Australian Academy of Science

Australian Frontiers of Science 2003

Program

31 July to 1 August 2003

Program

Thursday 31 July 2003

1.50 **Welcome**
Dr Jim Peacock, President

2:00 **Advanced materials**

Organiser Professor Marcela Bilek

Chair Professor David McKenzie, Applied and Plasma Physics, University of Sydney

Advanced materials synthesis
Professor Marcela Bilek, Applied and Plasma Physics, University of Sydney

Advanced materials characterisation
Associate Professor Dougal McCulloch, Faculty of Applied Science, RMIT University

2:40 Discussion

3:00 **Extinction events in the geological past – causes and effects**

Organiser Dr Annette George

Chair Dr Charley Lineweaver, Department of Astrophysics and Optics, University of New South Wales

Mass extinctions – not as simple as 'smoking kills'!
Dr Annette George, School of Earth and Geographical Sciences, University of Western Australia

Novel biomarker distributions and their stable isotopes in Permian/Triassic sediments
Dr Kliti Grice, School of Applied Chemistry, Curtin University

3:40 Discussion

4:00 *Afternoon tea*

4:30 **Gene silencing – from basic mechanisms to industrial and therapeutic applications**

Organiser Associate Professor Levon Khachigian

Chair Dr Wayne Gerlach, Johnson and Johnson Research Pty Ltd

DNA-based catalytic agents as potential inhibitors of vascular disorders
Associate Professor Levon Khachigian, Centre for Thrombosis and Vascular Research, University of New South Wales

Gene silencing in plants and other eukaryotes
Dr Peter M Waterhouse, CSIRO, Canberra

5:10 Discussion

5:30 Close

7:30 *Dinner: The Hall, University House*

Friday 1 August 2003

9:00 **Protein structure as a gateway to drug design**

Organiser Dr Joel Mackay

Chair Dr Jacqui Matthews, School of Molecular and Microbial Biosciences, University of Sydney

Zinc binding proteins as molecular scaffolds for drug design
Dr Joel Mackay, School of Molecular and Microbial Biosciences, University of Sydney

The role of protein structure in functional annotation of proteins
Dr Bostjan Kobe, Department of Biochemistry and Molecular Biology, University of Queensland

9:40 Discussion

10:00 **New approaches to the evolution of complex biological systems**

Organiser Dr Sandra Orgeig

Chair Associate Professor Chris Daniels, School of Earth and Environment Sciences, University of Adelaide

Evolutionary developmental physiology – how does individual developmental plasticity lead to heterochrony?
Dr Sandra Orgeig, Department of Environmental Biology, University of Adelaide

New approaches to the 'evolution' of complex ecological systems – kangaroo population dynamics
Professor Hugh Possingham, Department of Mathematics and School of Life Sciences, University of Queensland

10:40 Discussion

11:00 *Morning tea*

11:30 **Utilising large astronomical datasets**

Organiser Dr Brian Schmidt

Chair Associate Professor Rachel Webster, University of Melbourne

Scanning the sky – learning about the universe through large datasets
Dr Brian Schmidt, Research School of Astronomy and Astrophysics, Australian National University

Data challenges in astronomy
Dr David Barnes, School of Physics, University of Melbourne

12:10 Discussion

12:30 *Lunch*

1:30	**Quantum computing**
Organiser	Dr Howard Wiseman
Chair	Professor Bob Clark, Centre for Quantum Computer Technology, School of Physics, University of New South Wales
	Quantum computing – theoretical challenges Dr Howard Wiseman, School of Science, Griffith University
	Solid-state quantum computing and quantum electronic devices Dr Alex Hamilton, School of Physics, University of New South Wales
2:10	Discussion
2:30	**Molecular ecology – integrating genetics with demography to understand population biology**
Organiser	Dr Andrew Young
Chair	Professor Richard Frankham, School of Tropical Biology, James Cook University
	Monitoring, molecules and models – integrating genetics and demography in the analysis of plant population viability Dr Andrew Young, CSIRO Plant Industry
	Molecular ecology meets conservation biology – Australian mammal case studies Dr Andrea Taylor, School of Biological Sciences, Monash University
3:10	Discussion
3:30	*Afternoon tea*
4:00	**Panel discussion**
Chair	Dr Paul Willis, ABC TV
Panel	Marcela Bilek, Bob Clark, Wayne Gerlach, Hugh Possingham
5:00	Close

Advanced materials

Professor David McKenzie

David McKenzie has held a Personal Chair in Materials Physics in the School of Physics University of Sydney since 1997. Previous appointments have included: Director of the Australian Key Centre for Microscopy and Microanalysis (AKCMM) (2000); Deputy Director of the AKCMM (1994-1999); Reader at the University of Sydney and Visiting Professorships at Osaka University, Japan and Nanyang Technological University, Singapore and a Visiting Fellowship at Churchill College Cambridge. Research achievements have included the identification of the amorphous phase of carbon known as tetrahedral amorphous carbon, the development of theories for the formation of the cubic phase of born nitride, the development of techniques for the on line analysis of thin film materials by electron diffraction in the electron microscope. In 2001 he was awarded an ISI Citation Laurate award for 8 high impact papers and is listed in 2003 by ISI as one of the worlds 250 most most highly cited scientists.

