



# **HONOURS IN MATHEMATICAL SCIENCES**

## **The School of Mathematical Sciences**

**Suggestions for possible topics**



Below you will find some descriptions of Honours projects or areas of staff interest. These are suggestions only and you should also consider talking to staff to find out more about the opportunities for carrying out an Honours project with them.

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### **Dr Sue Barwick**

I have supervised honours projects in the area of Projective Geometry, and in the area of Applications of Projective Geometry to Information Security (in particular to Secret Sharing Schemes). Projects in these areas generally involve a literature review. That is, the students use the library to find research papers applicable to the project topic, read the papers and their project consists of a survey of known results about the topic. A prerequisite to work on a project in these areas is the third year subject Fields and Geometry III. Following are brief descriptions of two potential projects in these areas. I am also able to supervise projects on topics in Coding and Cryptography.

- **k-arcs in projective planes**

A k-arc in a projective plane is a set  $K$  of  $k$  points such that no three points in  $K$  are collinear. A non-degenerate conic is an example of a k-arc. There is a rich and interesting literature on k-arcs, and generalisations of k-arcs. Some of the questions to be answered are: what is the largest  $k$  for which a k-arc exists? What are some constructions of k-arcs? Can we classify k-arcs for certain values of  $k$ ? There are several different paths that can be followed in this topic, and the student can choose the one they are most interested in.

- **Geometric secret sharing schemes**

Suppose we have a secret, a group of people, and a list of subgroups of people (called an access structure) who are authorised to obtain the secret. For example, the secret may be the ability to open a bank safe and the security policy of the bank requires a minimum of 3 tellers to be present to open the safe. We can solve this problem by issuing physical keys, but some access structures can mean that everyone has to carry a large number of keys. A more practical and secure solution is to use mathematics, and it turns out that solutions involving projective geometry are very effective. A project in this area would involve studying how projective geometry can be used to construct secret sharing schemes, as well as looking at ways secret sharing schemes can be generalised.

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### **Professor Nigel Bean**

I have supervised honours projects addressing a wide variety of applications using mathematics from the field of operations research (stochastic modelling and optimisation). These applications have been in the areas of telecommunications, scheduling and rostering in industry, auctions and biology. I have also supervised projects that investigate the mathematical ideas that support these applications.

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### **Dr Nicholas Buchdahl**

I am happy to supervise Honours projects in the following areas, not arranged in any particular order:

- Complex analysis in one variable;
- Complex analysis in several variables;
- Differential geometry;
- Problems in analysis;
- Partial differential equations;
- Gauge theory;
- Algebraic topology;
- Differential topology.

In the past I have supervised Honours projects on

- The theorems of H. Cartan on Stein manifolds (Several Complex Variables);
- Topics in Several Complex Variables;
- The Riemann-Roch theorem (1 complex variable/partial differential equations);
- Donaldson's theorem on definite 4-manifolds (Gauge theory);
- Constructing constant curvature metrics on surfaces (Differential geometry/Analysis);
- Topics in advanced complex analysis (one variable).

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### **Associate Professor David Clements**

My areas of interest include:

- Numerical solution of partial differential equations,
- Flow from irrigation channels,
- Mathematical aspects of fracture mechanics,
- Earthquake models,
- Heat flow in solids.

## Dr Liz Cousins

My research interests are primarily in applied optimisation, in particular, combinatorial optimisation, and the application of random search methods. Recent honours projects I have been involved with include:

- Scheduling staff for a 24-hour call centre. This involved many constraints on the hours staff could work, the lengths of shifts, and the breaks between them, etc.
- Sequencing cars on an assembly line. There are limitations on which models of cars can follow others on an assembly line, because of the time taken to complete the various tasks of fitting windshields, wiring, etc. The car industry is interested in constructing as short a sequence of cars as possible, without violating constraints on adjacencies.
- Reserve design (choosing those parcels of available land which would best satisfy biodiversity measures), given various cost constraints.

(Each of the above projects used data from real-life applications.)

- The effect of dam releases on the salinity of the Murray River.

Potential honours students in this area should have an appropriate background in optimisation, such as can be gained from Optimisation III, and Mathematical Programming III.

