

**Australian Research Council  
Federation Fellowships  
2004**

**Professor Mark Bradford**

Current institution: The University of New South Wales

Host institution: The University of New South Wales

Primary research field: Structural Engineering

Project title: *Advanced analysis, behaviour and design of steel and steel-concrete composite engineering structures subjected to elevated temperatures*

Professor Bradford will research the structural behaviours of steel and steel-concrete composite framed buildings in fire by using advanced structural analysis techniques to simulate the response of buildings to elevated temperatures. This research is critical for the multi-billion dollar Australian steel industry because concrete is being used increasingly in preference to structural steel in multi-storey buildings and other engineering structures.

Because of its high thermal conductivity, insulating coatings are required for steel to meet safety requirements for passive fire protection. However, to date, there is little accurate guidance on the resistance of steel or steel-composite members at elevated temperatures. In the absence of reliable techniques for verifying this behaviour, the regulatory need for fire protection of steel may be excessive, and the high expense involved in providing this protection is resulting in structural steel being rejected in engineering design. This growing trend is leading to a potential downturn in structural steel production, which has serious economic and social ramifications for some Australian communities. The Federation Fellowship program will develop a consistent advanced nonlinear method for the analysis and behaviour of steel and composite building frames that are subjected to elevated temperatures.

**Professor Richard Brent**

Current institution: Oxford University

Host institution: The Australian National University

Primary research field: Computation Theory and Mathematics

Project title: *Exploring the frontiers of feasible computation*

Advances in the foundations of computer science lead directly or indirectly to advances in the applications of computers and information technology. Algorithms and complexity are fundamental to computer science and consequently they underpin the information and communication economy. The Federation Fellowship project aims to delineate the boundary between feasible and infeasible computational problems.

Algorithms and complexity theory are relevant to public-key cryptography, where breaking an encryption scheme should be infeasible, with applications in security and authentication in hostile environments. Other algorithms will be important for overcoming such problems as predicting climate change, mining data from the human genome and constructing software for intelligent robots.

**Associate Professor Ashley Bush**

Current institution: Massachusetts General Hospital

Host institution: The Mental Health Research Institute of Victoria/The University of Melbourne

Primary research field: Biophysical Chemistry

Project title: *The role of metals in the biology of the ageing brain*

In a rapidly ageing society, neurodegenerative disorders such as Alzheimer's and Parkinson's diseases will present a medical and economic challenge demanding novel and powerful science. This Federation Fellowship research program will lead to a deeper understanding of the basic mechanisms underlying such disorders and tools for designing new and effective treatments. The program will aim to advance basic understanding of the interactions between cellular proteins and biologically important metals; to learn how these interactions change as the organism ages; and to study the pathological results of aberrant metal biology using animal and cellular models of major age-dependent neurodegenerative disease.

### **Professor David Chalmers**

Current institution: University of Arizona

Host institution: The Australian National University

Primary research field: Philosophy of Cognition

Project title: *The contents of consciousness*

The Federation Fellowship project aims to develop a research centre that will be a world leader in the study of consciousness. The focus will be the question: How does human consciousness represent the world?

The science of consciousness has seen explosive growth internationally in the past decade, but the relationship between consciousness and representation is not well understood. Through local and international collaboration, researchers will develop a framework for understanding the representational content of consciousness and will analyse experimental work at the leading edge of neuroscience and cognitive science. The project aims to improve understanding of consciousness, of representation and of associated neural and cognitive mechanisms. Potentially, this could lead to social and medical benefits such as contributing to ethical and legal considerations associated with patients in coma.

### **Professor Alan Cooper**

Current institution: Oxford University

Host institution: The University of Adelaide

Primary research field: Global Change Biology

Project title: *Using ancient DNA to understand Australia's past and manage its future*

The Federation Fellowship will establish an ancient DNA research centre for Australia and use long-term natural records to investigate the genetic responses of animals, plants and micro-organisms to environmental change. By examining biological processes before, during and after major changes (eg coral bleaching, salination), the evolution and selective pressures at important genetic loci will be identified and related to environmental change. Key records will come from lake-beds, billabongs, coral reefs, rodent nests, megafaunal bones and ancient human material.

The research will provide a ground-breaking overview of ecosystem stability, contrasting genetic and environmental changes over time. It will also generate insights into problems such as invading pathogens and coral bleaching. The research will result in improved quarantine management and more effective planning and management of Australia's biodiversity.

### **Professor Stephen Crain**

Current institution: University of Maryland

Host institution: Macquarie University

Primary research field: Psycholinguistics

Project title: *Logic and language: Foundations of cognitive growth*

The Federation Fellowship project will investigate children's competence in using language from a biological perspective. Professor Crain will combine behavioural, computational and biological methods to better understand the nature of linguistic knowledge, how logical expressions are acquired and how knowledge of logic and language are put to use by children in production and comprehension.