Extinction events in the geological past – causes and effects

Dr Charley Lineweaver

Charles is a research astronomer and senior lecturer in the School of Physics, University of New South Wales, Sydney, Australia. He received his PhD in physics from the University of California at Berkeley. His fields of research are cosmology and more recently astrobiology. He teaches one of the most popular general studies courses at the University of New South Wales, 'Are We Alone?' (http://www.phys.unsw.edu.au/astro/seti)

He has lived in or travelled through 62 countries, speaks four languages and was a semi-professional soccer player in Germany.

Gene silencing – from basic mechanisms to industrial and therapeutic applications

Dr Wayne Gerlach

Wayne is Executive Director – Biotechnology at Johnson & Johnson Research Pty Limited in Sydney. From 1992 to early 2003 he was Director of the Johnson & Johnson Research Laboratories. This is a molecular biology research facility of Johnson & Johnson corporation.

Prior to this he was Senior Principal Research Scientist at CSIRO Division of Plant Industry in Canberra. At CSIRO he worked in areas of plant molecular biology, with a later concentration on plant disease, being Program Leader in this area.

Originally a graduate and PhD in genetics from the University of Adelaide, in 1990 he was awarded the CSIRO Rivett Medal for research, and in 1992 was awarded the Lemberg Medal of the Australian Society for Biochemistry and Molecular Biology. He has also held Rothmans, Harkness and Queen Elizabeth II Fellowships, and has held appointments in Cambridge, England, and at the University of California at Davis. He has published over 90 papers and book chapters in areas of molecular and classical genetics, as well as patent applications.

Protein structure as a gateway to drug design

Dr Jacqui Matthews

Jacqui completed her undergraduate degree at the University of New South Wales and followed this up with a PhD in protein folding from the University of Cambridge. She was a Postdoctoral Fellow at the Ludwig Institute for Cancer Research in Melbourne, before coming to the School of Molecular and Microbial Biosciences at the University of Sydney. Jacqui currently holds an ARC Australian Research Fellowship. Her work focuses on understanding, with molecular and atomic precision, the roles of particular proteins in normal development and in disease states such as breast cancer and childhood leukemia.

New approaches to the evolution of complex biological systems

Associate Professor Chris Daniels

Christopher is a Research Associate Professor in Environmental Biology at the University of Adelaide. Chris followed formal training in zoology (a PhD in the eco-physiology of reptiles at the University of New England in 1984 and a postdoc on the evolution of exercise capacity in reptiles at University of California Irvine) with two 8-year periods teaching human physiology to medical/science students, firstly at Flinders University then at the University of Adelaide. With more than 90 refereed papers, Chris has a strong research programme in evolutionary physiology, focusing on the evolution of air-breathing and lung development. In 2002 Chris assumed the directorship of 'BioCity: The Centre for Urban Habitats'. This multidisciplinary, multi-institutional, independently funded research centre examines the biological basis for, and the evolution of, urban ecosystems. Hence Chris' evolutionary research now spans cells to ecosystems to examine the broad concepts behind, and test hypotheses relating to, the evolution of complex biological systems.

Utilising large astronomical datasets

Associate Professor Rachel Webster

Rachel is Head of the Astrophysics Group at the University of Melbourne. She has a PhD from the University of Cambridge, UK, an MSc from Sussex University in the UK, and a BSc (Hons) from Monash University. Before moving to the University of Melbourne she held postdoctoral appointments and a University Research Fellowship at the Universtiy of Toronto. She has active research interests in gravitational lensing, quasars, clusters of galaxies and large-scale structure. She is the current chair of the National Committee for Astronomy.

Quantum computing

Professor Bob Clark

Robert undertook his BSc degree at the Royal Australian Naval College, Jervis Bay and University of New South Wales. He subsequently completed a PhD in Physics at UNSW and the Clarendon Laboratory, University of Oxford. After postdoctoral research at the Clarendon he was appointed University Lecturer in Physics at the University of Oxford and Fellow of The Queen’s College, Oxford in 1984 and was awarded an Oxford MA by special resolution. He headed a research group at Oxford investigating quantum effects in semiconductor systems. He returned to Australia in 1991 to take up the position of Professor of Experimental Physics at UNSW, where he founded and established the National Magnet Laboratory and Semiconductor Nanofabrication Facility. He is the Director of the Australian Research Council Centre of Excellence for Quantum Computer Technology, involving more than 100 researchers in six Australian universities.

Molecular ecology – integrating genetics with demography to understand population biology

Professor Richard Frankham

Richard holds honorary professorial appointments at Macquarie University, James Cook University and the Australian Museum, and has been appointed Hrdy Visiting Professor at Harvard University for spring semester 2004. Previously, he held academic appointments at Macquarie University for 31 years. He obtained his BScAgr (Hons 1) and PhD at the University of Sydney. He has published over 110 scientific papers and is senior author of *Introduction to Conservation Genetics*, the first textbook in conservation genetics. Japanese and Chinese translations of this textbook are in preparation. He was included in *Outstanding Scientists of the 21st Century*, 1st edition, International Biographical Centre. He is a member of two specialist groups of the Species Survival Commissions of IUCN; a member of the scientific advisory committee for the NSW State of the Environment Report 2003; a member of the editorial board of Genetical Research; and associate editor of *Conservation Genetics*.

