Thus, e.g. an azide-functionalised MINP can be coated at the surface of an alkyne-functionalised optical fiber.

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### **Aqueous chemistry of CO<sub>2</sub>, as relevant for greenhouse abatement**

A significant reduction in CO<sub>2</sub> output is crucial for the climate and long-term stability of the planet. In the Australian context an eminently promising method is post-combustion capture (PCC) of carbon dioxide in fossil fuel power plants. While the technology is not new, the process needs to occur on such a scale that it demands significant improvement in overall efficiency. In collaboration with CSIRO our research is directed at developing a complete understanding for the first time of the fundamental chemistry of carbon dioxide removal by amine solutions. Detailed examination of the speed (kinetics), extent (thermodynamics) and energy requirements (calorimetry) of all reactions for a range of amines will produce a model to guide technological improvements. This project is well funded and there is a good prospect of being able to continue working in this field after the Honours year.

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### **Chemistry / Biology / Mass Spectrometry (Kinomics)**

**Kinomics is a new discipline**, not yet commercially available anywhere in the world. It is a merger of genomics (concerned with genes) and proteomics (concerned with proteins) implicated in certain human cancers. It comprises a conceptually simple, *rapid*, large scale, high-throughput screening assay to study most of the cellular "kinome" – that is, most of the protein kinases which are expressed in a cell or tissue at a given point in time. It is important to recognize that kinomics is not limited to identification of the kinome, but can be applied to any cellular signaling pathway. Kinomics can be rendered disease or therapeutic specific. Regardless of the target, kinomics is able to rapidly, accurately, systematically and globally explore and classify therapeutically-relevant protein kinase targets for drug discovery and improved understanding of signalling in cancer. Kinomics will provide insights into signalling networks in multiple cancers, identify potential new therapeutic targets, and identify drug resistance mechanisms and signalling pathways that may lead to unwanted off-target drug effects. Kinomics is potentially the route to rapid diagnostics fingerprints in the emerging arena of disease fingerprinting and personal therapeutics. The ability to undertake a complete kinomic analysis was impossible prior to the development of kinobeads.

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Priority Research Centre for Chemical Biology

### **Flow Chemistry / Medicinal Chemistry / Organic Chemistry**

Traditional organic synthesis is conducted in a batch manner, i.e. small quantities of materials are mixed and heated for a standard period of time, and the product extracted and purified. Recent advances in flow technologies allow continuous production of novel materials. This technology has been introduced to the medicinal chemistry group at the University; it is currently the best-equipped flow chemistry laboratory in Australia. Reactions are conducted at higher temperatures and pressures, which has the effect of increasing reaction yield and compound purity, largely removing the more tedious aspects of compound purification. Students working in this area will develop new approaches to drugs spanning three research programs: anti-epileptic, anti-cancer and anti-parasitic drugs.

This new technology requires subtle optimisation and students will be exposed to cutting edge equipment and ultimately be responsible for the development of new drugs and biological tools to a considerable number of our national and international collaborators.

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### **Medicinal Chemistry / Drug Design**

Today 1% of the worlds' population suffer from epilepsy, of these 30% fail to respond to existing anti-epileptic drugs. Current anti-epileptic drugs were discovered in the 1960s. We have identified a protein called dynamin as a new ant-epileptic drug target and have advanced compounds that only target epilepsy at seizure onset, a significant advance on existing treatments. This is a major collaborative drug discovery and development effort drawing medicinal chemistry experience at the University of Newcastle (McCluskey), neurobiology and neurochemistry at the Children's Medical Research Institute Westmead Hospital (Prof Phillip Robinson), epilepsy (medical aspects) at the Royal Melbourne Hospital / Melbourne University (Prof Terry O'Brien), and the National Institute of Health (USA) (Captain Jim Stables). Students working in this area will experience the full drug development cycle through synthesis and biological evaluation of new drugs. You will advance these drugs to the next stage of evaluation and potentially to animal studies in both Melbourne and USA. During the course of your studies you will be trained in the latest technologies associated with drug design and chemical synthesis (see Flow Chemistry below).

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### **Medicinal Chemistry / Drug Design / Smart Devices**

Current anti-epileptic drugs act by reducing chemical signalling in the brain, **and are always 'on'**. This means that patients have reduced functional capacity, at best it has been compared to being drunk, at worst patients are physically incapacitated and physically ill. Huge numbers of patients are left unable to perform simple day-to-day tasks. This project represents a major advance in the 'on-demand' administration of drugs with the epileptic seizure triggering the release of an anti-epileptic drug at seizure onset. It will develop implantable organic electronic devices with the ability to specifically absorb and release anti-epileptic drugs 'on-demand'. This project is at the interface of chemistry, biology, physics and medicine, a unique opportunity to advance drug delivery in the 21<sup>st</sup> century.

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### **Nanomaterials / Organic Electronics**

Amyloid fibrils are linked to some of mankind's most crippling diseases, such as Cystic Fibrosis, Alzheimer's and type II diabetes, BUT they are emerging as exciting biocompatible, biodegradable, high strength (environmentally friendly), nano-materials, for use in a range of electronic devices. Amyloid fibres have excellent potential as electrically conducting nano-wires. This project will investigate the influence changing the rate of fibre growth has on the physical and chemical properties of the resulting nano-wires. This work will open the door to the next generation of electronic devices.

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Priority Research Centre for Chemical Biology

### **Chemical Taxonomy of Brown Alga *Cystophora* spp.**

In 1995 two significant papers appeared regarding the chemical taxonomy of alga from the *Sargassaceae* (formerly *Cystoseiraceae*) family. Chemical taxonomy uses the secondary metabolites present in an organism to elaborate their evolutionary and taxonomic relationships; Algae that produce similar compounds are closer to each other on the 'family tree' than those that have no compound types in common. Algae from the *Cystophora* genus belong to the *Sargassaceae* and since they are not well studied and are, by and large, only found in temperate Australasian waters, it seemed to us that we could make a significant contribution in this area.

This study is a mixture of interpretation of our previous results and those of others, and investigating the metabolites of the remaining unstudied algae in the genus. Work in this area will also lead into the study of marine chemical ecology.

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*Advanced Synthetic Materials Group*

### **Searching for New Lead Compounds As Dynamin Inhibitors**

Dynamin is an important enzyme in the process of vesicle formation which is one of the mechanisms used to transport chemicals and small particles across membrane walls or as a way of insulating an organism from endogenous or exogenous toxic compounds. In this project we are looking to the marine environment as source for compounds that can act as leads to new classes of dynamin inhibitors. In the initial stages new active compounds will be used to probe the, as yet poorly understood, mechanism of action of this enzyme. In the future this may lead to drugs useful in the treatment of diseases associated with dynamin kinetics, e.g. some common neurological disorders.

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*Advanced Synthetic Materials Group*

### **Nature-inspired silicate nanomaterials for biosensor and biocatalysis applications**

Biosensors are used to detect disease markers and toxins and biocatalysis is increasingly used for manufacturing high yield chemical products with low waste production. Silicate nanostructured materials fabricated based on nature-inspired processes offer major advantages over existing materials. For example, high surface area silicate nanoparticles can be used to immobilise and stabilise a wide range of enzymes under neutral conditions and with high efficiency. The project will create innovative advanced processes for the co-entrapment and stabilisation of active enzymes within silicate nanostructured materials, for new biocatalytic chemistry and biosensing applications. This project will give you the opportunity to gain transferable skills in the areas of biochemistry, physical chemistry and nanotechnology. The project will be co-supervised by A/Prof. Erica Wanless.

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*Priority Research Centre for Advanced Particle Processing and Transport*

### **Direct observation of bubble or droplet coalescence using high-speed video imaging**

Colloidal particles can be used to stabilise foams and emulsions in the absence of any surfactant by adsorbing in close-packed particulate monolayers at the interface. We are investigating the mechanism of bubble and droplet coalescence using high speed video at up to 3500 frames per second in order to understand the role of particles at the interfaces of coalescing bubbles and droplets. Such coalescence processes are important wherever there are bubbles from champagne to mineral separation by froth flotation, and in emulsions from foods to cosmetics. In addition, we have recently installed an important new instrument capable of complementary simultaneous

measurement of interfacial elasticity and surface tension. This will greatly increase our knowledge of bubble-bubble interactions for a range of industries. You will use both techniques to directly observe particle-stabilised bubbles or droplets and their coalescence

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*Priority Research Centre for Advanced Particle Processing and Transport*

### **Mineral processing using minimal water**

There is a need to develop methods to process minerals that will reduce the need to use the large unsustainable quantity of water that is currently used. An important characteristic of any new method is that it must be selective to differences in the physical or chemical properties of the valuable mineral, which is often a sulfide, as distinct from the host rock in the ore, which is usually a silicate. The aim of this project is to attempt to separate various minerals using triboelectric (surface charging) separation, thus obviating the need for water intensive processes such as flotation.

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### **Smart polymeric coatings**

Polymer films can radically change the surface of a material while leaving the bulk properties of the material intact. The polymer surface coating controls the interaction with other objects through nanoscale forces. We will construct the next-generation of polymer films that contain an inbuilt molecular-scale switch from attractive to repulsive interactions, offering a means for dictating macroscopic character such as the wettability, adhesion or friction of a surface. Academic and industrial interest in these coatings is increasing rapidly, for potential application as low-friction coatings for confined parts or rheology modifiers. This project can have either a polymer synthesis, characterisation (atomic force microscopy, optical reflectometry etc), or materials engineering focus. You will join the group effort aimed at synthesising and studying these smart polymer coatings and perform state-of-the-art surface characterisation that will ultimately determine their use!

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### **Surfactant and polymer adsorption**

Surfactant and/or polymer coated interfaces are present in the use of everyday formulations from shampoo to paint. A quartz crystal microbalance instrument will be used to investigate the adsorption of surfactant and polymer molecules at the solid/liquid interface in an effort to develop a sophisticated understanding of the adsorption mechanism and subsequent interfacial behaviour in a variety of solvents (aqueous, non-aqueous, ionic liquids). This project will be co-supervised by Dr Rob Atkin.

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## **EARTH SCIENCES**

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### **An investigation of dissolved organic carbon in stream waters**

Soil organic matter movement on the hillslope and catchment scale is poorly understood. What is even less well known is how soil carbon enters stream and river waters and is ultimately transported out to sea for deep storage. In this project the student will investigate the concentration of dissolved organic carbon in a branch of the Hunter River in which Hancock and his research team have installed water quality instrumentation. The student will be integrated into an existing project and research team investigating soil C on the catchment scale. The project is ideally suited to someone with a GIS and Remote Sensing interest as well as a background in chemistry/biology. End goal will be potentially publishable findings relating soil C to hydrology and catchment behaviour. This project is funded by an ARC Discovery Project grant.

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### **Prediction of soil moisture across catchments from limited spatial data**

Soil moisture is a driving factor in plant growth, runoff processes and agricultural systems. This project will examine soil moisture data from a number of sites in the Upper Hunter and examine how different sites within a number of catchments respond to rainfall. The project will assess how many and where soil moisture should be measured so that catchment scale predictions can be reliably made. The project is part of an ARC Discovery project looking at the spatial and temporal variability of soil carbon. This research is ideally suited to someone with an interest in soils and soil moisture and has good GIS and data management skills.

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### **Relationship between soil carbon and soil erosion**

Soil is the 2nd largest store of organic carbon globally. There appears to be a dearth of studies examining soil carbon at the hillslope and catchment scale. It is important that hillslope soil processes be understood if we are to model carbon dynamics at the catchment scale and better understand the role of soil carbon in climate change. In this project the student will investigate the relationship between soil carbon and its position in the landscape using an existing data set held by Hancock and research team. The student will be integrated into an existing project and research team investigating this issue. End goal will be potentially publishable findings relating soil C to soil erosion and deposition on the hillslope and catchment scale. This project is funded by an ARC Discovery Project grant.

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### **Spatial patterns of vegetation and soil in relation to geomorphology and hydrology in an undisturbed catchment in Kakadu National Park, NT**

In April 2006 Cyclone Monica, a Category 5 Cyclone hit the Northern Territory coast. Monica had a higher intensity than Cyclone Tracey with winds greater than 300km/hr. In mid 2006 an assessment of the impact of the cyclone on vegetation and erosion was done to ascertain the impact of such severe storms. It is important that such assessment be carried out as the climate change models predict a greater frequency and greater intensity of such storms in the future. This knowledge is also important for mine site rehabilitation especially in regard to the safe encapsulation of uranium mining waste. At present there is a large data base ready to be assessed

regarding the number of trees and trees species damaged/fallen in the storm in relation to soil type, geomorphic position and storm intensity.

The project will require several months in Darwin and Jabiru in the Northern Territory and be supported by the Environmental Research Institute of the Supervising Scientist, Department of Environment and Heritage.

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### **The evaluation of erosion models for the assessment of mine site rehabilitation stability and off-site water quality.**

Mining is a central component of the Australian economy. It is vital that best practice environmental assessments and technology be employed to assess post-mining rehabilitation designs. This project will assess the use of the SIBERIA and CAESAR models for their ability to predict erosion and landscape evolution on the ERA Ranger mine in the Northern Territory. These models are state of the art assessment tools and require calibration, validation and then analysis of their suitability as rehabilitation tools. The project is ideally suited for someone with an interest in GIS and Remote Sensing and environmental modelling. The project will require several months in Darwin and Jabiru in the Northern Territory and be supported by the Environmental Research Institute of the Supervising Scientist, Department of Environment and Heritage.

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### **The fluvial geomorphology of Mars**

In recent years a number of high quality maps and digital elevation models of Mars have been available. These are all free to those undertaking research. This data clearly show evidence of fluid flows on Mars. Hancock has developed a range of novel tools in recent years to analyse catchments and this will be applied to Martian landforms. In 2004-2005 Hancock undertook a pilot study and showed that Martian landforms are indeed similar to earth and that techniques developed for analysis on earth are applicable on Mars. This is blue-sky research which could have endless possibilities. End goal will be a better understanding of Martian landforms and the base for a research publication. The project would be ideally suited to someone who has a strong interest in geomorphology/geology as well as GIS and Remote Sensing skills/interest.

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### **The geomorphology and hydrology of mesas**

Mesas are a relatively common landform in arid areas of both Australia and overseas. Relatively little research has been conducted on their geomorphology, hydrology and vegetation patterns. Mesas are thought to be relatively stable landforms consequently the research interest in mesas comes from proposals for their flat caps to be used as radioactive waste storage areas and in Australia mining companies such as Newcrest are very interested in constructing mesas as large waste rock dumps. This project has a number of aspects that could be undertaken:

- The geomorphological modelling of mesas using the SIBERIA landform evolution model
- Rates of soil erosion down mesa hillslopes
- Rock and vegetation surface cover in relation to soil depth.

It is likely that some travel will be required to both Perth and the Telfer mine in the East Pilbara. This project is funded by an ARC Linkage Grant and is in conjunction with The University of Western Australia.