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## Associate Professor Jim Denier

### The mathematics of the brain

Ever wondered why you think? No, not why *you are here*, but how does the brain operate at a most basic and fundamental level? One of the important aspects behind the very process of thinking is concerned with electrical signalling (or firing) of neurons in the brain. It was just this problem that resulted in Hodgkin and Huxley\* being awarded a Nobel Prize in Medicine (of all things) for their mathematical model of the neuron firing process. This project will allow the student to explore the Hodgkin-Huxley model (and even simpler models). At its very basic level the project is a study in the area of dynamical systems, exploring such things as bifurcation theory and chaos. At a more ethereal level it will be an

exploration into the mind. Either way, it will be a lot of fun and you will learn something useful and interesting along the way.

\*Hodgkin, A. L. and Huxley, A. F. A Quantitative Description of Membrane Current and its Application to Conduction and Excitation in Nerve. *Journal of Physiology* 117 (1952), 500-544.

### Freak waves

The picture below shows a "freak wave" about to break over the foredeck of a cargo ship. This wave was estimated to be 20 metres high. Over the past ten years over 200 super-carriers (cargo ships that are over 200 metres long) have been lost at sea. Many of these losses have been attributed to an encounter with a freak wave. Recent data from the European Space Agency's *MaxWave* experiment detected ten giant waves (each over 25 metres high) in just a three-week period. These waves are not related to tsunamis. They are thought to result from a self-interaction process between much smaller amplitude waves that occur in the ocean. The interaction process serves to produce the self-focusing behaviour seen in the figure.



*A "freak wave" about to hit a cargo ship. The photo was taken from the wing of the bridge, approximately 17 metres above the level of the sea. The wave broke above this level!*

This project will allow the student to explore current theories for the generation of such large amplitude, freak waves. It will introduce the fascinating topic of nonlinear waves, how they are generated and how they can be described in a very precise mathematical way. Some background in *Differential Equations* and *Waves* would be useful.

### Mathematical models of the Black Death

Infectious diseases are everywhere and many new ones are classified (or simply re-discovered) each year. However, the most deadly infectious disease that has ever been recorded is the Plague (the Black Death) that struck down over a third of the world's population between the 14th and 17th Century. Until recently the cause for this plague been placed at the feet of the bacterium *Yersinia Pestis* and spread by the

fleas of the black rat (*Rattus rattus*). Recent research suggests that this is not the case; instead the Plague could have been the result of a viral haemorrhagic fever.

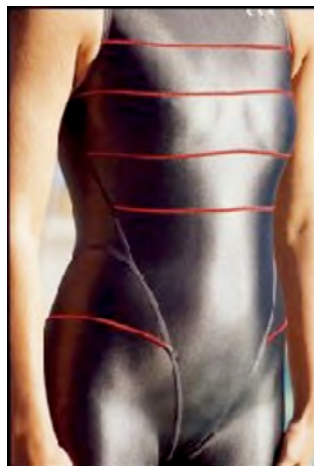


This figure shows the transmission of the plague through Europe in the 14th century.

This project will explore some of the recent theories regarding the Black Death and its transmission and will consider, in detail, the general problem of modelling the spatial spread of infectious diseases. It will be of interest to any student who would like to combine mathematical skills with some interesting modelling issues. Although there are no pre-requisites for this project a good grounding in *Differential Equations* will prove useful.

### Drag reduction

With the success of the Australian Swim team at the Beijing Olympics, drag reduction has become a topic that has moved out of the realms of the aerodynamics industry and entered our every day lives. The "fast suits" worn by our swimmers are designed to reduce the drag the swimmers experiences in moving through the water. The technology behind these swim suits comes from the aerodynamics industry where drag reduction presents a significant economic problem. Put simply, if you can reduce the drag an aircraft experiences then you can save money (and lots of it) on fuel costs. The figure above shows a new type of fast suit by swimsuit maker Tyr that is designed to increase the viscous drag felt by a swimmer when moving through water. The manufacturers believe it provides a higher level



of performance when compared to their competitor's fast suits. This claim is contrary to conventional wisdom and presents an ideal topic of investigation for an honours student.