Panel discussion

Dr Paul Willis

Paul got into science as a kid and has never grown out of it. He found his first fossil when he was a six-year-old pom and has been hooked on palaeontology ever since. Moving to Australia at the age of nine, Paul went on to study Geology and Zoology at Sydney University before completing a PhD at the University of New South Wales studying fossil crocodiles. Paul has been with the ABC since 1997 as a cross media science broadcaster, regularly appearing on radio, TV and online. He also tours with the public event 'Science In The Pub'. Paul broadcasts weekly radio segments to the ABC in Western Australia, Northern Territory as well as ABC Radio Tasmania every couple of weeks. 'It's easy to be outstanding in your field,' Paul jests, 'just pick an empty one that no one else wants to go near.'

Professor Marcela Bilek

Marcela was appointed Professor of Applied Physics at the University of Sydney in November 2000. She holds a PhD in Engineering from the University of Cambridge, UK, a BSc (Hons) in Physics from the University of Sydney and an MBA degree from the Rochester Institute of Technolgy, USA. Prior to her present appointment she held a visiting professorship at the Technische Universitat Hamburg-Harburg in Germany and a research fellowship at Emmanuel College, University of Cambridge, UK. She also worked for a number of years as a visiting research scientist at the Lawrence Berkeley Laboratory, University of California, USA. Aside from her academic experience, Marcela has also spent time working in industry as a research scientist at Comalco Research Centre, Melbourne, and at the IBM Asia Pacifc Group Headquarters in Tokyo. Her main research interest is in plasma-based thin film deposition and surface modification. She was awarded the Malcolm McIntosh Prize for Physical Scientist of the Year in 2002.

Advanced materials synthesis

Conventional methods of searching for new materials are the formation of new alloys by melting the constituents together or by chemical synthesis of new compounds especially polymers, inspired by chemical knowledge based on existing materials. More recently, ion based modification processes have added a new dimension by allowing us to create new materials, often in an amorphous or glassy form, and impart new properties to existing materials and surfaces. The stabilisation of many interesting metastable phases has also been achieved in this way, leading to new forms of existing materials (tetrahedral amorphous carbon is an example). The development of accurate and powerful first principles methods of molecular dynamics simulation has greatly added to our ability to design new materials before we synthesise them and to predict their properties. Now the focus is shifting to the creation of nanostructured materials with enhanced properties. There are many examples in nature where a material's most desirable properties are a result primarily of the fine scale structure (meso-scale structure which is on a scale larger than atomic dimensions but smaller than the wavelength of light) and not simply the composition. In this talk I will discuss briefly the types of methods being developed to produce materials with meso-scale structure. Multilayer materials are an example, under some conditions having properties departing unexpectedly from those of the constituents. There is also a need to link the structure to the observed properties and identify the important physical and chemical mechanisms which determine the structure during synthesis. The way in which structured materials interact with biological molecules is of particular interest for the development of biomedical devices. The growth of understanding in this subfield in particular will involve the cooperation of biologists, chemists, materials scientists and physicists.

Associate Professor Dougal McCulloch

Dougal was recently promoted to Associate Professor – Microscopy and Microanalysis in the Department of Applied Physics at RMIT University. In 1999 he established, and is now a director of, the RMIT Microscopy and Microanalysis Facility, which is utilised by researchers from many disciplines within RMIT and beyond. He is expert in applying a wide range of materials analysis techniques to the investigation of carbonaceous and thin film coatings including electron microscopy, surface and ion beam analysis and Raman and infrared spectroscopy. He also established the Car-Parrinello ab-initio molecular dynamics code in Australia and performed an extensive range of simulations on carbon and light element binary and ternary alloy systems. His achievements in this area were recently recognised when he was invited to give a keynote lecture at a symposium on Amorphous, Disordered and Incommensurate Materials at the 15th International Congress on Electron Microscopy (ICEM-15) held in Durban, South Africa in September 2002.

Advanced materials characterisation

There is an ever-increasing need to develop and improve techniques for the analysis of advanced materials, especially for those with features on the nanoscale (10^{-9} m). For example, in the electronics industries, the drive towards miniaturisation has resulted in finer and finer features and it remains a considerable challenge to find analysis techniques which can characterise components into the future. The need for higher resolution analysis methods has resulted in the development of new microscopy and surface analysis techniques which are optimised for the analysis of small volumes of material. Issues associated with the performance of thin film materials in electronics, biomaterials and wear performance include the atomic scale structure and the nature of preferred orientation. The information available from the electron microscope has been expanded to include the energy loss spectrum of the transmitted electrons and detailed analysis of the diffraction pattern to give preferred orientation information as well as atomic level information through the radial distribution function. These techniques are useful for amorphous materials as well as for polycrystalline materials. As a powerful supplement to experimental methods, accurate computer modelling has extended our knowledge of advanced materials and given us considerable predictive power. These computational methods are used to optimise structures and predict properties and can be used to design materials for particular applications. In this talk, I will briefly discuss some of the new state-of-the-art analysis and modelling methods being employed to study nanostructured materials. Such methods will also be of considerable value to other fields in which the understanding of features or objects on the nanoscale is important.