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**The use of remote sensing for the determination of soil carbon, soil erosion and soil biogeochemistry.**

Remote sensing offers the ability to quantify spatial and temporal changes in vegetation, soil quality and potentially soil biogeochemistry especially in relation to soil carbon and soil nitrogen. This project will examine a range of remote sensed data (MODIS, Landsat, ALOS and Quickbird) for their ability to predict above ground biomass, soil C and N as well as soil type and properties. The project is ideally suited for someone with an interest in GIS and Remote Sensing. The project will largely focus on the Upper Hunter Valley but may also examine data from Arnhem Land in the Northern Territory. This project is funded by an ARC Discovery Project grant and be supported by the Environmental Research Institute of the Supervising Scientist, Department of Environment and Heritage.

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**Assessment of General Circulation Model's (GCMs) ability to realistically simulate local and large-scale drivers of natural climate variability in southeast Australia**

Since the release of the IPCC 4th Assessment Report research has been directed at evaluating the ability of GCMs to simulate the present/historical climate in an attempt to identify the GCMs that are best for the region/application of interest. At present, most metrics used to assess the ability of GCMs to simulate climate variables (such as rainfall, temperate etc.) are based on seasonal and annual time scales. However monthly, seasonal, or longer averages can hide biases or systematic errors. This project aims to investigate the potential of an alternate GCM assessment technique which seeks to identify the GCMs that successfully simulate the major local and large-scale climate drivers known to be important for southeast Australia. We already know which GCMs do a particularly poor job at simulating El Niño-Southern Oscillation (ENSO), but what about the other drivers known to influence southeast Australia (e.g. Indian Ocean Dipole, Southern Annular Mode, Interdecadal Pacific Oscillation, Sub-Tropical Ridge, ENSO Modoki etc)?

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**Research into the use of Worms in Mitigating Greenhouse Gas Emissions from Dairy Farms.**

The recently carried Carbon Farming Initiative (CFI) of the Australian Federal Government is a response to the political realities that make agriculture a 'no-go' area as far as outright carbon taxation applies while acknowledging that agriculture itself represents around 17% of the nation's total greenhouse gas outputs. The CFI offers a voluntary scheme to farmers in which carbon credits may be earned through greenhouse gas mitigation projects in line with Australia's undertakings through the Kyoto Protocol. Such credits would be tradable both within Australia and overseas as such markets become operational. Consequently, farmers may obtain significant earnings capacity through such measures. However, in order to qualify any proposed methodology must be rigorously scientifically tested, peer reviewed and largely proven and the methodology itself must be monitored in an on-going manner to further prove the actual savings in order for the payments/credits to be secured. A project is available in collaboration with a small, non-profit company located in

Sydney's south west which has worked on waste reduction measures for many years including worm farming. Many of the worms they grow are fed cow manure and they have noted the capacity of worms to reduce the impact of manure as a greenhouse gas emitter. The research project would aim to test and quantify these claims with a view to determining whether worm farming represents a viable greenhouse gas mitigation strategy.

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### **Characterising southern hemisphere dry epochs and their causal processes**

This project aims to firstly catalogue the location, duration and severity of dry epochs in the Southern Hemisphere. This will involve a literature review and analysis of both instrumental and pre-instrumental (paleo) records. Secondly, the climatic drivers of the identified dry epochs will be investigated with the ultimate objective being to put the current southeast Australian drought into context and to more realistically quantify drought risk so more robust adaptation strategies can be developed.

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### **A comparison of Drought Indices – which one is best for Australia?**

With drought being such a large problem faced so often in Australia, it is crucial that a sufficient method be developed to effectively monitor the various categories and stages of drought. The current system employed in Australia to classify and monitor drought-affected areas (primarily agricultural drought) is the Rainfall Decile System, however there are a number of problems associated with this method, highlighting the need to apply alternative techniques. Therefore, the aim of this project is to review and assess the applicability of existing methods and indices (developed in the USA and Europe) for monitoring drought in Australia that will include, but are not limited to, the Palmer Drought Severity Index, Crop Moisture Index, Byram-Keetch Drought Index, Antecedent Precipitation Index, Standardised Precipitation Index, Total Water Deficit, Rainfall Anomaly Index and the Rainfall Decile System.

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### **Characterising southern hemisphere wet epochs and their causal processes**

This project aims to firstly catalogue the location, duration and severity of wet epochs in the Southern Hemisphere. This will involve a literature review and analysis of both instrumental and pre-instrumental (paleo) records. Secondly, the climatic drivers of the identified wet epochs will be investigated with the ultimate objective being to put recent flood events in QLD and NSW into context and to more realistically quantify flood risk so more robust adaptation strategies can be developed.

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### **Characterising Victorian bushfire risk and its causal processes**

This project aims to firstly catalogue the location, duration and severity of bushfires in southeast Australia, specifically Victoria. This will involve a literature review and analysis of both instrumental and pre-instrumental (paleo) records. Secondly, the climatic drivers of the identified bushfires will be investigated with the ultimate objective being to put the recent “Black Saturday” Victorian bushfires into context and to more realistically quantify bushfire risk so more robust adaptation strategies can be developed.

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### **Defining ‘east coast’ climate**

The area of land between the tablelands and the coast of NSW and southern Queensland is home to more than nine million people. A variety of high impact weather events occur in this area, generating damaging winds, flooding, hail, heavy seas and swell. Rainfall during these weather events also plays a critical role in our State's water supply, filling dams and supplying base flows for inland river systems and groundwater recharge. However, the climatic processes in this part of Australia are the least well-understood in terms of climate change and its impacts. This project will identify the drivers of climatic variability in the ‘east coast region and highlight differences between the ‘east coast’ and other areas of Australia. The project will form the basis for addressing the gaps in our knowledge relating to the impacts of climate variability and change along the ‘east coast’. This is necessary to develop informed and robust planning and adaptation strategies to ensure the sustainability of this heavily populated region.

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### **East Coast Lows and the Newcastle Pasha Bulker Storm**

The June 2007 Pasha Bulker storm was one of the most significant meteorological events in Australia's history. It was the 4th largest general insurance loss since insurance records were started in 1968. The storm consisted of three distinct impacts (1) flash flooding in the urban area of Newcastle on the 8 June (about 1 in 100 year return period) (2) more general flooding on the Hunter River 3 days later and (3) high winds and wave heights, the worst in the Newcastle-Sydney region since the “Sygna” storm in 1974. Both the Pasha Bulker and Sygna storms were the result of an East Coast Low (ECL). ECLs are the cause of most major flood events on the East Australian Coastal strip. The context for the June 2007 ECL and the resulting storm will be provided. How big was it historically? Where and when have similar ECL occurred before, and how frequently? What are the “typical” impacts associated with ECLs and was the June 2007 ECL “typical”? What is the likely trend of ECL intensity and frequency with climate change? What is the likelihood of similar events occurring elsewhere in Australia?

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### **Establish the long-term (1000 years) natural variability of East Coast Lows**

East Coast Lows (ECL) are complex weather systems that travel parallel to the east coast of Australia from south-east Queensland to Victoria. They can cause significant storm damage to both the natural system and human infrastructure (e.g. the Pasha Bulker storm). The historical records over the past century show that the magnitude and frequency of ECLs is linked to decadal-scale variability in the climate system. This project will use insights into the mechanisms that drive climate variability in Australia to produce a time-series of ECL frequency and intensity over (a) the last century using instrumental records and (b) the last 1000 years using proxy data based on palaeo reconstructions. The project will provide the basis for risk assessment of extreme ECL events both under natural and anthropogenic climate change.

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### **Interaction of Early Triassic magmas in New England**

This project is similar to the above, but involves studies of coeval mafic and felsic suites of the Late Permian - Early Triassic. In contrast to the Late Carboniferous, mafic magmas are more restricted in the Triassic, and largely occur as dykes. Dykes of intermediate and felsic composition are more abundant than the mafic varieties, however, a full spectrum of compositions from basaltic through to rhyolitic dykes occur.

The project would involve determining the physical and genetic relationship of dykes to the granite plutons, gaining an understanding of the role and processes of mixing and granite formation:

Does mixing occur in the lower crust, the upper crust, or during transportation in dykes? Are the intermediate magmas a direct mix, or is the process more complicated? How do the felsic dyke compositions (representing liquids) relate to the granites?

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### **Investigation of Early Permian plutons in northern NSW and their relation to the Texas - Coffs Harbour Orocline.**

Recent radiometric dating has revealed more northerly "along strike" extension to the early Permian Bundarra Batholith. This project aims to complete a reconnaissance study of the magmatic character and structural relations of these plutons. The timing and formation of the Texas-Coffs Harbour Orocline and the relationship of this structure to the plutons is a major focus of the study.

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### **Metamorphism, magma production and structural development of the Moona Plains Complex**

The Moona Plains Complex east of Walcha provides one of the few windows to deeper levels of the New England Orogen. Along with the Tia and Wongwibinda metamorphic complexes, high grade metamorphism and igneous activity occurred during the Late Carboniferous, with uplift during the Late Permian thrusting the complex over low grade Early Permian metasediments of the Nambucca Block. The study would involve structural mapping of the high grade metamorphic (amphibolite facies?) and igneous rocks in order to unravel the structural and metamorphic history of the area (including the late Permian uplift), and understand the complex's structural relationship to adjacent low grade rocks. Field mapping would be supported by petrographic, x-ray and microanalytical studies on campus.

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### **Exhumation of eclogites and blueschists – a tectonic ambiguity?**

The exhumation of deep crustal depths is an enigmatic process not comprehensively explained by tectonic theory. In the New England Orogen, eclogite and blueschist facies rocks (from depths of 20-60 km) are exposed and generally enveloped by highly deformed serpentinite. This project will use information deciphered from detailed analysis of tectonic fabrics formed in serpentinite and tectonic melanges to provide inferences on structural processes associated with exhumation of deep crustal rocks. The results of this project will provide important information on a long-standing tectonic ambiguity that has puzzled tectonicists for years.

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### **Formation of eclogites and blueschists – what can they tell us about plate tectonics?**

Eclogite and blueschist facies rocks form under high-pressure tectonic conditions and are generally associated with processes occurring along plate margins. This project will use detailed petrography and thermodynamic modelling to provide constraints on the evolution of eclogite to blueschist facies rocks exposed in the New England Orogen, NSW. Thermodynamic modelling will be carried out using the computer software THERMOCALC and will involve the calculation of phase diagrams with the aim of constructing pressure-temperature paths. The primary aim of this project is to provide robust physical constraints on the processes that occur in subduction zones.

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### **Identifying contraction and extension cycles in orogenic belts**

The geological record of the New England Orogen preserves evidence of successive periods of contraction and extension. The role of these contraction and extension cycles on controlling crustal growth and genesis of base metal deposits is still poorly understood. In this project, the student will unravel the deposition and then deformation history of Permian-Triassic basins exposed throughout the New England Orogen. To tighten up timing constraints on basin forming and closing events, geochronology will be an integral part of the project. This project will deliver improved timing and kinematic constraints on the evolution of an advancing-retreating orogenic system, which can be integrated into crustal growth or ore genesis models of Australia.

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### **Is crustal growth controlled by tectonic setting?**

The New England Orogen provides an ideal location to study the potential relationships between crustal growth and tectonic setting. During its 200 million year history, the New England Orogen was characterised by periods of advancing and retreating subduction as well as high and low geothermal gradients. As result, granite genesis during these periods can be studied to evaluate the contribution of crustal vs. mantle material - which can be achieved by carrying out U-Pb and Hf zircon studies. A recent reconnaissance study has revealed a link between periods of subduction zone retreat and large mantle contributions to granites (in turn encouraging crustal growth). The aim of this project is to carry out U-Pb and Hf zircon studies on granites that were emplaced during periods of subduction advance and retreat. This will test the hypothesis that tectonic setting is strongly linked to crustal growth.

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### **Unravelling the structural characteristics of accretionary wedges**

This project will involve combining field mapping with geophysics to interpret the internal structure and kinematic evolution of an accretionary wedge, located as part of the New England Orogen, eastern Australia. The aim of this project will be to compare the structural evolution of this accretionary wedge with analogue (sandbox modelling) and numerical models. This work will significantly add to our understanding of how accretionary wedges and fold and thrust belts evolve.

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## ENVIRONMENTAL SCIENCE & MANAGEMENT

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### **Indian mynah, *Acridotheres tristis*, population control and oral contraceptives (Ourimbah or Callaghan)**

Indian mynahs are an introduced highly invasive bird species that has become so abundant in the last two decades that it has the potential to pose a threat to native bird species, particularly in the competition for tree hollows for nesting. Current population control practices involve labour- and time-intensive trapping programs. The present project will aim to develop and deliver an oral contraceptive for Indian mynahs.

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Neuroscience Group / Priority Research Centre for Brain and Mental Health Research

Contact: *Prof John Rodger*

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Contact: *Dr Carmen McCartney (Co-supervisor)*

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Environmental Biology & Biotechnology Group

### **Assessment of the bioaccumulation of lead in chicken eggs from residential backyards in the vicinity of a disused Lead/Zinc smelter.**

Lead is a widely occurring environmental contaminant. In humans, it acts as a potent neurotoxin and is of particular concern during childhood development. The primary exposure pathway is via ingestion of contaminated soil or dust, but with increases in urban farming, exposure via home-grown produce is an increasing concern. The purpose of this study is to investigate the potential for lead accumulation from soil into chicken eggs produced in urban backyard chicken coops. The metal content of eggs, soil and chicken feed will be measured in 30 backyard coops across the Lake Macquarie and Newcastle regions and a survey of household consumption habits will enable estimation of lead exposure via home-grown eggs.

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Environmental Biology and Biotechnology

### **The ecology and conservation of the green and golden bell frog in the Hunter Region**

The Amphibian Research Group at the University of Newcastle is looking for two highly motivated PhD candidates to participate in a study on population biology and ecology of the endangered green and golden bell frog (*Litoria aurea*), with a focus on understanding habitat requirements, population dynamics, population viability and threatening processes for management and conservation. The work will involve the collection of data primarily from field surveys, trapping and radiotracking, supported by controlled experiments and population modelling. The prospective students will join a large and dedicated team of scientists and students working in the fields of amphibian ecology, evolutionary biology and conservation.

Contact: *Prof Michael Mahony*

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Environmental Biology and Biotechnology

### **Toward a Chlamydia Vaccine for the Koala**

The *Chlamydias*, particularly the strains *C. pecorum* and *C. pneumoniae*, are a major cause of disease in koalas. Chlamydial disease in the urogenital tract causes wet bottom, inflammation, lesions and sterility. Infection of the respiratory tract and eyes causes pneumonia, conjunctivitis and blindness. Yet there is currently no preventative treatment for this disease in koalas. This project aims to underpin the development of an effective koala chlamydia vaccine by establishing the fat-tail dunnart as a marsupial model species for *Chlamydia* infection. Longer-term, vaccine formulation and delivery strategies capable of eliciting appropriate protective immune responses in the marsupial reproductive tract will also be investigated.