This project will introduce the student to the problem of drag reduction through a study of the topic of turbulence in fluids flows. The project will involve a review of the state of the art in drag reduction technologies and can take a variety of directions depending upon the student's interests and background. Although there are no pre-requisites for this project some exposure to *Fluid Dynamics* may prove useful.

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### Dr Matt Finn

Chaotic mixing of fluids occurs in many scenarios, from stirring milk into your coffee, through to homogenisation of scalars in the atmosphere and ocean, such as heat, salt, pollutants etc. Mixing is also vital in multi-billion dollar industries, such as the chemicals industry, where energetic and financial costs involved with thorough mixing can be enormous. Thus understanding the underlying dynamics in mixing processes and improving mixer design is an important area of mathematical research.

A very powerful and elegant way of understanding chaos in mixing flows is by studying their topological properties. The topology of fluid motion can be characterised very concisely using the language of braid groups (see figure 1).

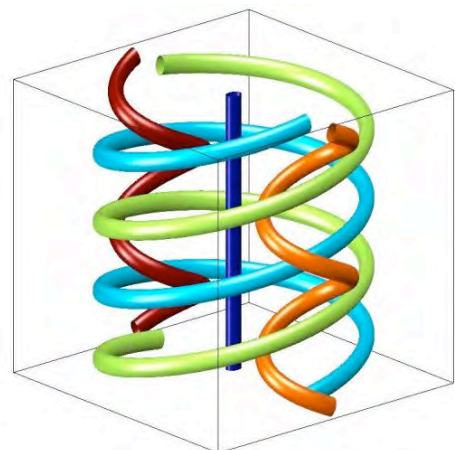


Figure 1

Using relatively simple topological considerations it is possible to predict rigorous lower bounds on mixing quality (according to certain measures). These predictions about flows can then be tested by performing computational simulations and stirring experiments (see figures 2 and 3).

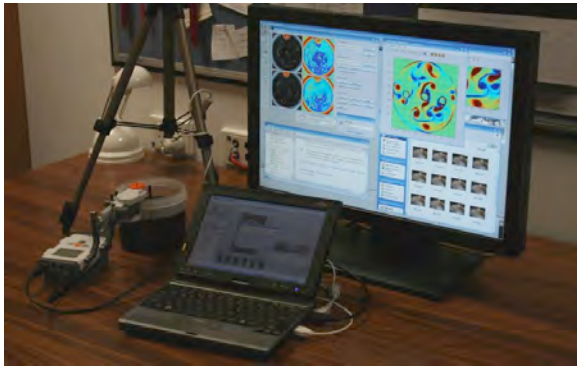


Figure 2

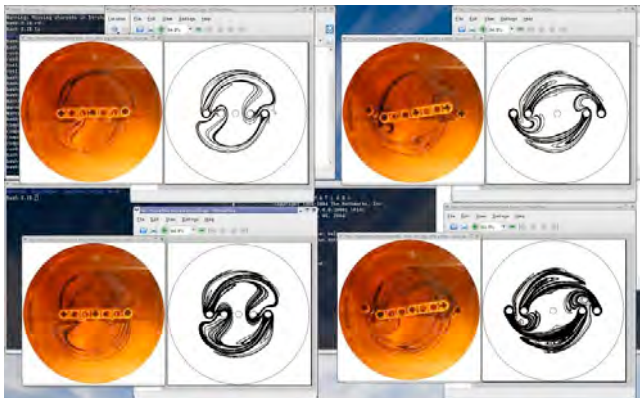


Figure 3

Several projects could be pursued based around these ideas, and would involve a mixture of topology/group theory, flow modelling and numerical simulation work, and even experimental work. The emphasis on these aspects in the project could be tailored easily to suit the interests of the student.

Three specific areas of investigation that would make an interesting and worthwhile project are as follows:

- describing the effects on flow topology of bifurcations of flow periodic orbits (analytical and numerical work);
- automated analysis of mixing flows using a camera and adapting image recognition ideas (a combination of experimental and numerical work);
- describing shedding and interaction of vortices in moderate viscosity mixing flows, and looking at the consequences on flow topology and mixing (an emphasis on flow analysis and numerical work).

## Dr David Green

My research interests currently include

- **Matrix-analytic methods**

These are fundamental to the analysis of a rich field of Markov processes, which have wide applicability in such things as

- Telecommunications networks
  - Network protocols
  - Computer systems
  - Maintenance and reliability
- and many other stochastic systems.