Dr Annette George

Annette is a Senior Lecturer in Geology at the University of Western Australia. Previously she held a teaching position at the University of Melbourne following her PhD graduation from Victoria University of Wellington in 1988. Annette's research interests focus on deciphering the tectonic history of sedimentary basins which involves the application and integration of a variety of geological techniques. She coordinates the Sedimentary Research Group at UWA which includes research and postdoctoral research fellows, PhD and honours students. The research also focuses on application of sedimentary techniques to understanding basin-hosted mineral deposits and petroleum reservoirs. Annette has published widely on a variety of sedimentary basins particularly the Devonian reef complexes of northern Australia in recent years. She received the Australian Academy of Science's inaugural Dorothy Hill Award in 2002.

Mass extinctions – not as simple as 'smoking kills'!

The geological record is marked by continual changes in biodiversity. While the beginnings of life and its subsequent evolution have captivated the minds of biologists and geologists for centuries, the periods of dramatic loss have only developed into a major topic of research and debate over the last 25 years. The evolution of complex organisms over the last 550 million years has included several well-established biotic crises of global proportions. Despite the research effort directed at these crises, particularly the largest ones, their causes are not clear cut. No one cause unites all extinction events. Even within these events, defining a single global cause is very difficult, notwithstanding the fact that many single causes dominate the literature. I will present some insights into the causes and effects of mass extinction events, highlighting two dramatic examples, from the Permo-Triassic (250 Ma) and Late Devonian (360 Ma), to illustrate their complexity. I will also highlight the importance of a multidisciplinary approach in unravelling global events based on regional examples.

Dr Kliti Grice

Kliti is a recipient of an ARC Queen Elizabeth II Fellowship. She received her PhD in 1995 (University of Bristol-UK) on stable isotopes of biomarkers for reconstructing (palaeo)environments. She held a postdoctoral position at the Royal Netherlands Institute for Sea Research. In 1998 she joined Curtin University of Technology, Perth. Since then she has established and leads a stable isotope research group within WA Centre for Excellence in Applied Organic Geochemistry (director Professor Robert Kagi). The stable isotope group carry out fundamental research applied to petroleum, water, (palaeo)climate and the environment. Kliti has received a number of awards including the international Pieter Schenck Award, the Australian Academy of Science's J G Russell award, and the inaugural WA Premier's Science Award. She has published around 30 papers and 60 conference presentations and is a member of PESA, EAOG, ACS and RACI.

Novel biomarker distributions and their stable isotopes in Permian/Triassic sediments

The ocean's properties interact with and respond to processes in the geosphere, biosphere and atmosphere and its deposits preserve records of environmental change. An understanding of the early history of life on Earth and environmental change requires information on primary producers and decomposers. Such information is still preserved in sediments in the form of biomarkers. Biomarkers derived from biochemicals in algae, photosynthetic bacteria and higher plants and organisms, processing already fixed carbon and so forth are probably the most important information carriers with respect to the environment. Gas chromatography-mass spectrometric techniques have been useful in identifying biomarkers in sediments and petroleum, but GC-MS alone does not always distinguish their natural product precursors. The development of compound specific carbon isotope technology has established the precursors of many biomarkers and has recently been shown to be a powerful tool in providing valuable information on our changing climates and environments. Marine and terrestrial life experienced the most severe crisis in the Earth's history between the Permian (P) and Triassic (T). In recent years drastically changing inorganic geochemical signals that reflect oceanographic and/or atmospheric perturbations at the P/T boundary have been observed. However, the mechanism leading to the mass extinction is still an ongoing debate. Global anoxia, overturn of stagnant deep oceans, melting of gas hydrates, volcanism and meteorite impact are the mechanisms that are continually invoked. Biomarkers and $^{13}C/^{12}C$ and D/H may innovatively contribute to a coherent portrayal of the decline, collapse and subsequent recovery of species at the P/T boundary. A biomarker-isotope approach is being applied to organic-rich P-T sections about the globe (Greenland, Canada, China, Australia) and preliminary results will be presented.

Associate Professor Levon Khachigian

Levon is an NHMRC Principal Research Fellow and Head of the Signalling and Transcription Laboratory at the Centre for Vascular Research at the University of New South Wales, where he is Associate Professor of Pathology. His research has dramatically increased our understanding of the fundamental transcriptional mechanisms that lead to the inappropriate expression of harmful genes in cells of the artery wall. It has led to his generation of novel DNA-based drugs that block arterial renarrowing after balloon angioplasty and, more recently, the process of tumour growth by inhibiting angiogenesis. He has published extensively in scientific journals of high impact, including *Science*, *Nature Medicine*, *Journal of Clinical Investigation* and *EMBO Journal*.

DNA-based catalytic agents as potential inhibitors of vascular disorders

DNA enzymes (DNAzymes) are RNA-cleaving phosphodiester-linked DNA-based enzymes that seek out and cleave their target mRNA in a gene-specific fashion. DNAzymes targeting the immediate-early gene product, early growth response-1 (Egr-1), for example, inhibit intimal thickening in rat carotid arteries following balloon angioplasty, permanent ligation, and in-stent restenosis in pigs after coronary stenting. Similarly, DNAzymes targeting c-Jun, a prototypic member of the basic region-leucine zipper family of nuclear proteins inhibit inducible c-Jun expression in vascular smooth muscle cells, block smooth muscle cell proliferation and attenuate intimal thickening in injured rat carotid arteries. We have also recently demonstrated that DNAzymes are capable of inhibiting target genes in microvascular endothelial cells. These agents block microvascular endothelial cell growth, neovascularization, tumor angiogenesis and tumor growth. DNAzymes, therefore, are versatile gene targeting tools with important therapeutic implications.