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### **Assisted Reproduction for Dasyurids**

Native carnivorous marsupials such as quolls and Tasmanian devils are increasingly at risk of extinction. The conservation of such dasyurid species is important for ecosystem maintenance because, as top carnivores, they have essential roles in pest control, carcass removal and subsequent disease control. This project aims to develop both short- and long-term sperm preservation methods for a well studied dasyurid model species, the fat-tailed dunnart, as well as examining their applicability various endangered quoll species and the Tasmanian devil. The isolation, culture and maturation of dasyurid oocytes will also be examined with the long-term aim of establishing intracytoplasmic sperm injection (ICSI) methods for dasyurids. Such assisted reproductive techniques (ART) will provide valuable tools for maximising the genetic diversity in current captive breeding programmes for Eastern quolls and the Tasmanian devil, and for gene banking in the longer-term.

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Environmental Biology and Biotechnology

### **Fertility-based population control for the feral Common (Indian) Myna**

Progress is being made in the US and Europe using various chemical sterilants to control feral birds. One in particular Nicarbazine (an antibacterial drug used in the poultry industry) is registered in the USA for pigeon control and is being tested experimentally for a range of pest species. Ovocontrol acts in birds to reduce egg hatching or egg production. The project will examine the dose effects and delivery strategies of Nicarbazine for the Common Myna.

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### **Assessment of General Circulation Model's (GCMs) ability to realistically simulate local and large-scale drivers of natural climate variability in southeast Australia**

Since the release of the IPCC 4th Assessment Report research has been directed at evaluating the ability of GCMs to simulate the present/historical climate in an attempt to identify the GCMs that are best for the region/application of interest. At present, most metrics used to assess the ability of GCMs to simulate climate variables (such as rainfall, temperate etc.) are based on seasonal and annual time scales. However monthly, seasonal, or longer averages can hide biases or systematic errors. This project aims to investigate the potential of an alternate GCM assessment technique which seeks to identify the GCMs that successfully simulate the major local and large-scale climate drivers known to be important for southeast Australia. We already know which GCMs do a particularly poor job at simulating El Niño-Southern Oscillation (ENSO), but what about the other drivers known to influence southeast Australia (e.g. Indian Ocean Dipole, Southern Annular Mode, Interdecadal Pacific Oscillation, Sub-Tropical Ridge, ENSO Modoki etc)?

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Environmental & Climate Change Group

### **Characterising southern hemisphere dry epochs and their causal processes**

This project aims to firstly catalogue the location, duration and severity of dry epochs in the Southern Hemisphere. This will involve a literature review and analysis of both instrumental and pre-instrumental (paleo) records. Secondly, the climatic drivers of the identified dry epochs will be investigated with the ultimate objective being to put the current southeast Australian drought into context and to more realistically quantify drought risk so more robust adaptation strategies can be developed.

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### **Research into the use of Worms in Mitigating Greenhouse Gas Emissions from Dairy Farms.**

The recently carried Carbon Farming Initiative (CFI) of the Australian Federal Government is a response to the political realities that make agriculture a 'no-go' area as far as outright carbon taxation applies while acknowledging that agriculture itself represents around 17% of the nation's total greenhouse gas outputs. The CFI offers a voluntary scheme to farmers in which carbon credits may be earned through greenhouse gas mitigation projects in line with Australia's undertakings through the Kyoto Protocol. Such credits would be tradable both within Australia and overseas as such markets become operational. Consequently, farmers may obtain significant earnings capacity through such measures. However, in order to qualify any proposed methodology must be rigorously scientifically tested, peer reviewed and largely proven and the methodology itself must be monitored in an on-going manner to further prove the actual savings in order for the payments/credits to be secured. A project is available in collaboration with a small, non-profit company located in Sydney's south west which has worked on waste reduction measures for many years including worm farming. Many of the worms they grow are fed cow manure and they have noted the capacity of worms to reduce the impact of manure as a greenhouse gas emitter. The research project would aim to test and quantify these claims with a view to determining whether worm farming represents a viable greenhouse gas mitigation strategy.

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Environmental & Climate Change Group

### **Characterising southern hemisphere wet epochs and their causal processes**

This project aims to firstly catalogue the location, duration and severity of wet epochs in the Southern Hemisphere. This will involve a literature review and analysis of both instrumental and pre-instrumental (paleo) records. Secondly, the climatic drivers of the identified wet epochs will be investigated with the ultimate objective being to put recent flood events in QLD and NSW into context and to more realistically quantify flood risk so more robust adaptation strategies can be developed.

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### **Characterising Victorian bushfire risk and its causal processes**

This project aims to firstly catalogue the location, duration and severity of bushfires in southeast Australia, specifically Victoria. This will involve a literature review and analysis of both instrumental and pre-instrumental (paleo) records. Secondly, the climatic drivers of the identified bushfires will be investigated with the ultimate objective being to put the recent "Black Saturday" Victorian bushfires into context and to more realistically quantify bushfire risk so more robust adaptation strategies can be developed.

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### **East Coast Lows and the Newcastle Pasha Bulker Storm**

The June 2007 Pasha Bulker storm was one of the most significant meteorological events in Australia's history. It was the 4th largest general insurance loss since insurance records were started in 1968. The storm consisted of three distinct impacts (1) flash flooding in the urban area of Newcastle on the 8 June (about 1 in 100 year return period) (2) more general flooding on the Hunter River 3 days later and (3) high winds and wave heights, the worst in the Newcastle-Sydney region since the "Sygna" storm in 1974. Both the Pasha Bulker and Sygna storms were the result of an East Coast Low (ECL). ECLs are the cause of most major flood events on the East Australian Coastal strip. The context for the June 2007 ECL and the resulting storm will be provided. How big was it historically? Where and when have similar ECL occurred before, and how frequently? What are the "typical" impacts associated with ECLs and was the June 2007 ECL "typical"? What is the likely trend of ECL intensity and frequency with climate change? What is the likelihood of similar events occurring elsewhere in Australia?

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### **Establish the long-term (1000 years) natural variability of East Coast Lows**

East Coast Lows (ECL) are complex weather systems that travel parallel to the east coast of Australia from south-east Queensland to Victoria. They can cause significant storm damage to both the natural system and human infrastructure (e.g. the Pasha Bulker storm). The historical records over the past century show that the magnitude and frequency of ECLs is linked to decadal-scale variability in the climate system. This project will use insights into the mechanisms that drive climate variability in Australia to produce a time-series of ECL frequency and intensity over (a) the last century using instrumental records and (b) the last 1000 years using proxy data based on palaeo reconstructions. The project will provide the basis for risk assessment of extreme ECL events both under natural and anthropogenic climate change.

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*Environmental & Climate Change Group*

### **Defining 'east coast' climate**

The area of land between the tablelands and the coast of NSW and southern Queensland is home to more than nine million people. A variety of high impact weather events occur in this area, generating damaging winds, flooding, hail, heavy seas and swell. Rainfall during these weather events also plays a critical role in our State's water supply, filling dams and supplying base flows for inland river systems and groundwater recharge. However, the climatic processes in this part of Australia are the least well-understood in terms of climate change and its impacts. This project will identify the drivers of climatic variability in the 'east coast region and highlight differences between the 'east coast' and other areas of Australia. The project will form the basis for addressing the gaps in our knowledge relating to the impacts of climate variability and change along the 'east coast'. This is necessary to develop informed and robust planning and adaptation strategies to ensure the sustainability of this heavily populated region.

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### **A comparison of Drought Indices – which one is best for Australia?**

With drought being such a large problem faced so often in Australia, it is crucial that a sufficient method be developed to effectively monitor the various categories and stages of drought. The current system employed in Australia to classify and monitor drought-affected areas (primarily agricultural drought) is the Rainfall Decile System, however there are a number of problems associated with this method, highlighting the need to apply alternative techniques. Therefore, the aim of this project is to review and assess the applicability of existing methods and indices (developed in the USA and Europe) for monitoring drought in Australia that will include, but are not limited to, the Palmer Drought Severity Index, Crop Moisture Index, Byram-Keetch Drought Index, Antecedent Precipitation Index, Standardised Precipitation Index, Total Water Deficit, Rainfall Anomaly Index and the Rainfall Decile System.

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The following represents a partial list of projects available. Please contact the respective academics for more details.

**Relationships between increased metabolic rate and demands on food resources in aquatic invertebrates**

This project could be conducted with marine or freshwater invertebrates and has the potential for using chemical stressors and/or increased temperature associated with climate change as the driver for metabolic change. The basic question is 'Do animals with elevated metabolic rates eat more and so impose greater pressure on available food resources?'

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Environmental Water Science Research Group

**Surveys of the freshwater mussel fauna and associations of mussel assemblages with other freshwater invertebrates in the Hunter River catchment**

Freshwater mussels are among the most endangered aquatic species on a global scale and there is an urgent need to develop indicators of habitat condition that can be used to rapidly evaluate the health of river reaches that support mussel assemblages. Surveys of aquatic insects have been used extensively to evaluate water quality and this group has the potential to serve as early indicators of changing water quality that could impact freshwater mussel survival. In this field-based project, surveys of both mussels and aquatic insects will be undertaken in select rivers of the Hunter-Central Rivers catchment. The specific objective will be to determine if there are specific aquatic insect taxa that are consistently associated with healthy freshwater mussel assemblages and if other landscape-level factors also influence where mussels occur in rivers.

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Environmental Water Science Research Group

**Characterizing the cost of resistance to chemical stressors in invertebrates from a chronically-contaminated field site**

Human activities have lead to a number of chronically-contaminated terrestrial and aquatic habitats in Australia. A key question related to these sites is what the long-term effect of exposure to the existing chemical residues has had on resident organisms. This project will focus on a contaminated site in either NSW (e.g. Cockle Creek, Lake Macquarie) or farther afield (e.g. Port Pirie, South Australia) and use both laboratory and field techniques to determine if aquatic invertebrates from the site exhibit resistance to chemical stressors and if this resistance has an energetic cost as determined by metabolic rate.

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Environmental Water Science Research Group

\*Prof Joe Bidwell also has research interests in:

- Evaluating the quality of urban stormwater in Newcastle,
- Developing indicators of ecosystem function in the Kooragang wetlands,
- Determining salinity tolerances and energetic effects of exposure to freshwater pulses in intertidal invertebrates.

### **Analysis of Sludge in Roof Gutters & Rainwater Tanks in a Mining Community**

A project is proposed in a Hunter Valley community which involves a research student sampling and analysing sludge accumulated in roof gutters and rainwater tanks. The analysis would include elemental composition, soil particle size, hydrocarbon content, microbial population, leaf & humus accumulation & coal content. An attempt would be made to identify sources based on prevailing meteorological conditions and land use activity.

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*Environmental Water Science Research Group*

### **Bioremediation of Contaminated Groundwater**

There is a project looking at remediation using microorganisms and other additives which can be used to assist in the process of decomposing organic contaminants in groundwater.

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*Environmental Water Science Research Group*

### **Microbial and Pathogen Source Tracking in Catchments**

Using a variety of established source tracking methods, a research student would examine various sources of contamination in a catchment and identify potential surface and groundwater pathways. Methods would be used to track sources of chemical & microbiological contamination in the field.

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*Environmental Water Science Research Group*

### **Tracing Sources of Contamination**

A research student is required to examine several tracers used to track sources of contamination in the environment. In particular, the student would examine the fluorometric properties of various fluorescing whitening agents in a laboratory investigation and assist with determining a method for their analysis in environmental samples. Field work would also be required to test the usefulness of a number of the studied tracers in particular environmental applications.

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*Environmental Water Science Research Group*

*\*A/Prof Phil Geary also has research interests in:*

- Environmental impacts associated with the on-site treatment and disposal of domestic and agricultural wastewaters, and stormwaters;
- Movement and fate of contaminants in soils and groundwaters;
- Design and performance of small-scale treatment systems such as sand filters and constructed wetland systems; and
- Effluent transport through vadose zone and tracer applications using fluorescein, bromide and lithium.

### **Effects of estrogenic compounds on native molluscs**

Estrogenic compounds are a subset of endocrine disrupting chemicals which mimic the female sex hormone estrogen. Such compounds are present in sewage effluent and are discharged into our own local aquatic waterways via sewage treatment effluents. We are interested in how estrogenic compounds influence the production of the female egg yolk protein vitellogenin, and using this as a biomarker of exposure in real field situations. We are also interested in the “gender-bending” properties of estrogenic compounds and how estrogens may facilitate sex change, turning males into females in aquatic organisms. There are possibilities for honours students conducting studies both in the field and at the Fisheries Research Station at Port Stephens investigating effects of estrogens on molluscs, including the native commercial, edible species, the Sydney Rock oyster. Such a project would provide both experience in lab and field work and also working within an industry context.

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### **Effects of endocrine disrupting chemicals on gene expression involved in fish steroidogenesis**

In recent years, there has been growing public and scientific concern about environmental chemicals that have the potential to alter the normal functioning of the endocrine system in humans and wildlife. These chemicals, often called endocrine disrupting chemicals (EDCs), may be found in many everyday products, including plastic bottles, metal food cans, detergents, flame retardants, toys, pharmaceuticals, personal care products, and pesticides. The aquatic environment is an important sink for chemicals. Exposure to EDCs, even at minute concentrations, has been linked to abnormal development of gonads, inter-sex conditions, skewed sex ratios and decreases in reproductive success in wild and laboratory aquatic animals. Thus, EDCs have emerged as a major long-term threat to biodiversity and sustainability of aquatic ecosystems.

Steroidogenesis (biosynthesis of steroid hormones) is one of the important biological levels at which EDCs can exert their effects. In fish, early steroidogenesis occurs in the interrenal organ (which is analogous to the mammalian adrenal cortex) of developing embryos. We propose that a subset of EDCs can specifically alter gene expression involved in fish interrenal organogenesis and steroidogenesis, and thus disrupt the normal production of steroid hormones during early development. It is anticipated that certain responsive genes could be used as indicators of EDC exposure and integrated components of bioassays for EDC detection. The aims of the project are therefore to (1) identify EDC-responsive genes involved in interrenal organogenesis and steroidogenesis in zebrafish (*Danio rerio*) embryos; and (2) correlate the changes in their expression levels to the size of the interrenal organ and the endogenous levels of key steroid hormones in EDC-exposed embryos. The outcome of this research would advance the technology to detect EDCs and provide new mechanistic insights into modes of action of EDCs.

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### **Flood resistance traits of macrophytes and riparian grasses**

This project looks at the traits of riverine plants that are resistant to high flows and the deposition of sand splays. Rhizomatous and stoloniferous species such as *Phragmites australis*, *Paspalum distichum*, *Cynodon dactylon* and *Pennisetum clandestinum* appear to play an important role in channel contraction in sand-bed streams. How do these species survive or take advantage of the physical disturbance provided by flood? To answer this question the traits of these species would be examined and their association with sedimentation and erosion processes determined through field survey or experimentation. The practical implications of this research is to

understand the role that these plants play in river restoration, i.e. preventing erosion and assisting channel contraction after over-widening.

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Ourimbah Campus

### **Influence of floods & drought on the regeneration of River Oaks**

River Oak (*Casuarina cunninghamiana*) is an important riparian species in NSW because it dominates riverine corridors and plays an important role in fluvial geomorphology. The recruitment of River Oaks depends on both the flood and drought regime. However, there is very little information on the ability of seedlings to tolerate inundation and waterlogging and survive periods of drought. There is also no existing data on the ability of this species to compete with introduced pasture grasses and the extent to which it can tolerate watertable drawdown after flood. This research will improve our knowledge of the water requirements of a major riparian species, thereby enabling effective management.