The Federation Fellowship project involves the design and construction of a child-friendly, non-invasive functional brain imaging facility. The project will develop a new methodology in functional brain imaging and conduct experimental investigations on the early development of logic and language in children. The study will include children who are learning different languages and children with autism, dyslexia, and special language impairment.

### **Professor Simon Grant**

Current institution: Rice University

Host institution: The Australian National University

Primary research field: Economic Theory

Project title: *Optimism, pessimism and confidence – their economic impacts*

When modelling uncertainty, economists typically assume that people use 'well-behaved' and precise probabilities. The Federation Fellowship project aims to incorporate a richer set of attitudes about uncertainty into economic theory, including imprecise estimates of chance, optimistic (or pessimistic) bias, and relative confidence. This will enable more rigorous analysis of topics like irrational exuberance (panic), consumer stampedes, and (in)tolerance of risk, thereby improving the measurement of benefits and costs of related actions or policies. A deeper understanding of how individuals perceive and react to uncertainty will provide policy-makers with better measures of the costs associated with uncertainty.

### **Professor Paul Griffiths**

Current institution: University of Pittsburgh

Host institution: University of Queensland

Primary research field: History and Philosophy of Science and Technology

Project title: *Biohumanities: Philosophical, historical, and socio-cultural studies of contemporary bioscience*

The Federation Fellowship research will investigate the interaction between the ways in which genes are conceptualised and the dissemination of research findings in molecular biology. Empirical social research, including case-studies, surveys and small-group techniques, will be used to throw light on the process of disseminating scientific research findings to a range of audiences. For example, case-studies will be used to investigate whether representations of genomes, genes and gene action are systematically transformed during the process of dissemination.

The research will be conducted in close collaboration with the Australian scientific community and will be disseminated back to the scientific community, to the humanities and to the Australian public.

### **Professor David Hill**

Current institution: City University of Hong Kong

Host institution: The Australian National University

Primary research field: Systems Theory and Control

Project title: *Complex networks: Dynamics, optimisation and control*

Complex networks, such as large power grids, the Internet, transportation networks and co-operation networks of all kinds, provide challenges for frontier technologies such as computing, communication and control. Advanced societies have become dependent on large infrastructure networks to an extent beyond our capability to plan and control them. The recent spate of collapses in power grids and virus attacks on the Internet illustrate the need for research on modelling, analysis of behaviour, planning and control in such networks. This Federation Fellowship project will establish research in this area for Australia's benefit.

### **Professor Peter Hodgson**

Current institution: Deakin University

Host institution: Deakin University

Primary research field: Physical Metallurgy

Project title: *Advanced products through multi-scale microstructure engineering*

The metals manufacturing industry is important in Australia. The future growth and sustainability of the sector is critically dependent on the development of innovative metal products and materials. In the Federation Fellowship program, Australia's leading research group in metal manufacturing will develop new products and processes through the controlled manipulation of the microstructure at a number of levels from nano-scale to macro-scale. The areas of application include the automotive industry, biomaterials, surface engineering and the emerging area of microforming technologies.

### **Professor Ary Hoffman**

Current institution: La Trobe University

Host institution: The University of Melbourne

Primary research field: Population and Ecological Genetics

Project title: *Evaluating the adaptive potential of organisms to respond to environmental change*

The Federation Fellowship research program will use technological advances to develop a gene inventory for climatic change adaptation. The inventory will result in new methods for monitoring the impact of climatic change on populations, and for testing the adaptive potential of organisms from threatened habitats. A key hypothesis is that these organisms have restricted genetic options to counter environmental change, increasing extinction risk.

The program will investigate genetic adaptation to pollutants in midges, a key group for monitoring water health. Biological signatures of aquatic pollutants should result from assessing the evolutionary potential of DNA species markers.

### **Professor Stephen Hyde**

Current institution: The Australian National University

Host institution: The Australian National University

Primary research field: Materials Engineering

Project title: *Self-assembly and complexity: Networks and patterns from materials to markets*

Self-assembly is responsible for the growth of complex multi-scale structures found in biology and materials science and is a crucial concept for development of viable nanotechnologies. Complex systems, from biological ecosystems to financial markets and the Internet, are also characterised by spontaneous clustering and linkages that determine their collective behaviour.

The Federation Fellowship project will investigate in detail the geometry, topology, materials science and statistical physics of networks, leading to design and characterisation of robust self-assembled materials and complex systems.

### **Professor Chennupati Jagadish**

Current institution: The Australian National University

Host institution: The Australian National University

Primary research field: Optical Physics

Project title: *Ordered semiconductor nanostructures for electronics and photonics applications*

The Federation Fellowship program will develop innovative concepts and technologies to manipulate atoms to control size, shape and position of nanostructures in order to control their electronic and optical properties. The research program will produce important innovations and advance Australian knowledge in electronics, photonics, communications and computer technologies. It will also enable Australia to become a significant player in nanotechnology and has the potential for the development of patentable technologies of immense interest for high technology industries.