Dr Peter Waterhouse

Peter is a senior principal research scientist and leader of the gene silencing laboratory at CSIRO Plant Industry, in Canberra. He joined CSIRO directly after obtaining his PhD from Dundee University (UK) and has remained there ever since, except for a sabbatical year at the MRC/Cambridge University (UK). His early research was the key to our current understanding of the evolution, genome organisation and gene regulation strategies of luteoviruses, umbraviruses and oryzaviruses. More recently, he and his team made the world-first discovery that double-stranded RNA induces gene silencing (often referred to as RNAi) in plants. Since this finding, he has focused on understanding the natural roles of this mechanism and exploiting it for genomics, virus protection and quality trait research. He has several patents covering the applications of this work and about 100 publications which include a book, book chapters, and reviews and primary research papers in high impact journals.

Gene silencing in plants and other eukaryotes

As early as the 1920s it was known that plants could be protected against a severe virus by prior infection with a related but mild strain of the virus. The mechanism providing this 'vaccination-like' protection has remained largely unknown until recently. However, over the last 6 or so years we, and others, have elucidated the mechanism and shown it to be involved in defence against plant viruses. It operates by the sequence-specific degradation of single-stranded RNA and is targeted by small fragments of double-stranded (ds) RNA. This discovery has led to an extremely powerful technology for the destruction of, not only viruses, but also of any specific mRNA, and hence the silencing of any gene, within a cell. The specificity of the destruction is simply governed by the sequence of the dsRNA introduced into the cell. In this talk, I will describe how dsRNA is being expressed in plants as a tool for gene discovery, gene validation and to engineer desirable traits in plants.

During the last year, it has become clear that this dsRNA-induced mechanism also plays a key role in regulating the growth and development of almost all eukaryotes ranging from fungi to humans. I will discuss the widening perspective of how this regulatory pathway, that was not contemplated 15 years ago, plays a central role in multi-cellular life.

Dr Joel Mackay

Joel is currently a senior lecturer in the School of Molecular and Microbial Biosciences at the University of Sydney. He finished a BSc and MSc at the University of Auckland before completing a PhD at the University of Cambridge. Joel has a strong background in biomolecular recognition and nuclear magnetic resonance spectroscopy, which form the basis for his current research, understanding the mechanisms of gene regulation at a molecular and atomic level. He has published over 50 journal articles and books chapters and has received a number of awards for his research, including the Roche Molecular Biochemicals Medal from the Australian Society for Biochemistry and Molecular Biology in 2001, and the ANZMAG Young Investigator Medal and Minister's Prize for Achievement in the Life Sciences in 2002.

Zinc binding proteins as molecular scaffolds for drug design

Many currently available pharmaceutical agents are small molecules that function as enzyme inhibitors. Small molecules fit into the active sites of enzymes and can effectively impede their activity. However, not all biological processes depend on enzymes, but on protein:protein interactions such as those that mediate cell signalling and transcriptional pathways. Pharmaceutical agents that inhibit protein-protein interactions would also be of great value. Recent research on the physical interactions that occur between proteins indicate that flat interaction surfaces are often involved, and it appears probable that large, rather than, small inhibitory molecules will be most effective as drugs. Indeed, proteins are prime candidates for this role.

The design of proteins with tailored and adaptable binding functions remains an elusive but exciting goal in protein science. Small size, a well-defined structure, and the ability to maintain structural integrity despite multiple mutations are all desirable properties for such designer proteins. Many zinc-binding domains fit this description. We are currently investigating the suitability of zinc-binding domains as scaffolds for presenting selected binding functions. We have focused on two different systems, a serendipitously discovered peptide from the transcriptional regulator CBP and a PHD domain from the co-regulator Mi2b. We have shown that both folds are extremely resistant to mutation and that we can engineer new functions into these domains. I will present our most recent results with these systems.

Dr Bostjan Kobe

Bostjan is an Associate Professor in Structural Biology at the Department of Biochemistry and Molecular Biology, with a joint appointment with the Institute of Molecular Bioscience, both at the University of Queensland. He received his BSc at the University of Ljubljana, Slovenia, and his PhD at the University of Texas Southwestern Medical Center at Dallas, USA. Since his PhD studies, he has worked at the Howard Hughes Medical Institute in Dallas, and St Vincent's Institute of Medical Research in Melbourne. He moved to the University of Queensland in 2000. His research interests involve the structures of biological macromolecules, particularly the interactions between proteins. He is the recipient of an NHMRC Senior Research Fellowship. He received the Minister's Prize for Achievement in Life Sciences in 2001. He has published over 50 scientific papers and accumulated over 2000 citations. He is the member of the Editorial Board of the *Journal of Structural and Functional Genomics*.

The role of protein structure in functional annotation of proteins

The function of a protein depends on its structure. To get a clue about how proteins carry out their functions, we therefore need to know their three-dimensional structures. This can be done using the method of X-ray crystallography, where we need to obtain a crystal of the protein of interest, place the crystal in a strong X-ray beam, collect the diffraction pattern, and determine its structure with the help of computers.