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### **Integration of climate change concerns in environmental governance in Australia**

There have been ongoing debates in Australia as to how the country can best respond to the potential adverse effects of climate change. Following the directives of the Commonwealth Government all relevant agencies in Australia are developing appropriate programs to counter the effects of climate change. Climate change concerns have now become an environmental governance issue. This research will investigate these debates and initiatives, and their integration into environmental governance using a variety of methods including field study, case study, and organization and community survey. Local government authorities and local agencies with environmental responsibilities as the grassroots level administration in Australia will be selected as case studies for this research.

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### **Cryptic invader: green alga *Codium fragile* ssp. *tomentosoides* in NSW**

*Codium fragile* ssp. *tomentosoides* is one of the most invasive algae, and its introduction to NSW can have serious environmental implications. Due to its similarity to the native subspecies (*tasmanicum* and *novae-zelandiae*), the introduction is likely go undetected until the alga is well established. This study will undertake the first quantitative assessment of the invasion by non-native *C. fragile* in NSW and document its distribution and abundance along rocky shores and estuaries of the state. This will help to identify the degree of infestation and to assess potential damage to the environment.

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### **Discrimination of invasive subspecies of a green alga, *Codium fragile* using molecular methods**

*Codium fragile* is a green alga that has two native sub-species in Australia that are very similar to an invasive sub-species *S. fragile tomentosoides*. It is generally suspected that the latter has been introduced to Australia, but the extent of its spread is unknown. The project aims to develop reliable methods of discrimination of invasive sub-species of *C. fragile* and evaluate the extent of its distribution around NSW.

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### **Ecology of Razor Clam, *Pinna bicolor* in Lake Macquarie, New South Wales**

Razor clams (*Pinna bicolor*) are large bivalve molluscs, whose abundances in Lake Macquarie have been steadily increasing within the last five years creating potentially hazardous situation for the recreational users of the lake. There are very few studies of this species in Australia, and the reasons behind the increases in abundance are unknown. The project will study the population structure and life history of razor clams in Lake Macquarie with the aim to identify the factors influencing its patterns of abundance and distribution.

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### **Tracing the origin of the noxious green alga *Caulerpa taxifolia*: using morphological and molecular approaches to identify possible sources of invasion in Australian estuaries**

*Caulerpa taxifolia* is an aggressive noxious green alga that was first detected in NSW estuaries and coastal lagoons in 2000. The alga is extremely hardy and can tolerate a wide spectrum of environmental conditions. Such an invasion could have drastic consequences for Australian ecosystems because loss of seagrasses leads to the significant loss of biodiversity and habitat for fish and their prey. The information on possible sources of invasion is crucial for successful management of this species. The main aims are to identify whether there are any consistent differences in morphology and genetics of native and invasive strains of the alga and to develop molecular markers for identifications of invasive strains.

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# GEOGRAPHY & ENVIRONMENTAL STUDIES

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Contemporary global processes of social, cultural, economic, political and environmental change continue to drive the complex transformation of urban and regional geographies and their environments in Australia and internationally. These transformations produce critical challenges for urban, regional and environmental governance, for the prospects of creating just and sustainable urban and regional communities, economies and environments, and for devising public policy to guide inclusive forms of social, economic and urban development.

From geographical and interdisciplinary perspectives, research in Geography and Environmental Studies focuses on geographical analysis of the factors driving urban and regional transformations, their outcomes and the policy challenges they present. Through basic, applied and community-engaged research, conducted at multiple-scales, our research investigates the processes, dynamics and challenges of change and development, focusing on the key research areas of:

1. City lives, city politics, city natures
2. Sustaining urban and regional communities and environments
3. Critical development studies

*Specific research topics include:*

## **Asset Based Community Development (ABCD): outcomes and impacts**

Asset Based Community Development (ABCD) offers a reframing of the usual needs based approach to community (and economic) development. But what difference does it make? What are the impacts of using ABCD as opposed to a needs focus? What difference does it make to communities and to community (and economic) development practitioners? Research in this area could investigate case studies of ABCD projects in Australia and other parts of the globe.

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## **Experimental and ethical economies**

What are the various ways that groups of people in different parts of the globe and in different contexts are experimenting with economic practices that address issues of social justice, economic equity and environmental wellbeing? What types of transactions, and labour, financial and property arrangements are being drawn on to build ethical economies? Research in this area could focus on case studies of cooperatives, community enterprises, community businesses and community financial institutions as well as mainstream businesses. Participant observation, interviews, focus groups, workshops and other innovative research methods to encourage co-learning between researcher and participants would be particularly well-suited to this area of research.

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## **Cities as translocal spaces**

Globalisation is transforming city spaces, urban cultures, urban politics and urban lived experience. Increasingly cities can no longer be understood as bounded spaces. Rather a translocal understanding is needed to grasp how cities are shaped and lived through networks and relations connecting individuals and communities, urban social movements, policy makers (and more) beyond the immediate locality. Research topics might include investigation of the translocal geographies of urban-based political and social movements, networks of urban policy transfer, urban-based social justice.

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### **Geographies of urban governance**

The governance of cities and metropolitan regions has been transformed by the impacts of globalisation, competitive neoliberalisation, environmental threats and demands for democratic participation. New paradigms and practices of urban governance have emerged as the challenges of managing urban development, infrastructure and services meet changing socio-cultural, environmental and economic imperatives and expectations. These forms of governance include networks connecting state, private sector and community actors (e.g. partnerships), micro-urban governance in private communities (e.g. owners' corporations) and trans-urban governance networks addressing key challenges (e.g. Cities for Climate Protection). Research topics in this field could address the emergence, institutionalisation and effects of new spaces of governance.

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### **Urban Carbon Governance**

Effective responses to climate change hinge on the capacity to govern carbon, especially in our growing cities. Australia's urban carbon governance framework has proved ineffective, and there is no systematic knowledge of it to inform improvement. This research project would contribute to a wider project aimed to document and analyse the 'who', 'how' and 'where' of urban carbon governance, and the related politics and spatiality. The project will provide empirical and theoretical knowledge to advance the capacity to govern carbon and enhance Australia's environmental.

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### **Urban publicness**

Contemporary cities are argued to have become increasingly privatised spaces, marked by the private ownership and management of urban space (malls, gated communities etc), and a related decline of urban public space, urban public culture and urban commons. Yet urban publicness is shaped by more than the geography of ownership. It is shaped by processes and practices through which new 'publics' and new 'public' spaces are created and lived by urban residents. Research could investigate what are the new practices of urban publicness? What are the forms of property ownership and regulation that sustain or hinder them? What are the new and emergent spaces of publicness and urban commons.

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### **Urban social inclusion**

Cities have long been sites where the uneven distribution of resources and recognition is expressed. Recent policy initiatives have been framed around the notion of 'social excluded' places and people and the challenge of attaining 'social inclusion'. Yet we have relatively poor understandings of how social inclusion is both understood and experienced differentially across diverse communities and neighbourhoods with diverse levels of mobility

and connectivity. Research topics in this field could address both urban spatial variations in the availability of resources and opportunities and the diverse understanding and experience of social inclusion.

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### **Geographies of home and home making**

Recent research in geography has investigated the homemaking as a dynamic process. Research in the field has investigated the home-making practices of newly arrived migrants, new suburban residents, people living in medium density developments, public housing tenants, gay men, people with an intellectual impairment and the experiences of people living with animals as pets and pests. Other research has looked at practices of home making that occur in gardens and neighbourhoods. Research topics in this field could investigate, home making on the Newcastle urban fringe or in semi-rural environments, home making in a retirement village, sea- tree- or hill-change location; the role of food and cooking in homemaking practices; the use of green domestic technologies and home making practices.

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### **Geographies of mobility**

Issues of mobility and transport access are crucial to developing more sustainable and inclusive cities. Recent geographical research has emphasised the importance of understanding flows of people around cities. While research on mobility in geography is growing, there is considerable scope to contribute to our understanding of mobility in Australia. Some potential research projects include examining cycling as a form of commuting, examining activism to increase resources for cycling and incorporate plans for cycling into urban development, examinations of public transport and mobility, examinations of international mobility and its consequences for minority groups.

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### **Understanding neighbourhood dynamics**

Recent research on neighbourhood has emphasised that neighbourhoods cannot merely be understood as a set of socio-economic characteristics, but rather are brought into being through the actions of neighbourhood residents and other people who use the neighbourhood. At the cutting edge of urban research this notion that neighbourhoods are performed requires further investigation. Research in this field could investigate the role of social interactions in creating the neighbourhoods, the role of new developments or threatened developments in provoking the mobilisation of neighbourhood resources or the role of particular sorts of community assets such as schools and green spaces in developing neighbourhoods.

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### **More-than-human geographies**

Areas of interest include: exploring the relations between human, nonhuman animals and material worlds; encounters between humans and animals in everyday spaces; questions of animal agency, presences and intersubjectivity; borders and boundary crossings in human-animal relations; the engagements of animal geographies with posthumanist, postcolonial, and (post)environmental enquiry

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### **Society-nature relations**

Areas of interest include: conservation practices on private land; cultures of environmental management, conservation and regulation; socio-cultural aspects of ecological restoration; biobanking and biodiversity legislations.

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### **Urban natures**

Areas of interest include: exploring how nature is enacted in everyday urban life; the ecopolitics of native plant reintroductions in urban parks; human-pet relations in cities and towns; spaces of encounter with urban biodiversity; towards postcolonial ecologies of urban nature.

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### **The effects of Climate Change on small Island states**

Climate change remains an ongoing global threat though its effects will be felt first by small island states. Understanding how these places adapt to stresses placed upon them by a changing climate and what strategies exist or need to be developed to help respond to these challenges will be an ongoing concern for researchers and governments alike.

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### **Perceptions of remoteness**

Ideas and perceptions of 'what is remote' are changing under globalisation though stereotyped biases continue to exist. For many, the word 'remote' is interchangeable with the word 'rural' and as such, being located in places labelled this way can result in marginalisation and peripheralisation. An ongoing concern for people in these communities and researchers alike is ensuring that myths about what is rural and/or remote are dispelled so that local people are included, rather than excluded from important decision-making surrounding their future.

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### **Resource geographies and contestation issues**

Conflicts over resources once thought to be a thing of the past are re-emerging as our world becomes more concerned about the rise of globalisation, climate change and security. As countries plan for their future, geopolitical and geostrategic battles are being fought over access to resources and territory as dwindling local supplies begin to bite. Everything from water rights, oil and gas exploration rights, mineral rights and so on are under negotiation though often without the consultation or agreement of local peoples. The consequences need examination so that any future negotiations are seen to be transparent and equitable. Achieving this, however, remains a big ask.

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### **Sustainability and the environment**

'Sustainability' as a concept is not new, though achieving it remains elusive. In terms of environmental decision-making, sustainable practice needs to be linked to issues such as environmental justice and equity so that achieving inter-generational security is ensured. How to ensure this though is debateable and needs further research.

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### **The commodification of nature and natural resources**

Natural resources are not naturally 'resources' until human intervention. Our use of them changes their 'value' as we see them as a means for commodification rather than simply being of intrinsic value. This process of change is usually unconscious, but its results can be devastating.

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- i) **Critical development studies**
- ii) **Geographies and identities of borderlands**
- iii) **Globalisation and social movements**
- iv) **Intellectual property rights, sustainable agriculture and land reform in the Philippines and the Pacific**
- v) **Participatory action research**

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\*\*Sarah's research interests are in development studies, sustainability, social movements and feminist theory, particularly women in development. She has done work in Southeast Asia, the Pacific, Australia and Latin America. She has also worked extensively with Indigenous people mostly in Arnhem Land.

**Possible research topics include:**

- Analyses of particular development projects (in Australia and overseas)
- Local impacts of global change
- Environmental politics and social justice
- Effects of neoliberal development on women
- The constructions of “globalisations from below” by social movements
- Migration to Newcastle and transnational communities
- Sustainable agriculture and alternative agriculture networks
- Indigenous tourism
- Indigenous social enterprise

These are general ideas and would need to be refined with an appropriate case study or more specific topic in consultation with Sarah.

# School of Mathematical and Physical Sciences

## MATHEMATICS

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### **Graph Searching / Graph Theory**

An active area of current research in graph theory revolves around the basic idea of trying to determine whether an intruder is located somewhere in a graph, and designing strategies to capture an intruder. This project involves an examination of one or two models for graph searching and a possible exploration of an unsolved problem (of which there are many).

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### **Symmetry in Graphs/ Graph Theory**

There are a variety of topics under the general scope of symmetry in graphs for which I would be happy to supervise post-graduate students. Some of the topics are: Isomorphism of Cayley graphs, constructing non-Cayley vertex-transitive graphs, hamiltonicity problems for vertex-transitive graphs, decomposition problems for vertex-transitive graphs, and CI-groups.

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### **Gravitational radiation**

Examining various weak field approximations, and multipole expansions.

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### **Superintegrability and Killing tensors**

Examining conformal relations between manifolds admitting various Killing structures. This can be related to classifying Hamiltonian systems admitting polynomial constants of the motion.

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### **Time-Critical Routing and Scheduling with Mathematical Optimization**

Mathematical optimization problems that combine routing and scheduling with time as a critical factor include, for example, express post network design, commercial airline schedule design, and disaster relief deployment, but extend to many practical problems in transportation and logistics. Such problems display surprising intractability, and current approaches approximate, typically by discretizing time. This introduces error, but currently little is known about how to estimate the magnitude of the error, nor how to reduce it.

This project will investigate the mathematical structure of such problems, develop new approaches for error estimation and for obtaining verifiably optimal solutions, and result in better algorithms for practical planning

problems. The results will be tested numerically on data sets derived from such problems, and benchmarked against current state-of-the-art techniques.

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### **Mathematical Models and Algorithms for Optimizing the Design and Operations of Global Enterprise Logistics Networks**

With globalization and increasing scarcity of natural resources, organizations have seen an explosion in the size, complexity and importance of their logistics problems. Mathematical optimization provides essential solutions in many sectors, but when questions of network design and transportation routing combine with goods consolidation and transshipment, current approaches fail. This project will investigate the causes and develop new mathematical algorithms for effective solution of these problems, tested numerically on applications from a variety of industries.

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### **Using Operations Research to Improve Hospital Efficacy**

The use of Operations Research in Health Care is a field of rapidly increasing activity around the world. It is providing a scientific basis from which to study problems associated with bottlenecks in hospital admissions systems, the allocation of hospital resources, scheduling of operations, and many others. This project will be a collaboration with the Innovation and Reform Unit of the Hunter New England Area Health Service, and will focus on the best use of human resources in hospitals, with the goal of improving both the quality and efficiency of ward-based care. Analysis of current practices will be carried out, and mathematical models will be developed to support identification of new methodologies. It is expected that simulation studies would be used to assess and quantify their potential benefits.