### **Professor Alan Mark**

Current institution: University of Groningen

Host institution: The University of Queensland

Primary research field: Biophysical Chemistry

Project title: *Self organisation in (bio) molecular systems: Simulating the folding and aggregation of peptides, proteins and lipids*

Molecular self-assembly is a basic property of living systems. Most proteins fold spontaneously and then further self-organise into functional complexes – effectively biological machines. Understanding how this occurs is a fundamental theoretical challenge with widespread application.

The Federation Fellowship research program will focus on developing methodology to simulate, computationally, the folding and aggregation of peptides, proteins and lipids. The aim will be to accurately predict the structures of small peptides in solution and to refine crude models of larger molecules (complexes). This will facilitate the development of peptide-based therapeutics and will be essential in exploiting the growing volume of genetic information in biology and medicine.

### **Professor Michael Nielsen**

Current institution: The University of Queensland

Host institution: The University of Queensland

Primary research field: Theoretical Physics

Project title: *Principles of quantum information science*

The aim of the Federation Fellowship research program is to formulate general principles governing the power and behaviour of quantum information. These principles will enable the development of powerful new applications of quantum information. The main areas to be addressed include: general conditions for a physical system to be usable for quantum computation; the development of new algorithms for quantum computers; the development of new quantum communication protocols; and the theory of quantum entanglement. The research program will involve establishment of a cross-disciplinary group of computer scientists, mathematicians and physicists at the leading edge of fundamental science and technology.

### **Professor Philip Pettit**

Current institution: Princeton University

Host institution: The University of Sydney

Research field: Political Science

Project title: *The foundation, role, and design of democracy*

Democracy now reigns unchallenged as the master ideal in contemporary societies, western and non-western, developed and developing. But what is democracy? What is its essential role? And by what institutions can that role be best played in the changing circumstances of local, national and international life?

This Federation Fellowship research program will develop a unified theory of the foundation, role and design of democratic institutions. In this project, democracy will be considered an ideal which requires not only the authorisation of the community as a whole, but also the protection of individuals and minorities and the legitimation of constitutional and civil instrumentalities to secure this protection. The project will result in a full and accessible conception of democratic governance, including a set of principles or benchmarks for auditing and assessing democracies. The practical focus of the research will be on identifying institutional arrangements that advance democratic rule.

### **Professor Leigh Simmons**

Current institution: The University of Western Australia

Host institution: The University of Western Australia

Primary research field: Evolutionary Biology

Project title: *The evolution of female mating frequency and its consequences*

The Federation Fellowship project will research the evolutionary significance of female mating frequency for male and female reproductive biology. The research program proposes to use innovative approaches to examine the evolution of ejaculate characteristics, focussing on the evolution of sperm form and function.

The research will use vertebrates and invertebrates as model organisms to test predictions and assumptions of theoretical models relevant to internal and external modes of fertilisation. The project will allow cutting-edge, theoretically informed and experimentally grounded conclusions to be drawn regarding selection under sperm competition. Professor Simmons' research on sperm form and function has implications for understanding human infertility.

### **Professor Stephen Simpson**

Current institution: Oxford University

Host institution: The University of Sydney

Primary research field: Plant Protection (Pests, diseases and weeds)

Project title: *Integrative behaviour: A new synthesis*

The Federation Fellowship research program will use a uniquely integrative behavioural approach to analyse swarming in locusts, and to develop and apply powerful new models in nutrition to address key problems in biology, agriculture and human health. The research will lead to an understanding of the molecular and environmental mechanisms controlling swarming in locusts, providing new management and control strategies.

More generally, Professor Simpson will develop research projects based on his 'Geometric Framework', a unifying theoretical and experimental structure for studying animals in their multidimensional nutritional environment. Using this framework, research into human obesity could result in improved health policy. Other applications include: new technologies for designing nutritional regimens for animal production; an understanding of the responses of insect pests to changing environments; and insights into the flow of nutrients across trophic levels within terrestrial ecosystems.

### **Professor Scott Sloan**

Current institution: University of Newcastle

Host institution: University of Newcastle

Primary research field: Geotechnical engineering

Project title: *Geostructural stability analysis with adaptive mesh refinement*

In order to build geostructures such as tunnels, cuttings, foundations and dams, engineers must determine the maximum load the ground can support without collapse. During the Federation Fellowship, Professor Sloan will develop new methods for predicting the stability of geostructures and translate this research into innovative computer software and better civil design procedures. With billions of dollars spent annually on the construction of Australian infrastructure, this research will lead to cheaper and safer design of civil infrastructure.