Crystallography used to be a rather laborious technique, and was therefore only used to obtain structures of carefully selected, 'important' proteins. However, recent technical advances now make it possible to study structures on a larger scale, resulting in the birth of a new field called structural genomics. The aim of structural genomics is to determine the structures of all representative proteins found in nature. Structural genomics is a part of an initiative called functional genomics, aiming to define the functions of all proteins in humans and other organisms. The knowledge of the three-dimensional structure of a protein can also help in designing drugs that target the protein.

Many proteins function through recognising and binding to other proteins, and this process has been the focus of our laboratory. I will illustrate our work with three current projects. The first example involves a protein called importin-alpha, which helps transport proteins from the cytoplasmic cellular compartment into the nucleus. This is an example of a traditional project, where we are aiming to understand how one protein functions in the context of an important cellular process. The second example involves a larger-scale initiative, aiming to determine the structures of all proteins involved in the function of macrophages, special cells with roles in combating pathogens that attack us. Finally, I will illustrate how structural information can be used in a more general sense to untangle pathways for transmitting signals through the cell.

Dr Sandra Orgeig

Sandra is an ARC Research Fellow in Environmental Biology at the University of Adelaide. After completing her honours degree at the University of Cape Town, she gained an Overseas Postgraduate Research Scholarship in 1990 to undertake a PhD in Physiology at Flinders University. Following postdoctoral work in physiology at the University of Adelaide, she gained an ARC Postdoctoral Fellowship in 1996 and an ARC Research Fellowship in Environmental Biology in 1999. She is the recipient of the Fenner Medal and Young Tall Poppy Award in 2002 for her work on the evolution of the pulmonary surfactant system, and the role of cholesterol in regulating the biophysical function of this lipid-protein mixture at the air-liquid interface of the lung during thermal fluctuations. Sandra has published over 50 scientific papers. Her current interests are in evolutionary developmental physiology, where she uses the surfactant system as a model to examine the effect of environmental factors on lung development.

Evolutionary developmental physiology – how does individual developmental plasticity lead to heterochrony?

Evolutionary developmental physiology has consisted predominantly of descriptive studies, limited to the particular system or organisms of interest, with very few integrative and functional studies. A new theoretical framework for examining the regulation of physiological processes during development, both within an individual and across species may provide the mechanism that describes how developmental plasticity can lead to heterochrony (defined as an evolutionary change in the rate/timing of developmental processes between species). A key question in developmental physiology is to what extent is the timing of the onset of a particular regulatory system fixed within an individual, and to what extent can it be altered by environmental factors? For example, timing can be altered either chronologically (eg, delaying or bringing forward the onset or completion of a system) or by altered rank in a developmental sequence. Such altered timing within a developing individual is called heterokairy. Can this developmental plasticity over time lead to the process of heterochrony, through classical Darwinian selection of different phenotypes, thereby leading to the diversity of a system across a broad range of species? I will address these questions with examples from my work on the evolution of air-breathing and the evolution of the development of lungs and the pulmonary surfactant system. The surfactant system, which controls surface tension in the lung and is crucial for the first breath at birth, develops differently between vertebrate species. It is possible that, in this case, heterochrony may be linked to several environmental variables, particularly hypoxia.

Professor Hugh Possingham

Hugh is a Professor in Mathematics and Zoology at the University of Queensland, where he is the Director of the Ecology Centre. Hugh completed Applied Mathematics Honours at the University of Adelaide and his DPhil at Oxford University in 1987 as a Rhodes Scholar. Postdoctoral research periods followed at Stanford University and the Australian National University (QEIII Fellow). In 1991 he moved to Applied Mathematics at the University of Adelaide and in 1995 he was appointed Foundation Chair and Professor of Environmental Science. In July 2000 he took his current position at the University of Queensland where he was recently awarded an ARC Professorial Research Fellowship. Hugh has received the Australian Academy of Science's inaugural Fenner Medal, Australian Mathematics Society medal, a Eureka prize and a medal from the Modelling and Simulation Society of Australia. The Possingham lab includes five postdoctoral researchers and eleven PhD students working on empirical and theoretical aspects of applied population ecology.

New approaches to the 'evolution' of complex ecological systems – kangaroo population dynamics

A theory of how to manage wild populations underpins the applied fields of pest management, harvesting (especially fisheries) and conservation. While these problems are not new, how we model, manage and monitor the dynamics of populations is undergoing a revolution. Population ecology is moving away from the null-hypothesis testing paradigm, to confronting alternative models of the dynamics of populations with large-scale long-term data. A particularly intriguing and new area of applied ecological research is the complex interaction of optimal management, optimal monitoring and optimal learning.

We illustrate these emerging paradigm shifts and new problems with examples from our research on kangaroo population dynamics and management.

Specifically we will:

- visualise the large-scale population dynamics of the red kangaroo and show how that generates insights into population processes,
- interrogate a set of nested models with regional scale data and discover that we know less about the drivers of kangaroo dynamics than we thought,
- show how harvesting has counter-intuitive consequences for kangaroo evolution, and
- explore the problem of optimal monitoring and learning in a complex dynamic system.