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Co-supervisor's: A/Prof Chris Levi, Hunter New England Area Health & Mr Chris Kewley, Hunter New England Area Health

### **Compressed Sensing/ Nonlinear Optimisation**

To analyse optimisation methods for finding sparse signals which reconstruct known measurements. Traditionally in signal or image reconstruction problems, the scientist recovers a signal and then compresses it using JPEG, wavelet or other methods of reducing the size of the data set to be stored. Recent exciting work performed by Australian Fields medallist Terry Tao among others has focussed on determining *ab initio* sparse reconstructions. The theory behind current methods for such *compressed sensing* is poorly understood and the project offers considerable room to make mathematical discoveries.

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### **Computer assisted discovery and proof / Experimental Mathematics**

To work on the implementation and design of methods to assist with the discovery and or proof of analytic objects, such as inequalities in one and more variables, identification of values of series and integrals and much more.. One goal is to provide `intelligent agents' to allow human researchers to quickly validate or falsify conjectured inequalities and in the former case to provide automated proofs whenever possible. Another goal is to develop partially automated validation systems for mathematical formulas. This project will provide also an opportunity to learn a great deal about modern computer algebra systems.

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### **High Precision Integration / Computational Mathematics**

To work on the implementation and analysis of algorithms to compute physically meaningful integrals to at least double precision in more than two dimensions. Such integrals arise in statistical mechanics, quantum field theory, geosciences, mathematical finance and many other places; and their accurate evaluation is one of the central challenges of modern numerical and symbolic computer analysis.

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### **Convex and Non Linear Analysis**

To study maximal monotone operators on non reflexive Banach spaces and to understand how the geometry of the Banach space effects the structure of the maximal monotone operators which the space supports. To develop new theory of Fitzpatrick functions and related representative convex functions. To correspondingly apply modern convex analysis to other problems in Banach space geometry.

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### **The Clifford Fourier transform**

The Fourier transform, and more particularly the fast Fourier transform, is the backbone of signal processing and ideally suited to the analysis of real-valued (or complex-valued) one-dimensional signals, and even multi-dimensional signals taking real or complex values. It is indispensable, for example, when treating grayscale (black and white) images. For colour images, it is often used on each of the three colour channels (red, green and blue) separately, thus ignoring the important correlations between channels. In this project we further develop the theory of the Clifford Fourier transform which treats vector-valued signals as single algebraic entities, capturing the interaction between channels. Beyond applications in harmonic and Clifford (hypercomplex) analysis, this project has the potential to develop useful signal processing tools.

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### **Efficient Finite Element Techniques for Navier-Stokes and Elasticity Equations**

This project is concerned with finding efficient finite element techniques for solving Navier-Stokes and elasticity equations. Navier-Stokes equations arise in the fluid flow, and elasticity equations arise in the dynamics of solids. The project focuses on nearly incompressible and nonlinear elasticity equations, thin structures, plate

theory and time-discretisations. This project requires strong numerical analysis background as well as programming skill either in C or MATLAB. A person having strong background in solid and fluid dynamics simulation can bring his own package.

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### **Finite element method for solving biharmonic equations**

Often it is hard to solve fourth or higher order partial differential equations as they require sophisticated finite element methods. This project aims at finding efficient, optimal and flexible finite element method for solving biharmonic equations and applying them in practice. This project requires strong background in numerical analysis as well as programming skill either in C or MATLAB.

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### **Solving partial differential equations using finite element method**

The finite element method has become a very powerful and popular tool to solve boundary value problems coming from science and engineering. This project is concerned with solving linear and nonlinear partial differential equations arising in the modeling of engineering and scientific phenomena. The main focus will be to solve Navier-Stokes, Stokes and elasticity equations. This project requires strong background in numerical analysis as well as programming skill either in C or MATLAB. A person having strong background in solid and fluid dynamics simulation can bring his own package.

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### **Mortar finite element method for coupled problems**

Often a problem has different partial differential equations in different domains. One example is fluid-structure interaction, where an elasticity equation is to be used in structure part, whereas Navier-Stokes equations are to be used in fluid part. It is often necessary to use different discretisation schemes or different triangulations in different domains. It is important to apply an efficient coupling scheme. This project is concerned with such multi-physics problems. This requires strong numerical analysis background as well as programming skill either in C or MATLAB. A person having strong background in solid and fluid dynamics simulation can bring his own package.

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### **Nonlinear Analysis and Fixed Point Theory**

Many problems in the behavioural, communication, computational, economic, life and physical sciences and in engineering and technology translate into problems concerning fixed points of certain mappings. For instance; equilibria of discrete and continuous dynamical systems correspond to fixed points of nonlinear maps on infinite dimensional function spaces. The solution of nonlinear optimization and control problems lead to variational inequalities and thence to the search for fixed points of related nonlinear operators. Signal reconstruction frequently involves the approximation of fixed points by various iterative schemes.

Nonexpansive maps arise when modelling conservative or dissipative situations and their fixed point theory presents a tantalizing intermediary between the classical theorems of Banach and Brouwer which has led to a fertile interplay between metric geometry and fixed point theory.

The convergence and ergodic structure of orbits and various iterative schemes, such as those of Ishikawa, relate to the stability and long-term average behaviour of the system being modelled.

A principal goal is to further our understanding of nonexpansive and related types of mappings, with an emphasis on identifying widely applicable, easily verifiable conditions on Banach, and more generally metric, spaces that ensure the existence of fixed points for all nonexpansive self-mappings of appropriate nonempty domains such as closed bounded, convex and possibly weakly compact subsets of a Banach space. Special emphasis is given to the more difficult cases, where the underlying space lacks the nice geometric structure of, for example, a Hilbert space, or situations where there is no natural linear structure. Recently such situations have arisen in robotics and models of cognition.

Alternating projection algorithms, first considered by von Neumann in 1932, and variants of them have become standard tools for handling inverse and signal/image reconstruction problems, where one seeks a feasible point in the intersection of a family of constraint sets. When all of the constraint sets are convex subsets of a Hilbert space these iterative schemes for approximating fixed points of an appropriate map have rigorous theoretical under-pinnings. However, despite the absence of any sound theoretical justification, for more than three decades the same algorithms have been routinely and successfully employed solve real world problems involving non-convex constraints. We seek to provide theoretical foundations in such situations and in spaces other than Hilbert space.

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### **Learning and Pricing: Uncensoring Lost Demand**

We consider a capacity provider who offers a new product to a new market. The provider is uncertain about two elements: the value of the product and the size of the market. The information is revealed during the sales period by the market response. A method has been developed to update the provider's prior belief based on market responses, and update the price to maximize expected revenues over a rolling horizon. However, the method assumes the provider can observe the lost demand, an assumption which is not valid in some settings. We want to extend the method to be able to uncensor the lost demand.

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### **Classify simple totally disconnected groups.**

The simple connected groups have been completely classified since the middle of the 20th century but until recently there was no prospect of such a classification for totally disconnected groups. However the structure theory currently being developed is beginning to provide tools and structural invariants that might be used in a classification. Making a complete classification would be an enormous program of research but there are many sub-projects that will contribute, including some of the previous ones.

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### **Invariant subspaces of shift operators**

Shift operators are easily described and have some obvious invariant subspaces. In some cases, it is known that the obvious invariant subspaces are the only ones but in others it is not. This project aims to understand these other cases.

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### **Simple subgroups of the automorphism group of a tree**

Many examples of simple automorphism groups of trees are known. The aim is to develop our understanding of these groups to be more than a set of examples.

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### **Symmetry groups of cubical complexes**

The structure theory of totally disconnected groups gives rise to so-called 'flat' cubical structures. On the other hand, the automorphism group of a cubical complex is totally disconnected. The project aims to clarify the link between totally disconnected groups and cubical complexes.

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### **Topological Groups**

Symmetry groups occurring in many parts of mathematics and its applications have a natural topology. As a topological space, such groups may be **connected**, as is the group of rotations of a sphere for example, or **totally disconnected**, as is the group of symmetries of an infinite binary tree. While connected groups are well understood and have a rich structure theory, totally disconnected groups were not well understood until the recent invention of new techniques. The way is now open to develop a structure theory of totally disconnected groups that parallels the theory of connected groups. Numerous projects are available that will develop aspects of this general theory or apply it to harmonic analysis, number theory, combinatorics and/or geometry.

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Priority Research Centre for Computer Assisted Research in Mathematics and its Applications (CARMA)

### **Number theory and special functions**

Discover and prove identities for  $\pi$ , for values of the Riemann zeta function and, in general, for values of special functions including hypergeometric and modular functions. Develop a theory of automorphic functions for linear differential equations.

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Priority Research Centre for Computer Assisted Research in Mathematics and its Applications (CARMA)

# PHYSICS

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## **Statistical Characteristics of ULF Waves in the Polar Cap**

Plasma waves with 0-50 mHz frequency propagate throughout geospace and form an important diagnostic tool for Space Weather applications. They are usually studied using ground-based magnetometers, but their properties in the polar cap are largely unknown. This project will investigate (1) statistical characteristics of the wave amplitude and phase (propagation) distribution inside the polar cap and (2) their physical interpretation.

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Centre for Space Physics

## **ULF Wave Effects on GPS Signals**

GPS signals monitored by ground-based and satellite-borne receivers are affected by propagating ULF plasma waves that cause refractive index variations along the transmission path. This project will answer the following questions. (1) How often do ULF-related perturbations occur in GPS data? (2) How do the spectral characteristics of these compare with magnetic pulsations at those locations? (3) Are there phase differences between spaced GPS receivers that can be reconciled with propagating ULF waves or field line resonances? (4) Hence, what is the physical mechanism causing these perturbations? (5) What size navigation errors result from these effects? (6) What strategies could be used to mitigate these effects?

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Centre for Space Physics

## **ULF Waves and Relativistic Radiation Belt Particles**

Relativistic electrons precipitate into the atmosphere from the Earth's radiation belts with important consequences for technological systems and atmospheric constituents. The mechanisms driving this are largely unknown. This project will address the following questions. (1) Is there evidence for the modulation of relativistic electron precipitation by ULF plasma waves? (2) What wave conditions (amplitude, frequency, azimuthal extent) are required? (3) Over which regions (latitude, local time) does this occur, and to which regions does this map? (4) What proportion of the radiation belt particle budget is affected in this way? (5) What is the physical process? These issues affect about \$200B of hardware in orbit.

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## **Estimation of Pipeline-soil voltages due to Geomagnetic Induced Ground Currents**

Space weather is a term used to describe many effects on Earth that result from the Earth's location in the outer atmosphere of the Sun. One of these effects involves the protection and corrosion mitigation of long gas pipelines. Cathodic protection methods are used to inhibit the pipe corrosion by applying a reverse voltage bias between the ground and pipe. However, disturbed solar and ionosphere conditions generate voltages on these pipelines that can exceed the cathodic protection system, enhancing the pipe corrosion process. While there have been a number of studies of this process at high latitudes (e.g. Alaska, Norway), the effects at low latitudes (e.g. Australia) are not well known. Furthermore, the pipeline corrosion mitigation industry apply standards based on high latitude studies.

This project will work with existing collaborations with the Australian pipeline industry to measure gas pipeline voltages, compare these with solar and space weather conditions and suitable computer modeling in order to quantify and understand these effects for Australian conditions. The results of these studies will be used to assess and develop more relevant pipeline cathode protection standards. This project is joint project between IPS Radio and Space Services (<http://www.ips.gov.au>) and the University of Newcastle Space Physics Group.

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### **Modelling magnetised plasma perturbations in the near-Earth Space Environment**

ULF magnetised plasma waves convey significant amounts of energy throughout the near-Earth space environment, the Earth's magnetosphere. They range in frequency from 0.001-1 Hz with a wide variety of generation and propagation mechanisms. The interaction of ULF disturbances with the ionosphere is a developing area of study, relevant to quantifying ionosphere variations affecting applications for GPS, radio astronomy (interferometer measurements), HF ionosphere signal propagation (e.g radar) and geophysical minerals prospecting. The Space Physics Group at the University of Newcastle has developed the first 2D, time dependent computational model of ULF wave processes that track the disturbance from space, through the ionosphere to the ground. Development of the 3D model is well advanced. The project will involve aspects of the development of the computational modeling (e.g. including a realistic height dependent ionosphere, developing a realistic outer boundary for the magnetopause) and use the results to compare with experimental data.

*(Note: This project is quite flexible and will be defined in more detail in discussions with interested students).*

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Centre for Space Physics

### **Origin of higher frequency (Pc1-2) perturbations in the Polar Cap**

The Earth's ionosphere can act as a resonant cavity for electromagnetic plasma waves. This project will involve numerically solving the time dependent Maxwell wave equations to explore the properties of this cavity and to compare with experimental data. The computational model is unique in combining realistic descriptions of the conductivity and geomagnetic field in the ionosphere and may be extended into a 3-D formulation. A particular focus of this project will be recent observations in the high latitude, polar cap region recorded by Newcastle Space Physics Group instrumentation located in Antarctica.

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Centre for Space Physics

### **Radar Signatures of the Plasmopause**

An important dynamic structure in the inner magnetosphere is the plasmopause. Modeling work suggests that ULF wave energy transfer from the auroral regions to Australian latitudes critically depends on the structure and location of this boundary. Observations of ULF wave signatures using the TIGER HF radars located in Tasmania and New Zealand have so far shown a distinct band of enhanced ULF amplitude confined within several degrees of latitude [Ponomarenko et al., 2005]. Are these the signature of wave growth associated with a well formed plasmopause?

This project will use existing methods for locating the plasmopause, (EUV instrument onboard the IMAGE spacecraft, ground magnetometer data, GPS data) to identify the radar signature of this structure. This will be excellent training in the operation and data returned from multi-pulsed HF radar instrumentation, similar to those use in surveillance.

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### **Remote Sensing of ULF Waves in Geospace Plasma Using SuperDARN Radars**

This project uses HF (8-20 MHz) radars in Tasmania and New Zealand to study the signatures of ULF plasma waves in the high latitude ionosphere. The project focuses on advanced analysis techniques used in geophysics, including spectral and correlation algorithms, to elucidate the spatio-temporal and spectral structure of ULF waves and obtain new information on their generation and propagation mechanisms.

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### **Substorm signatures in over-the-horizon radars**

Large releases of energy in near-Earth space result in almost daily 'substorms' that cause auroras and damaging effects on technological systems. A characteristic magnetic field perturbation, called Pi2, is produced at substorm onset. Pi2 have mostly been studied using ground magnetometer arrays. We have developed techniques to more directly and precisely identify and image Pi2 using over-the-horizon radars such as those that form the backbone of Australia's defence surveillance. This project will use our own HF radars to image the substorm ionosphere and identify the dual (2-D) radar signature of Pi2, characterise the properties of these, and explain causative the physical mechanism. This will bring new understanding to this most important topic.

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### **The Global Ionosphere Current System**

The Iridium constellation of >70 polar orbiting 800 km altitude communications satellites provides global data and voice services. This project will use proprietary data from the Iridium satellites attitude control systems to investigate the ~million amp currents associated with auroras, and their relation to current systems closer to the equator. Links between high and low latitude currents are still relatively unknown. This project will use unique data from the Iridium satellites and low latitude magnetometer networks to determine the extent of the coupling between high latitude ionosphere current phenomenon and low latitude effects.