In developing cutting-edge algorithms and computer software for designing infrastructure, Professor Sloan will place particular emphasis on developing adaptive methods for three-dimensional problems involving complex ground profiles. Commercialisation of the new methods worldwide will provide technology transfer from university-based research to industry, enhance the skills analysis of Australian engineers, create jobs for engineering programmers and lead to software exports.

### **Professor Steven Smith**

Current institution: University of Edinburgh

Host institution: The University of Western Australia

Primary research field: Plant and Molecular Biology

Project title: *Metabolomic and genetic approaches to the discovery of genes that direct carbon partitioning in plants*

Plants make starch, sucrose, cell walls (fibre), oil, organic acids, vitamins and other products of great economic and social importance. The partitioning of carbon resources into such products determines crop productivity and quality. This partitioning is strongly influenced by nutrients, water and salinity.

The Federation Fellowship research program will use the powerful genomics resources of *Arabidopsis*, including the new discipline of metabolomics, to understand the regulation of carbon partitioning in leaves and to discover genes that direct partitioning. National research capability will be enhanced and new resources will be generated to breed crops with improved yield potential and product quality under varied environmental conditions.

### **Professor Mathias Trau**

Current institution: The University of Queensland

Host institution: The University of Queensland

Primary research field: Physical Chemistry

Project title: *Beyond microarrays: Nano-scaled devices for high-throughput biomolecular sensing*

This Federation Fellowship project will build and test nano-scaled devices with the capability of 'reading' massive amounts of biomolecular information. The research will address a major stumbling block currently inhibiting the full use of genomic data generated from the Human Genome project. It will lead to the development and commercialisation of bio-sensing techniques to rapidly and accurately screen low concentrations of biological mixtures containing large libraries of compounds such as DNA, proteins, antibodies, peptides or drug leads.

With appropriate high-throughput biological reading devices, spectacular advances in human health care, such as personalised medicine, will become realisable. In developing such devices, this project will aim to substantially catalyse the Australian nanotechnology/biotechnology industry.

### **Dr Jill Trehwella**

Current institution: Los Alamos National Laboratory

Host institution: The University of Sydney

Primary research field: Macromolecular Chemistry and Biochemistry

Project title: *Molecular mechanisms of biochemical regulation: Neutron and x-ray scattering studies*

The Federation Fellowship research project will develop and use novel neutron and x-ray scattering methods to study the molecular mechanisms by which nature regulates biochemical processes. Healthy function requires cells to tightly control and coordinate a myriad of molecular activities.

Dr Trehwella's research will focus on a set of interdependent molecular networks inside cells the behaviour of which is controlled by the so-called 'second messengers' that translate external signals into the right cellular responses.

The experimental research will provide a unique structural framework for understanding how these signals are transmitted. This knowledge will provide an important foundation for advances in biomedical research and biotechnology applications.

### **Associate Professor Howard Wiseman**

Current institution: Griffith University

Host institution: Griffith University

Primary research field: Optical Physics

Project title: *Quantum measurement, control and information: Forging links to underpin quantum technology*

The 21st century is seeing the birth of the first truly quantum technologies—devices the operation of which can be explained only by using quantum physics—which can outperform any conventional technology. The Federation Fellowship project will advance new theoretical foundations for designing quantum technologies by forging links between the three key areas of quantum measurement, control, and information. As the miniaturization of technology continues, quantum design principles will be required for more and more devices. The discoveries made will help keep Australian science at the forefront of this revolution.

### **Associate Professor Rachel Wong**

Current institution: Washington University School of Medicine

Host institution: The University of Queensland

Primary research field: Developmental Neuroscience

Project title: *Assembly of neural circuits during development*

The Federation Fellowship research program will investigate how nerve cells wire up accurately during development. Specifically, it will determine how neuronal connections are established in the retina to produce a sensory structure essential for vision. The research will also generate innovative tools for watching, in live animals, the making and breaking of connections during normal and abnormal development.

These discoveries will significantly increase our knowledge of how the nervous system develops or degenerates. They will also provide crucial information for future studies into genetic approaches, drug therapies and bioengineering technology to repair the injured nervous system.

### **Professor Bernard Wood**

Current institution: University of Bristol

Host institution: Macquarie University

Primary research field: Geology

Project title: *Origin and evolution of the Earth's chemical reservoirs*

The aims of the Federation Fellowship project are to understand the processes by which the Earth separated into its chemically distinct layers (core, mantle, crust, atmosphere, oceans) and to determine the nature of the continuing interactions between the surface environment in which we live and the deep interior.

Experimental study of these processes will involve establishment of a world-class facility for materials synthesis at high pressures and temperatures. This facility will provide the means to simulate the processes occurring within the Earth and will enable synthesis of new high-density materials of technological interest.