Dr Brian Schmidt

Brian is an ARC Professorial Fellow at the Research School of Astronomy and Astrophysics, Australian National University. He received a double degree in physics and astronomy from the University of Arizona in 1989, and his PhD in astronomy from Harvard University in 1993. From 1993-94 Brian was a postdoctoral fellow at the Harvard-Smithsonian Center for Astrophysics, and immigrated to Australia in 1995, when he took up a postdoctoral fellowship at the ANU at what was formerly known as Mount Stromlo and Siding Spring Observatories.

Brian is the leader of the High-Z-SN Search team, a collaboration of 20 astronomers on five continents whose discovery of an accelerating universe was awarded Science Magazine's Breakthrough of the Year award in 1998. He is also a member other international investigative teams, including the Supernova Intensive Survey and the REACT Gamma Ray Burst Follow Up Program, both with the Hubble Space Telescope, and the Trans-Neptunian Object Search with the recently destroyed Great Melbourne Telescope. Schmidt has received India's Vainu Bappu medal (2002), the Australian Academy of Science's Pawsey Medal (2001), the Australian government's Malcolm McIntosh Prize (2000) and the Harvard University Bok Prize for Outstanding Astronomical Thesis (2000).

Scanning the sky – learning about the universe through large datasets

Astronomy is increasingly relying on very expensive instruments to continue to answer outstanding questions in our field. However, it is possible to attack many of these questions using extremely large datasets, looking for rare events (which are bright enough to be seen with existing instrumenation), or by creating large statistical ensembles of data which can extract the information in a slightly less direct manner. I will discuss how astronomers are planning to acquire and analyse these large datasets, and provide some examples of how these datasets can help Australian astronomers to continue to attack the outstanding questions about our universe.

Dr David Barnes

David is a Research Fellow in Astronomy and Astrophysics at the University of Melbourne, where he also received his BSc and PhD degrees. After graduating in 1998, David spent two years working as a research astronomer and visualisation programmer at the CSIRO's Australia Telescope National Facility, before moving to Swinburne University of Technology in Melbourne. There he continued astronomy research while building and maintaining the University's supercomputer facility which now ranks as one of the top three in the country. In 2002, David returned to the University of Melbourne as a Research Fellow, and is presently Project Scientist for the Australian Virtual Observatory. His research interests include galaxies, groups of galaxies, sky surveys and advanced algorithms for radio astronomy data processing. David is an author on 24 papers, and has been granted time on many of the world's radio astronomy telescopes.

Data challenges in astronomy

A team of astronomers has recently completed a 5-year program at the Parkes Radio Telescope to map the entire southern sky and generate a unique sample of more than 4300 galaxies. Large-area surveys such as this remain one of the basic tools of astronomy, and almost always reveal new perspectives on astrophysical processes and the structure of the universe. After reviewing some definitive advances resulting from ambitious all-sky observations, I will introduce the main challenges facing present and future surveys, and describe how Australian and international astronomers are working together to address them. I will discuss 'virtual observatories' and 'grid computing', in particular the distributed and cross-disciplinary nature of grids.

Dr Howard Wiseman

Device miniaturisation inevitably leads into the quantum world. Over the past 10 years, Howard has been a world-leader in developing theories for controlling quantum devices by feedback. He has applied his theories in areas from metrology to quantum computing, in fields from optics to nano-electronics. Just last year, his theories were validated in two ground-breaking experiments conducted by his collaborators in the USA. In recent years, Howard has also made important contributions in the field of quantum information. This includes work on small-scale space-efficient quantum algorithms (theory and experiment) and the theory of quantum entanglement constrained by restrictions on the possible physical operations on a system. He was awarded the Australian Academy of Science's Pawsey Medal in 2002. Currently he is a QE-II Research Fellow and Manager for the Griffith University Program within the Australia-wide Centre for Quantum Computer Technology.

Quantum computing – theoretical challenges

Quantum computing is an as-yet unrealised technology, predicted to revolutionise computing in the 21st century. It is part of the field of quantum information, which has already yielded devices used for ultra-secure communication in the US. I introduce quantum computing by starting with the basic element of quantum information: the quantum bit or q-bit. I explain some recent work by me and co-workers, showing that even a single q-bit processor is superior to a conventional single bit processor. By putting many q-bits together one should be able to construct a full-scale q-computer, which can exploit the strange features of quantum physics to solve certain problems much faster than any conventional computer. I discuss what uses this will have, and give a speculative time line for the future emergence of quantum computer technology. Finally I discuss current research challenges on the theoretical side.

Dr Alex Hamilton

Alex is an Associate Professor in the School of Physics at the University of New South Wales, and manager of the quantum measurement program in the ARC Centre of Excellence for Quantum Computer Technology. Alex's expertise lies in the field of Experimental Condensed Matter Physics, having worked on semiconductor nanofabrication and the study of quantum effects in nanometer scale electronic devices at ultra-low temperatures for over 15 years. He obtained his BSc in Physics from the University of London in 1988, and a PhD from the University of Cambridge in 1993. He was awarded a highly competitive EPSRC postdoctoral fellowship to continue his work at the Cavendish Laboratory, which led to new understandings of electrical conduction in highly correlated low-dimensional quantum systems. Alex moved to UNSW in 1999, where his team is developing techniques for controlling and reading out quantum information in silicon quantum computer devices. He has published over 50 research papers, and is Australasian editor of the international journal *Solid State Communications*.