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### **Generation of wave Energy beyond Geosynchronous orbit**

Magnetised plasma waves in near-Earth space are possible candidates for accelerating electrons to high energies and threatening satellite infrastructure. The generation mechanism of these waves is a Kelvin-Helmholtz (fluid shear) instability about 10 Earth radii away. This project will develop simulations of this instability, integrate this with 3-D simulation code of the magnetosphere and compare results with current satellite (Cluster, THEMIS, Double Star), ground and HF radar measurements.

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Centre for Space Physics

### **Hybrid Modelling for Space Science**

The space environment near the Earth comprises a fully ionised gas (plasma) responding to and generating electric and magnetic fields. This is common physics with current research efforts to develop nuclear fusion technology. The project will develop hybrid code (particle and fields solved self consistently) simulations, and compare results with satellite, experimental data in order to further understand the wave-particle interactions that appear naturally in space physics and also heating mechanisms in nuclear fusion containment devices.

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### **MRI-based treatment guidance for cancer treatment**

Combinations of magnetic resonance imaging (MRI) scanners and linear-accelerators for radiation therapy treatment are currently under development. A proposal for an installation at Liverpool Hospital in Sydney is under development. The Mater Hospital is also soon to install a state-of-the-art 3T MRI scanner. These next-generation devices will enable high contrast real-time MRI images to be used to guide the treatment dose to the tumour while avoiding normal tissues. The aim of this project is to acquire multiple MRI images for a group of patients and develop and test methods to use these scans to plan and guide radiation therapy treatments.

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*Medical Physics Group / Priority Research Centre for Information Based Medicine*

### **Real-time image-based dosimetry for radiation therapy**

Flat-panel Imaging devices can record dose from high energy modulated radiation beams in real-time during cancer treatment. These measurements could be combined with a dose calculation model to calculate dose to the imager in real-time. This would be compared with the expected dose in real-time. This could ensure that treatments are accurate and that errors in treatment are detected and avoided. This project will investigate methods to measure the dose in real-time with the imaging device including investigating a new imaging system design. Methods for fast comparison of expected and measured dose will be developed potentially with GPU devices. This would be the first system to verify patient dose distribution delivery in real-time with imaging devices.

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### **A dual imaging/dosimetry system for radiation therapy**

Current flat-panel imaging devices in radiation oncology are designed for high quality imaging and have severe limitations as dosimeters to verify accurate dose delivery. We have developed a novel design for an imaging system that performs extremely well for dosimetry but less well for imaging. The aim of this project is to develop methods to adapt this design to perform as a dual-mode imager enabling both high quality imaging and high quality dosimetry. This work could facilitate the development of a new device for radiation therapy verification.

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### **Automatic prostate segmentation using MRI for improved accuracy of prostate radiation therapy**

For prostate radiation therapy a radiation oncologist manually delineates (segments) the border of the prostate on a planning magnetic resonance imaging (MRI) scan to define the target high dose region and to limit the doses to surrounding normal tissues. However for the same patient there are differences in the borders of the prostate outlined by different clinicians (inter-observer variability) which produces uncertainties in the prostate location. This project is a collaboration with CSIRO and will develop advanced methods to automatically segment the prostate on MRI scans using our expertise in advanced atlas-based image segmentation. This project has the potential reduce the uncertainties and margins in prostate treatment leading to lower normal tissue doses and improved quality of life following treatment.

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### **Does the initial treatment plan predict doses delivered to normal tissues during prostate radiation therapy?**

Increasing the dose to the prostate (dose escalation) in radiation therapy has been shown to increase local control for medium and high risk patients with five year survival rates now very high. However increasing the dose increases the risk of long-term bladder, rectal and other toxicity which can reduce the quality of life for these patients. At present we use a computed tomography (CT) scan acquired prior to the treatment course to predict these doses. However changes in bladder and rectum size and shape and beam positioning changes occur during the nearly forty daily treatment deliveries. This could change the doses received by these organs and our initial prediction of the dose may not be a good estimate.

In this project we will determine actual delivered doses to these organs using daily on-treatment CT scans to capture the anatomical shape and size at each treatment, combined with calculation of delivered dose on each on-treatment scan. We will then determine whether the initial treatment plan is predictive of delivered doses to the rectum and bladder. This will allow us to determine the uncertainties in these current treatment plan predicted doses. The results will lead to development of better methods to determine actual delivered doses to improve patient treatments.

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### **Three-dimensional real-time patient dosimetry for radiation therapy**

Flat-panel Imaging devices can record dose from high energy modulated radiation beams in real-time during cancer treatment. These measurements could be combined with a dose calculation model to calculate dose to the patient in real-time. This would be compared with the expected dose in real-time. This could ensure that treatments are accurate and that errors in treatment are detected and avoided. The calculation of dose within a patient in real-time from transit dose images requires very fast calculations. The aim of this project would be to develop graphical processor units (GPU) based physics models for real-time patient dose verification in radiation therapy treatment.

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### **Biosensors from Plastic Electronics**

Current state-of-the-art biosensor fabrication involves assembling complex molecular structures on hard conventional semiconductor materials such as silicon. Our aim is to demonstrate that low cost biosensors can be fabricated by simply incorporating bioactive materials into organic field effect transistors. Using soft electronic polymers as the matrix for the bioactive material eliminates the need for complex molecular surface assembly. Previous work at the University of Newcastle has clearly demonstrated that prototype sensors can be built using OFETs. This project will involve building and characterising OFETs and is focussed on understanding the device physics of these electronic components. The long term goal of this project is the development of flexible and inexpensive biosensors for a variety of applications.

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*Priority Research Centre for Organic Electronics*

### **Developing a Helium Beam Microscope**

Scanning helium microscopy offers the tantalizing possibility of using the wave-particle nature of helium atoms to image the structure of delicate surfaces with unprecedented resolution. This project will involve developing the new ARC-funded helium beam microscope at Newcastle and producing preliminary images. This project will involve collaboration with the Cavendish Laboratory at the University of Cambridge.

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### **Extending the Spectral Response of Organic Solar Cells**

State-of-the-art organic solar cells are limited by the wavelength response of the active semi-conducting polymer layer since these materials typically only photogenerate charges below 500 – 550 nm. In the natural world, plants use a range of porphyrin-based molecules (such as chlorophyll) to allow photosynthesis to occur across the solar spectrum. This project aims to develop photovoltaic devices containing artificial porphyrin light harvesting molecules. The goal of this project is to develop, for the first time, plastic solar cells that generate electricity from the entire solar spectrum.

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### **Field Ionisation He Detection using Carbon Nanotubes**

Scanning helium microscopy is an emerging imaging technology that uses low energy (<50 meV) helium atom beams as a completely non-perturbing probe of nanoscale structure. However, this exciting new technology is currently limited by the lack of an effective 2D imaging system for neutral He atoms. Carbon nanotubes (CNTs) offer the possibility of acting as effective field ionisation tips for He atoms thus allowing them to be detected. This project will aim to grow CNT arrays using a new state-of-the-art chemical vapour deposition (CVD) system in the Centre for Organic Electronics.

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### **Large Area Printing of Organic Solar Cells**

The development of new sources of renewable energy is urgently required if the worst effects of man-made climate change are to be avoided. This project will build on the recent exciting advances made by the Centre for Organic Electronics (COE) in device fabrication to develop new methods for printing large photovoltaic arrays based on semi-conducting polymers. This project will make use of the new state-of-the-art ink jet printer that has been recently purchased by the COE for developing organic electronic circuits.

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### **Novel Electrodes for Organic Solar Cells**

The capability of organic solar cells to provide large scale global sustainable energy solutions will be limited by the current high costs and supply issues associated with the current electrode materials. This project will explore novel inverse architectures and transparent conducting materials to address the issue of developing low cost electrode structures for these exciting new devices.

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### **Novel Encapsulants for Organic Solar Cells**

State-of-the-art organic solar cells are limited by the durability and lifetime of the active layer materials in these blended devices. This project will study the role of new encapsulant materials and structures to extend the lifetime of these devices.

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### **Phase Contrast Mechanisms in Scanning Helium Microscopy**

The aim of this multinational collaborative research project is to develop the world's first imaging detector for neutral helium atoms for use in a new surface-imaging instrument – the scanning helium microscope. Scanning helium microscopy is an emerging imaging technology that uses low energy (<50 meV) helium atom beams as a completely non-perturbing probe of nanoscale structure.

Currently, there is little understanding of the mechanisms that would provide contrast in this microscopy. The ultimate goal of this project is to understand the phase contrast mechanisms that would operate in scanning helium microscopy and is motivated by recent research by Dr Dastoor and colleagues at the University of Cambridge. This project will involve modelling work with the goal of understanding the phase contrast processes.

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### **Photocurrent Mapping of Organic Solar Cells**

State-of-the-art organic solar cells are limited the complex morphology and structure of these blended devices. This project will use a Near-Field Photocurrent Microscopy (NSPM) to simultaneously map the photocurrent and the morphology of organic solar cells. NSPM is a new technique that has been recently developed at the University of Newcastle and is the first technique that is capable of directly measuring the photocurrent from organic solar devices. This project will apply NSPM to the study of P3HT/PCBM blend structures, which are the most efficient blend materials currently available.

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### **Printing of Electronic Arrays using State-of-the-art Ink Jet Printing**

The Centre for Organic Electronics has recently purchased a new state-of-the-art ink jet printer for developing organic electronic circuits. This project will involve developing organic thin film transistor arrays for a variety of sensor applications. The project will involve developing an understanding of the device physics of these transistor arrays.

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### **Structure and Morphology of Conducting Polymer Blends**

Conducting polymer blends underpin all of the activities of the Centre for Organic Electronics, especially in the areas of organic solar cells and biosensors based on organic transistors. This project will study the role of structure and morphology in these blend materials as characterised by advanced synchrotron based techniques. The successful Honours student will be required to travel to use the new synchrotron facilities in Melbourne and may be required also to undertake experiments at the Advanced Light Source, Berkeley, USA.

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### **Ultra-fast Laser Spectroscopy of Organic Electronic Materials**

The charge generation and charge conduction mechanisms involved in organic electronic devices occur on extremely short timescales and as such are not well understood. This project will aim to use a state-of-the-art femtosecond laser spectroscopy system to probe these mechanisms using pump-probe spectroscopy.

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### **Laser Processing**

This project will use a state-of-the-art femtosecond laser, continuous diode laser and nanosecond pulsed lasers to investigate annealing and welding of materials in organic solar cell development.

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### **Two-Photon Microscopy**

Two-Photon Microscopy allows deep imaging of live tissues. The optical arrangement and optimisation of a two-photon microscope incorporating a novel scan engine will be the topic of this work.

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### **Ultra-fast Laser Continuum Generation**

Supercontinuum generation in optical materials is widely used in ultra-fast spectroscopy. This project will use a state-of-the-art femtosecond laser spectroscopy system to generate and analyse continua in microstructured optical fibre.

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### **Organic semiconductor electronics**

This project will explore the full capacity of organic conductive polymers in electronics applications. The world class facilities at Priority Centre for Organic Electronics (PROCE) hosted by the University of Newcastle have been established to allow us to fabricate flexible electronics, including organic light-emitting display (OLED), organic field-effect transistor (OFET) and organic photovoltaic cell (OPVC) and their combination organic integration circuit (OCI).

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*Priority Research Centre for Organic Electronics*

### **Organic silicon hybrid devices**

By using a scanning tunnelling microscopy (STM), this project involves a fundamental understanding on the interactions between organic molecules and silicon surfaces at an atomic level. The formed structures will be used to make organic silicon hybrid devices for biosensor applications.

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### **Predicting optical properties of materials**

Predicting and understanding the optical properties of materials from first principles can be considered as one of the "last frontiers" in solid state physics. Whilst many other properties of materials, such as mechanical and electronic properties are very well described by fundamental quantum mechanical methods, optical properties often remain poorly described. The reason for this lies in the fact that the optical properties are related to the excited electron states within the material, where the complex response of the electrons to the incident light, including the response of the other electrons must be included. This project will use the latest generation of computer codes to perform such calculations. A variety of metals, semiconductors and insulators will be examined and the applicability of the different levels of approximation to each of these types of materials will be examined.

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*Surface and Nanoscience Group*

### **Materials design for low-loss plasmonic applications**

There has been a sustained surge of activity recently in the closely-related fields of 'plasmonics' and 'meta-materials'. 'Plasmonics' is the field of science dedicated to exploring and exploiting electromagnetic plasmon resonances in the broader sense<sup>1</sup> while 'meta-materials' are composite structures in which electromagnetic resonances are specifically exploited to produce new, 'artificial' material. These topics have in common that they exploit coupled electromagnetic resonances of light and electrons occurring on nano-antennas that are much smaller than the incident wavelength of the light.

One problem retarding development in this field is that of 'optical loss, which can be considered to be attenuation of the plasmonic resonances due to insufficient electrical conductivity of the relevant nano-antenna at optical AC frequencies. This problem will be addressed in this project. The aims are:

- (1) how to modify the dielectric function to reduce optical losses to the lowest practical level.
- (2) to develop more robust (corrosion resistant) materials solutions for obtaining plasmon resonances in the blue to green region of the spectrum.

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Surface and Nanoscience Group

### **Secondary Ion Mass Spectrometry of Implant Diffusion in Silicon**

In the NASA Genesis mission, a spacecraft orbited the sun for 3 years collecting atoms given off by the sun, the so-called solar wind, into silicon wafers. The spacecraft returned to Earth and the wafers are now being analysed. During the collection phase, the samples were at a temperature of 200 degrees C so solar wind atoms implanted into the silicon diffused. In this project the diffusion of solar wind elements in silicon wafers will be measured by secondary ion mass spectrometry to understand the atomic motion in the original Genesis samples.

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Surface and Nanoscience Group

### **Radiation Damage in MAX Phase materials**

MAX phase materials have the capacity to operate in extreme environments and may be candidates for high temperature and high radiation environments. One particular environment is as a construction material in a fusion reactor where it would experience significant radiation damage. This project would involve the synthesis and characterisation of single crystal materials and then a study of its response to high levels of radiation damage.

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### **Surface structure and growth of atomic layer surfaces**

Ion scattering from surfaces has effectively been used to measure the structure and composition of the outermost atomic layers of surfaces. The structure of surfaces governs its physical, chemical and electronic properties. The structure will be studied as thin (less than one atomic layer) films are grown on the surface to change its electronic and magnetic properties.

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# STATISTICS

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## **Advances in Correspondence Analysis**

Over the past five decades correspondence analysis has gained an international reputation as a powerful statistical tool for the graphical analysis of the association between multiple categorical variables. Such a technique involves exploring the multivariate nature of association structures between two (or multiple) variables in a low-dimensional space. The advantage of doing so is that one may easily visualise the sometimes complex relationship that exists between responses. The level of such complexities may be as straight forward as two variables having a symmetric structure (as is typical when performing a chi-squared test of independence) or may involve a variety of different predictor/response relationships requiring more sophisticated measures of association. This project will provide further advances into a variety of aspects of correspondence analysis for variables with a variety of complex association structures. In particular, this research will involve exploring some of the theoretical, practical and computational issues of the technique and provide new insights into the visualisation of association.