Solid-state quantum computing and quantum electronic devices

Quantum computers promise unprecedented computational power for certain tasks if they can be scaled to large numbers of quantum bits (qubits). Systems with small numbers of qubits have already been demonstrated, using ions in atom traps and small molecules in liquid NMR. However there is intense interest in solid-state quantum computer architectures, which can be scaled up to include many quantum bits. The key difficulty is that the qubits must be well isolated from the external environment for the quantum computer to operate, yet it must also be possible to couple an external measurement system to read out each qubit at the end of the calculation. In this talk I will outline the experimental challenges to implementing solid-state quantum computers, and review experimental progress in the field. In particular I will focus on silicon-based quantum computers, and the progress that has been made at UNSW towards developing reliable single shot projective measurement techniques that allow the detection of the motion of single electrons on nanosecond timescales.

Dr Andrew Young

Andrew is a Principal Research Scientist at the CSIRO Division of Plant Industry where he leads the conservation biology subprogram. He received his BSc and MSc (Hons) in plant ecology from Auckland University and his PhD in genetics from Carleton University, Ottawa. He moved to the CSIRO in 1993 to take up a postdoctoral fellowship and has continued his ecological and genetic research there for the past 10 years. His work integrates the use of molecular genetic markers, demographic analysis and simulation modelling to investigate the spatial and temporal dynamics of ecological processes such as mating, seed dispersal and recruitment in plant populations. He is the recipient of the Australian Academy of Science's 2003 Fenner Medal for his work on the importance of self-incompatibility genes in regulating plant population viability. He has published more than 40 scientific papers and edited two books. He is on the editorial boards of *Conservation Biology*, *Conservation Genetics* and *Biological Conservation*.

Monitoring, molecules and models – integrating genetics and demography in the analysis of plant population viability

Recent advances in molecular genetic marker methods and analytical techniques for assessment of parentage and paternity are presenting significant new opportunities for quantifying the spatial and temporal dynamics of important demographic and evolutionary processes such as pollination, seed dispersal and selection. Combined with improvements in the development of individual-based, population simulation models that incorporate both genetic and demographic processes in a spatially explicit way, these methods, along with more standard controlled pollination and growth experiments, are proving powerful in elucidating the factors that determine the viability of native plant populations and how these change with habitat destruction and degradation. Results from these analyses are also pointing to how species respond differently to the same set of environmental challenges depending on their ecology. Data from several plant species from the critically endangered grassland and grassy woodland ecosystems in south-eastern Australia demonstrate the value of this integrated research approach, with evidence that inbreeding, genetic erosion and long-distance immigration can all play a role determining local population viability and regional species persistence. These results highlight the importance of basing conservation management decisions on hard population biology data.

Dr Andrea Taylor

Andrea is a Logan Research Fellow in the School of Biological Sciences at Monash University, where she completed her undergraduate degree in 1986. Her PhD on molecular genetics in conservation management of a highly endangered wombat species, was from the University of NSW. This followed a research assistantship on koala conservation genetics at La Trobe University, and a 4-month research visit to the National Cancer Institute in Maryland, USA. As part of her PhD studies she spent an extremely valuable 18 months at the Zoological Society of London's Institute of Zoology. Her postdoctoral research at Macquarie University involved population genetics of marsupials introduced to New Zealand. Her research focuses on applying molecular genetic and analytical tools to issues in conservation management of Australia's faunal populations, and has resulted in almost 50 publications. She is a member of the editorial board of the UK journal, *Animal Conservation*.

Molecular ecology meets conservation biology – Australian mammal case studies

High-resolution DNA techniques coupled with modern population genetics theory and analyses constitute the tools of the molecular ecologist. Together they enable elucidation of aspects of organismal biology, ranging from the finest scales of parentage and individual identification through to continental phylogeographic patterns and phylogenetics (taxonomy). In the face of escalating extinctions, the ability to perform these analyses relatively rapidly can add inordinately to the efficacy of conservation management and planning of land use. In this talk I will illustrate the diversity of conservation applications with a series of examples from the work of my group on Australian native fauna, in particular marsupials. These will include: (1) genotyping of remotely-collected biological samples to non-invasively census a highly endangered species, (2) forensic examination of predation on a highly endangered species, (3) illumination of dispersal characteristics in cryptic species, (4) analysis of the impact of habitat fragmentation, and (5) prioritisation of populations for conservation action. Such data are essential for constructing demographic models to predict the viability of populations and species under the increasing range of threats to which they are exposed.

AUSTRALIAN FRONTIERS OF SCIENCE ANNUAL SYMPOSIUM

The aim of this annual symposium is to bring together the very best young scientists to discuss emerging technologies, new opportunities and exciting cutting-edge advances in their fields. Over the course of the symposium these gifted young scientists will explain what they do and why, and during this process, will come to discover how an idea can bridge disciplines. The symposium will involve participants from universities, government and industry, and its discipline focus will be across both the biological and physical sciences.

In future years the symposium will be held in other states to give greater opportunity for young scientists to participate. It will be a truly national activity, with chairs of sessions, organisers, speakers and participants selected from all states of Australia.