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*Statistics Research Group*

## **Non iterative estimation for log-linear models**

Log-linear models are a popular statistical tool for analysing the association between two or more sets of categories. Typically, estimating parameters from log-linear models involves iterative procedures. However there are various computational hurdles that can arise including poor specification of initial values and non-convergence. However, recent studies have found that these parameters can be estimated very easily without resorting to iterative techniques. This project will explore the use of iterative and non-iterative techniques for the parameter estimation of log-linear models and will explore the development, applicability and reliability of non-iterative techniques for such models. This will include a simulation study to identify where the possible benefits, or pitfalls, lie for both approaches.

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## **Bayesian Hierarchical Modelling**

Bayesian techniques have increasingly been used in the analysis and reporting of performance measures in health care, education and industry. This thesis will explore the effects of various Bayesian models on parameter estimation and/or methods for monitoring processes, with a focus on the model's use in organisational quality improvement. The methods may be applied to health care, education, business or industry depending upon the student's preferences.

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*Statistics Research Group*

## **Statistical methods in climate change research**

The impacts of climate change are well documented in the Northern Hemisphere, where phenology (flowering time, birds) provide much of the basis of climate effects reported (2001 and 2007 IPCC). There is however a dire scarcity of phenological recording in Australia. No Australian contribution on phenological indicators of climate change appeared in the 2001 IPCC report. The development of a Southern Hemisphere phenological climate proxy is of national priority. This project will develop new statistical theory and methods for climate research in any of the following areas: time series clustering; combining time series; wavelet methods; functional data

analysis in time and space; meta analysis for global studies; synchronization mathematics; trajectory analysis using Bayesian and non Bayesian mixture analysis; transition state methods and Bayesian hierarchical methods. As such this project offers scope for individual theoretical research. This project will build on work by Professor Hudson published in 2010 in the book entitled, *Phenological Research: methods for environmental and climate change analysis Mathematics and Statistical Methods, Design & Applications*, Springer. Your research is anticipated to be added to a chapter of a new book on southern hemisphere climate change. Methods will be applied and tested on Australia wide data from the Bureau of Meteorology (BoM), Climate Watch and the National Climate Change Adaptation Research Facility.

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*Co-supervisors: Dr M Keatley, University of Melbourne; and researchers at Cambridge University, UK*

### **Bioinformatics and Chem-informatics in Drug Discovery**

The principle that chemical structure determines molecular activity has meant that preliminary High Throughput Screening of molecules in search of new drugs has focused on identifying molecules with a similar structure to a known active molecule (protein). High throughput docking of small molecule ligands into high resolution protein structures has revolutionised computational approaches to drug discovery. The receptor structure is kept fixed, while the optimal location and conformation of the ligand is sought via sampling algorithms. This project will develop novel Bayesian and non Bayesian methods (mixture, artificial intelligence and support vector machines) for classification and create new indicators of molecular ligand binding for drug discovery. The theory will be tested on calpain inhibitors for cataract treatment. The mathematical tools and new indicators developed will provide alternatives to diagnostics currently used in molecular libraries, and aim to provide better prediction and less false positives and negatives in drug evaluation. Other molecular libraries will be accessed to test the robustness and predictive accuracy of the methods. Local input will be sought from the Priority Research Centre for Bioinformatics, Biomarker Discovery and Information-Based Medicine (CIBM), the University of Newcastle. This research is part of an ongoing collaboration with the University of Cambridge, UK, the University of Adelaide, and GKSS, Berlin.

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*Co-supervisors: Professors Abell, University of Adelaide, & Cambridge University, UK, and Dr Joanne Thandrayen, School of Mathematical and Physical Sciences*

### **Using movements to uncover mental processes**

There are well-established mathematical theories of the cognitions underlying simple choices, but discriminating between the most sophisticated competing theories is difficult, given existing data. A new source of data might help constrain the theories and shed light on what happens in the moments before a choice is made. One new method uses data measured from movements - an observer makes a decision and simultaneously reaches their arm toward a target. This project will involve integrating data from movement-based experiments with cutting-edge theories of decision making and related statistical theory (wavelets, survival methods, transition state approaches, dynamic mixture models).

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*Co-supervisors: Professor Andrew Heathcote, A/Prof Scott Brown, Dr Ami Eidels, School of Psychology, University of Newcastle*

### **Statistical surveillance methods in climate and health**

The field of health informatics, a discipline at the juncture of information science, computer science, and health care has experienced a tremendous growth in tandem with the development of new computational and e-technologies. This project will explore and develop spatial and temporal and also mixture statistical methods for surveillance studies, as applicable to topological climate maps, and to the surveillance of health, disease and injury. Data will be available from the School of Medicine and Public Health, the School of Health Sciences (Faculty of Health) and the WHO.

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### **Modelling Trajectories: Longitudinal and Time Series methods**

How can we best model trajectories incorporating exposures, interventions, treatments (or otherwise) to best represent progression, accounting for the inherent variability within and between subjects/patients? The aim of this project is to develop a suite of rigorous mathematical statistical and visual methods to model trajectories and allow for a significant reduction of multivariate, say, patient data, into a workable number of specific trajectories and to model these efficiently. This project will explore and develop the theoretical framework for such joint modelling of multivariate profiles over time. The methods will be tested and applied to some of the datasets, as listed below. These are based on NHMRC funded research - in collaboration with investigators at the University of Newcastle and the University of Adelaide. The data sets pertain to 4 projects: [1] Control Laws for Reach-to-Grasp coordination in people with stroke (Professor Paulette Van Vliet, Priority Research Centre for Brain and Mental Health Research (CBMHR)); [2] Motor cortex facilitation during speech listening and quiet reading in children born preterm (A Prof Pitcher, the Robinson Institute, The University of Adelaide); and [3] Psychological treatment of co-morbidity and other trajectories, Professor Amanda Baker (CBMHR), Hunter Medical Research Institute (HMRI) and the CBMHR; [4] Patterns of optimal use of a web based weight loss program to maximise weight outcomes (Professor Claire Collins, Priority Research Centre in Physical Activity and Nutrition, University of Newcastle). You can choose at least one of the datasets, and as such this project offers scope for individual research and choice of areas of application (stroke research, neuro-physiological and/or psychometric research).

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*Co-supervisors depending on the data used to test the theory:*

- *Professor Van Vliet, Priority Research Centre for Brain & Mental Health (CBMHR);*
- *Professor Pitcher, the Robinson Institute, University of Adelaide;*
- *Professor A Baker, Hunter Medical Research Institute (HMRI), and the Faculty of Health, University of Newcastle;*
- *Professor C Collins, Priority Research Centre in Physical Activity and Nutrition.*

### **Sleep Research: Fatigue modelling algorithms for railway drivers**

Fatigue is a major contributor to deaths and injuries both on the road and in many workplaces. This research aims to create of new work-related fatigue models for the rail industry and has clear work, health and safety implications. This project involves the development of multivariate Bayesian mixture and other multivariate time series methods to classify railway drivers' sleep/duty/wake/break profiles. Methods and models will accommodate time series of highly disparate lengths across drivers, and of high dimension. This research is part of a CRC Rail Innovation Grant funded project, and a collaboration with the University of SA, Centre for Sleep Research.

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### **Bayesian knowledge updating and statistics for robot soccer**

A number of topics are possible from problems arising from the University of Newcastle's robot soccer team, the NuBots. The topics are related to classification and prediction problems for the vision system, as well as experimental design and computer experiment problems for the behaviour module. This project would suit a candidate with strong computing skills. See <http://robots.newcastle.edu.au/> for more details on the team.

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### **Flexibly shaped distributions**

The Generalised lambda distribution and the g-and-h and g-and-k distributions are families of distributions that allow a great variety of shapes within one distributional form. A PhD topic on this could concentrate on:

1. computing issues, making use of Approximate Bayesian Computation, alternatives to likelihood methods, and/or GPU computing; or
2. analytical properties of estimators.

For more details refer to the web site at: <http://tolstoy.newcastle.edu.au/~rking/publ/>

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### **Socio-spatial statistics**

One of a number of projects considering the spatial pattern of disadvantage in the Hunter region. This project will consider the impact of spatio-temporal correlation on multivariate methods. You will also consider research questions around the impact of different sorts of boundaries on the social gradient and the effect of changing geographic scale. This project will include making use of data from public and government sources.

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### **Subjective probability and prior distributions**

One interpretation of Bayesian states that the *prior distribution* (a key element of the Bayesian paradigm) is the subjective degree of belief about the parameter concerned. This project addresses the philosophical and psychological problems with such an interpretation.

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### **Nonlinear Time Series Analysis**

Nonlinear time series modelling is a rapidly developing subject in time series analysis. We have been witnessing almost exponential growth in the applications of nonlinear time series models, ranging from solar sciences to earth sciences, from biosciences to economics and finance. Research projects include adaptive estimation of mixture nonlinear time series models or ergodicity conditions of mixture nonlinear time series models.

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### **Bayesian hidden Markov model in DNA sequence segmentation**

Many genome sequences display heterogeneity in base composition in the form of segments with similar structure. Early evidence of segmental genomic structure was noticed early on that in the salivary glands of *Drosophila melanogaster* whereas the problem of statistically segmenting DNA sequence has a history about four decades. One approach describes DNA sequence structure by a hidden Markov model (HMM). Change-point detection is an identification of abrupt changes in the generated parameters of sequential data. It has proven to be useful in application such as DNA segmentation modeling. This project focuses on the various change-point identification of a Bayesian hidden Markov model describing homogeneous segments of DNA sequences. A simulation study will be used to evaluate the change-points followed by the real-life examples.

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### **Bayesian structural equation modelling**

The death rate from colorectal cancer has declined in recent years due to improved screening methods and advances in treatment. Hence, a growing population of people are living with a history of colon cancer. This project will assess the psychosocial outcomes of longer term survivors using structural equation modelling. Bayesian extensions to this approach will be investigated to implement data characteristics and uncertainty within this modelling framework.

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### **Bayesian inference - noninformative priors**

An advantage of the Bayesian approach is the possible inclusion of prior information/knowledge. However, it is desirable, for the purpose of scientific communication and sensitivity analysis, always to base inference on "noninformative" priors also. The currently recommended methodology to obtain such priors is reference analysis, but our research indicates that this methodology is incomplete. When dealing with extreme data, reference priors can be shown to be too informative for the binomial and Poisson parameters, for example. Possible research topics include the identification of alternative criteria when reference analysis fails in this manner, and the study of appropriate noninformative priors in related applications such as logistic and Poisson regression.

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## PSYCHOLOGY

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### **Addressing smoking and other health risk behaviours for people with mental illness**

Smoking and rates of other health risk behaviours are higher for people with a mental illness than for the general community, and morbidity and mortality associated with a range of chronic diseases are higher as a consequence. Collaborative, cross-disciplinary projects available may examine the 'determinants' of these inequities in health risk, including the role of health care providers, health care services and other 'system' factors, and also developing and trialing interventions to effect change.

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Clinical and Health Research Group

### **Changing 'SNAP' health risk behaviours (Smoking, Nutrition, Alcohol, Physical Activity) for population groups at risk**

Effectively addressing the SNAP risk factors at a population level (or for high risk population sub-groups) provides the potential to substantively reduce rates of our most common and fatal chronic diseases - including cardiovascular disease, respiratory disease, diabetes and many cancers. Collaborative, cross-disciplinary projects available may explore the determinants of behaviour change for SNAP risk factors - including a consideration of individual, societal and systems influences - as well as developing and trialing interventions to effect change.

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Clinical and Health Research Group

### **A Modern Take on a Textbook Classic: Hick's Law**

When people have to make decisions, they take longer if there are more alternatives to choose between. The slow-down is almost always the same, no matter what kinds of decisions are being made. This regularity seems to describe something fundamental about decision-making, so it has been known as "Hick's Law" for more than 50 years. Despite being written about in every introductory textbook, there are no really good theories for why Hick's Law arises. You will join an ongoing project in my lab that tests new limits for Hick's Law, using simple experiments, and you will also develop mathematical theories for the law.

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Human Experimental and Applied Dynamics (HEAD) Group

### **Fast, or Careful?**

When making decisions, we are constantly faced with the need to trade speed for accuracy: we can make lots of decisions quickly, but with lots of errors; or we can make a few decisions slowly and accurately. There are comprehensive cognitive theories for how this tradeoff occurs, and these theories have been well accepted by the scientific community for decades. However, some of the basic assumptions of those theories have never been tested – we will conduct experiments to find out which assumptions hold up to closer scrutiny, and we will use this information to better develop the comprehensive theories. There is also scope in this project to examine interesting applications of decision theory, such as in aging or clinical populations.

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### **Rapid Decisions**

Our lives are filled with almost continuous rapid choices. We make these simple choices almost without knowing, but they are critically important. There are several comprehensive mathematical theories of how the choices are made, and there are also new attempts to bridge the gaps between these mathematical theories and neural theories about how the decision processes are implemented in the brain. You will work on a series of experiments and mathematical developments to test some of the leading theories, and help fill in their areas of weakness.

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### **Avian visual cognition**

Birds inhabit very different visual ecologies to land-based mammals and have fundamentally different brains. How has this impacted on the way in which they process movement and depth information and recognise objects?

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### **Evolution of cognition: Spatial**

How has the ability of nectar feeding birds to remember locations in their environment been shaped by the spatial and temporal distribution of their food?

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### **Human faces as evolved signalers**

Human faces convey information about age, sex, health, fertility, etc. and movements of the face operate as complex social signals. Any project investigating people's sensitivity to these signals. I am particularly interested in non-verbal dynamic signaling in a variety of social contexts and in the evolution of attractiveness cues.

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### **Sex differences in spatial cognition**

To what extent can we understand human sex differences in spatial memory and navigational ability in terms of the different evolutionary selection pressures faced by males and females in our ancestral past?

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### **Human factors and organisational psychology**

Human factors issues in aviation and marine industries.

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### **Developmental trajectories of intelligence, working memory and processing speed**

The relationships among intelligence, working memory and processing speed as they develop during childhood are investigated using a cross sectional / longitudinal design.

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### **The development of executive control functions**

Executive function is a higher order cognitive ability that is important for goal-directed behaviour. Our research investigates the development of executive function during childhood and adolescence, focussing on three core components of executive function: working memory, task switching and response inhibition.

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### **Cognitive Psychology: Are human faces special?**

People are extremely efficient in recognizing other peoples' faces. We can recognize a familiar face from distance, in dim light, and even if the face is partially occluded. Contemporary theories of face processing argue that faces are special because different facial features (eyes, nose, mouth) are combined together to create a 'holistic' experience. We shall test this assertion using the well-known Garner paradigm.

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### **Cognitive Psychology: 'Hot Hand' in computer games.**

The 'Hot Hand' phenomenon in basketball (Kahneman & Tversky), or other sports, refers to one's ability to make a successful shot after a sequence of successful shots, compared to her or his chances of making the next shot after unsuccessful shot(s). Presumably, high confidence after a successful trial improves performance on subsequent trial(s). We shall test if the 'Hot Hand' phenomenon exists in computer games, and focus on whether or not gamers are willing to take higher risks after successful trials.

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### **Cognitive Psychology: Challenging the automaticity account of the Stroop phenomenon.**

In a Stroop task, participants are presented with colour names printed in colour and are asked to indicate the print colour, while ignoring the word. People are often slower in naming the colour of incongruent displays (such as the word GREEN printed in red) compared to naming the colour of congruent displays (RED printed in red). Presumably, this slowdown in performance (termed the Stroop effect) is due to the automatic nature of reading: when presented with words, people cannot ignore the words, which in turn slow them down on incongruent trials. We shall challenge this account and test whether it is mandatory.

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### **Social Class Differences in Social Integration Among University Students**

Recent research has found that working-class students are less socially integrated than middle-class students at university. In particular, working-class students participate in fewer social activities, feel lonelier, and have less of a sense of belonging at university. The present research project will investigate the potential reasons for this social class difference in social integration.

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Human Experimental and Applied Dynamics (HEAD) - Social Psychology Laboratory / Priority Research Centre for Brain and Mental Health Research

- (i) Improving Spatial Performance Using Online 3D Learning Tasks**
- (ii) Investigating the Relationship Between Spatial Ability and General Academic Ability**
- (iii) Exploring Factors of the Spatial Ability Construct**
- (iv) Relevance of Response Time in the Measurement of Spatial Performance**

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Human Experimental and Applied Dynamics (HEAD) Group

### **A learning outlook to the fear and categorization of ethnic others**

Intergroup anxiety (the anxiety experienced during anticipated or actual interactions with individuals of other ethnicity) and intergroup categorization (the act of mentally separating us from them along ethnic dividers) are powerful predictors of intergroup prejudice and discriminatory behaviour in society. The present project takes a systematic approach to explore the extent to which intergroup anxiety, as well as out-group categorization processes, can be modified through both direct experience of an aversive interaction with ethnic faces, and observation of another person's (the 'demonstrator') aversive experience. The student will work under the supervision of a researcher in learning and cognition (Dr Griffin) and a researcher in social psychology (Dr Paolini), both internationally recognized experts in their fields and learn to use state-of-the-art technology to manipulate direct and observational aversive learning, assess ethnic categorization of human faces, and measure psychophysiological responses of arousal.

This exciting new line of research has the potential to inform the design of individual-level treatments of anxiety and stereotype reduction, as well as group-level intervention programs aiming to reduce racial tension in society.

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Neuroscience / Priority Research Centre for Brain and Mental Health Research

### **Predicting people's willingness to engage in intergroup contact and intergroup friendship**

Growing evidence indicates that intergroup friendship, the friendship between individuals of opposing groups (e.g., Anglo-ethnic individuals, straight and gay individuals, young-old people), is probably the most effective form of intergroup exchange able to diminish prejudiced attitudes towards entire discriminated groups. Willingness to engage in contact with people of different backgrounds naturally precede the formation of intergroup friendships, yet research investigating the determinants of people's seeking/avoidance of meaningful intergroup exchange is surprisingly scant.

In the proposed research, we use a combination of natural observation, survey, and experimentation to investigate individual difference variables and contextual factors that affect this willingness to engage in intergroup relations. For example, ongoing work investigates two motivational-affective drives: *intergroup anxiety* (the anxiety experienced when engaging or anticipating and intergroup interaction; associated with avoidance; Stephan & Stephan, 1985) and *self-expansion* (the desire to expand the resources, perspectives, and identities of the self through the formation of close relationships with different others; associated with engagement, Wright, Aron & Tropp, 2002). The relative predictive powers of these and other critical factors, in their *trait* (i.e., individual differences) and *state* (i.e. contextual manifestations) forms, as well as their interactive effects, are investigated.

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Human Experimental and Applied Dynamics (HEAD) - Social Psychology Laboratory / Priority Research Centre for Brain and Mental Health Research

### **Auditory Temporal Processing**

Sounds are dynamic in nature, containing rapid transitions in amplitude and frequency over time. These transients convey information crucial for accurate perception of speech, music and information essential for adaptive behaviour. This research program seeks to better understand the perceptual and neural basis of our extraordinary ability to hear these temporal characteristics of sound by examining the relationship between brain electrical responses (EEG/ERP methods) and perceptual (psychoacoustic/psychophysical methods) sensitivity to temporal variations in sound.

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Neuroscience / Priority Research Centre for Brain and Mental Health Research

### **Brain mechanisms in binaural hearing**

One of the most remarkable features of auditory perception is our ability to very small detect differences in the timing of sound arriving at each ear. This sensitivity to the microsecond level of timing of sounds is an order of magnitude more precise than any other sensory modality and underlies our ability to localise sounds in space as well as to accurately perceive sounds in noisy environments. This research seeks to better understand the role of the auditory brain in the representation and analysis of binaural information using measures of brain electrical activity (EEG/ERP) and psychoacoustic methods.

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### **Neuroplasticity in somatosensory cortex**

Previous EEG studies have shown that entrained neuroelectric activity of somatosensory cortex to prolonged or rapidly repeated tactile stimulation reflects activity of a synchronously active neural population. Recent research has shown that this response is not static, reflecting only the hardwired connections to the skin, but is modified progressively and is reversible over short periods of time (seconds to minutes). This suggests that this measure of EEG activity may provide an important index of brain plasticity with potential applications to clinical populations such as stroke.

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### **Brains, behaviour and ecology in the Indian mynah**

Why do some species have bigger brains than others? Do big brains confer greater intelligence? Do some environments select for greater intelligence? This project will investigate the relationship between brain anatomy, cognitive performance, and ecology in the Indian mynah, an exotic species of song bird, and vocal mimic, to identify the neural and ecological factors that support the evolution of complex cognition and intelligence.

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### **Exploring the minds of nonhumans: complex cognition in the Indian mynah**

Exciting new advances in the study nonhuman minds, notably those of birds, have revealed the existence of complex cognitive abilities that extend well beyond those expected from basic associative learning mechanisms. These include capabilities like the ability to recall past events and to plan for future ones ('mental time travel'), to extract information from a given learning situation and apply it to novel situations, and to recall information about specific past events ('where, when, what (WWW) memory' also known as episodic memory). Building on these recent advances, this project will explore various aspects of complex cognition in the Indian mynah, an exotic species of songbird, vocal mimic, and outstanding learner and innovator.

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## **Early life programming of health and Disease**

The research focus of the laboratory is the role of early life events in the programming of development. Over the past 15 years our laboratory has been addressing the impact of maternal and neonatal factors on fetal development and subsequent susceptibility to pathology in later life. Utilising a variety of animal and human models, we have been working towards providing a perinatal etiology for chronic pain, anxiety, schizophrenia, and irritable bowel syndrome. Whilst appearing diverse, these disorders all appear to have common links to infection in early life. We are also focusing on the possible epigenetic pathways that transmit such predispositions from one generation to the next non-genomically. We currently have projects available for PhDs in the following areas:

**(i) Fetal origins of cancer**

A relationship between early life infection and childhood leukaemia has been demonstrated. This project will investigate this proposal in an animal model of human breast cancer. We are also interested in exploring the relationship between smoking during pregnancy and cancer development in the offspring.

**(ii) Role of early life infection in schizophrenia and cognitive alterations in working memory.**

There is a long history relating viral exposure during pregnancy to the onset of schizophrenia in later life. This project is investigating the relationship between infection in early life and the development of schizophrenia and cognitive alterations in later life in an animal model.

**(iii) Role of early life infection on predisposition to psychopathology**

Previously, we have demonstrated early life exposure to bacteria results in an increased propensity for adult onset anxiety using a rat model. This project will examine what transgenerational implications such a predisposition may hold. In other words could infection in early life induce anxiety in one generation that is then transmitted to subsequent generations.

**(iv) Does the early life environment predispose to drug use in adulthood**

In this project we are using an animal model to investigate the possibility that early life stress or early life exposure to cannabis can increase the likelihood of drug taking behaviour in adulthood.

**(v) Developing new approaches to assist the brain recover from inflammation and inflammation induced damage**

Inflammation within the brain (neuro-inflammation) can result from prolonged levels of psychological stress, depression, stroke or cardiovascular disease. Importantly, neuro-inflammation can produce significant changes in mood and cognitive function that make recovery from these conditions more difficult. The objective this research project is to examine and optimise a variety of practical and clinically translatable strategies to combat neuroinflammation, with a long-term view of improving recovery.

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Laboratory of Neuroimmunology / Neuroscience Research Group

## **Developmental pathways of cognitive and emotional control from late adolescence to early adulthood**

### **Does adolescent risk-taking behaviour represent misaligned development of Emotion vs. Cognition?**

While adolescence is known as a time of turbulence and risk-taking, for some young people it carries lifetime consequences. Adolescents engage in risky behaviours *despite* knowing the potential consequences. Recent theories argue that cognitive and emotional parts of the brain mature at different rates, resulting in a mismatch between risk awareness and behaviour control. This study looks to the brain to understand what draws some adolescents to high risk-taking behaviour.

We will test the above proposition by examining differences in the rate of development of cognitive and emotional control using behavioural, brain activation and brain morphology measures. We will examine if differences in the rate of development of cognitive and emotional control are related to level of risk-taking and problem behaviours. This will help develop interventions to reduce risk-taking and its consequences for the young person and society.

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### **Recovery from mild ischaemic stroke – the effect of white matter lesions of cognitive and motor control**

Cerebral white matter is especially vulnerable to hypoxic-ischemic injury throughout the lifespan; white matter lesions (WML), which generally occur without any acute clinical symptoms, have been linked to cognitive deficits associated with cerebrovascular disease. The degree to which WML in healthy aging represents age-related change or a precursor to the development of vascular dementia remains unclear.

The current research program project will implement cognitive and motor control paradigms developed by our research team to map the pattern of cognitive and motor control deficits associated with the location and extent of WML in patients with and without previous minor ischaemic stroke who show no evidence of dementia. This work will lead to targeted interventions to reduce to impact of WMLs on cognitive and motor function and prolong healthy aging. This work is conducted in collaboration with the Stroke Research team of the Priority Research Centre for Brain and Mental Health.

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### **Structural and functional organisation of cognitive control processes**

Our research program aims at understanding the cognitive and neural architecture of executive control processes. We use a range of paradigms that allow us to examine the role of voluntary mechanisms vs contextual factors that affect the way we control our intentions and actions. Our program integrates across mathematical models of behaviour and neuroimaging methods such as event-related potentials (ERP), magnetoencephalography (MEG) and functional magnetic resonance imaging (fMRI) in order to develop integrative models of cognitive control.

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### **The role of control processes in cognitive decline in normal ageing and psychopathology**

Executive dysfunction is associated with many clinical conditions and normal ageing. Our work aims to examine specific patterns of cognitive control decline in psychopathologies associated with frontal lobe dysfunction and develop cognitive remediation programs targeted to different clinical groups.

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### **Mechanisms Underlying Myopia**

The incidence of myopia (short-sightedness) has risen dramatically throughout the world within one generation. It is now a leading cause of blindness in Asia. It is caused by aberrant visual input during development. Several projects are available and involve investigating the underlying mechanisms of myopia using an animal model and optical, molecular and immunocytochemical methods.

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*Neuroscience / Priority Research Centre for Brain and Mental Health Research / Sensory Dysfunction Section*

### **Neural mechanisms of adaptation and plasticity**

We have discovered how to make neurons establish new connections in the retina of the eye, which has application to reversing neural degenerations. This project will pinpoint the source, targets and causal neuronal factors underlying this plasticity in guinea pig and mouse retina.

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*Neuroscience / Priority Research Centre for Brain and Mental Health Research / Sensory Dysfunction Section*

### **Executive function deficits following sedative psychotropic drug overdose and implications for everyday functioning**

Overdose with sedative medications is a common clinical problem. Current clinical practice is to discharge the patients in the following morning based on crude clinical observations. The aim of this study is to assess the residual impairments of these patients using electrophysiological and neuropsychological measures of executive functioning and to determine whether these deficits are predictive of everyday functioning.

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### **Predicting transition to psychosis from an at-risk mental state**

The aim of this project is to determine whether we can predict transition from an at-risk mental state to a psychotic disorder based on deficits in cognition, electrophysiological measures of early auditory processing deficits and neuroanatomy.

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### **Remediating cognitive deficits in patients with schizophrenia**

One of the most robust findings in patients with schizophrenia is that they exhibit substantial cognitive deficits particularly in verbal memory and executive functions. The purpose of this project is to develop and evaluate a remediation program that attempts to reduce the extent of these deficits in patients and their impact on overall functioning.

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### **Brain asymmetry in processing the time cues in sound**

As we age, many individuals with intact audiograms (normal hearing sensitivity) will experience difficulty hearing speech in noisy environments. One hypothesis for why this occurs is that there is a decline in the ability to track important temporal/timing cue in the speech signal. We have demonstrated that persons with very good temporal processing ability show asymmetry in how the brain responds to these time cues. Persons with poor temporal processing do not show this asymmetry. Similarly, this asymmetry reverses in good temporal processors in noisy listening environments but again, no asymmetry is seen in poor temporal processors. Studies will be conducted to further explore this ability-related asymmetry using electrophysiological, psychophysical and/or neurocognitive measures and it's importance to groups with impaired temporal and speech processing abilities.

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### **Fixing faulty filters: The building blocks of psychosis**

Antipsychotic medications are the principal treatment for schizophrenia. The primary action of most antipsychotic medications is to reduce levels of the chemical dopamine in a brain region called the striatum. The dopaminergic system is critical to our ability to engage in goal-directed activity, to learn and to process the relevance of events in relation to context. The primary functional consequence of the medication-induced change in dopamine is to correct a breakdown in the process by which salience or importance is attributed to events. Correcting salience-coding equates to fixing a "faulty filter" that influences whether events become candidates for the focus of our attention. Recent conceptualisations view abnormal dopamine levels as a secondary consequence of a primary problem in the glutamatergic chemical system. Glutamate is a chemical critical to the acquisition and expression of learning. Problems in glutamate and dopamine in striatal and prefrontal regions of the brain are considered central to core treatment-resistant cognitive deficits observed in schizophrenia.

This stream of research involves the development of protocols using measures of brain activity to test the cognitive processes, mental illness and the pharmacology of the systems associated with how the brain automatically filters relevance in the environment.

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### **Nicotine and Cognition in Schizophrenia**

Whilst nicotine use is declining in the general population (25-30%), it remains very high in individuals with schizophrenia (70-90%). Two hypotheses put forward to explain the high rates of nicotine use in schizophrenia include a focus on self-medication and addiction vulnerability. We are conducting studies to further explore some of the unique effects of nicotine on cognitive abilities in this group.

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### **Objective emotion versus subjective feeling**

The human brain automatically reacts to any environmental stimulation with emotional responses. Parallel to cognitive processes these emotional responses guide our behaviour. The present project is meant to demonstrate that automatic emotional responses do not always match subjective feelings. Objective physiological recordings and subjective ratings under controlled emotional situations are used to test this hypothesis.

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## **Disclaimer**

All information is correct as at August 2011, but is subject to change as the content is reviewed and updated. Refer to the Faculty of Science and Information Technology web site for the latest research topics available:

**[www.newcastle.edu.au/faculty/science-it/](http://www.newcastle.edu.au/faculty/science-it/)**

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