- **Point processes**

In particular the use of Markovian models to model traffic streams, which have direct application to telecommunications systems.

- **Simulation modelling**

Many real world systems are too complicated to assess performance measures simply using mathematical analysis, and simulation modelling is a powerful adjunct in such cases. I am currently involved with a research venture that uses simulation techniques in the modelling and design of systems for traffic control and provision of quality of service.

Some past Honours projects include

- TCP congestion control
- Voice over IP
- Mathematics in Bridge

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## Associate Professor Finnur Lárusson

I am happy to supervise honours projects in complex analysis and the many areas of mathematics that interact with it. An honours topic that I particularly like is the theory of compact Riemann surfaces. It provides an opportunity to meet and apply important ideas from functional analysis, homological algebra, manifold theory, partial differential equations, and sheaf theory in an accessible geometric context. The first goal of a project in this area would be to get to the central theorem on compact Riemann surfaces, the Riemann-Roch Theorem. After that, the project could continue in various different directions.

There are many other options, including several complex variables, differential geometry, topology, and category theory. In recent years I have supervised an honours project on wavelets, a newly developed area within real and functional analysis

with applications to image compression; a project about the correspondence between planar trees and so-called Shabat polynomials, involving combinatorics, covering space theory, and complex analysis; a project on one-dimensional complex tori, also known as elliptic curves; and a project about category theory and toposes of graphs.

If you have an idea for an honours project in pure mathematics that is not mentioned here, feel free to talk to me about it.

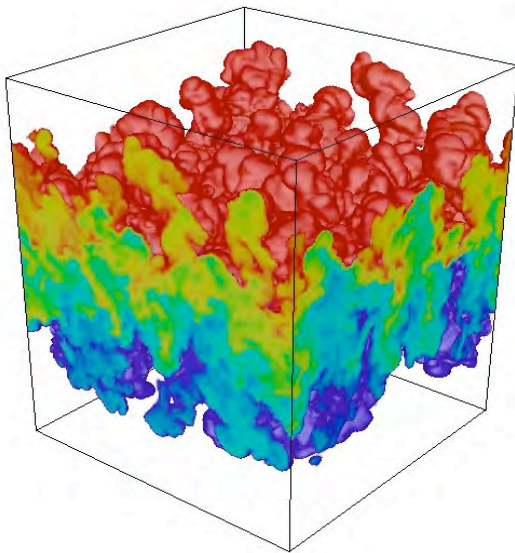
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## Dr Trent Mattner

### Vortex models of turbulence

Turbulent flows are characterised by irregular unsteady three-dimensional fluid motion over a wide range of spatial and temporal scales. Turbulence models are needed because direct simulation of many turbulent flows is impracticable. One of the most distinctive features of turbulent flows are fine-scale tube-like regions of intense vorticity. This has led to models of turbulence based on random ensembles of such structures.

In this project, students can explore the fundamental vortical structures that form the basis of these models or develop and test a model of a turbulent flow.



*This example of variable density turbulence occurs when different density fluids are subject to an acceleration, as occurs in super-novae.*

### Turbulence in variable-density flows

Variable-density turbulence occurs in a wide variety of situations, including super-novae, combustion, and atmospheric and oceanic circulation. In these examples, turbulent mixing affects many other processes, including nuclear and chemical reactions,

dispersion of pollutants, and biological activity. Accurate prediction of variable-density turbulence is therefore essential in order to optimize engineering devices, guide policy, and understand natural phenomena.

The aim of this project is to develop and test computational tools to predict variable-density flows.

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## Dr Andrew Metcalfe

### Drought indices and relationship to global climatic indices

The Environment Agency (EA), in the UK, uses a variation of the Standardized Precipitation Index (SPI) used in the USA. The EA index includes a relationship between the standard deviations for all durations and starting months that allows the index to be used continuously for as long as the drought lasts. The project is to compare the practical performance of these two indices, and to investigate other drought indices, and any relationship with global climatic indices such as the El Nino Southern Oscillation. Data for UK, Australia, and maybe USA, will be available. [in collaboration with a hydrological consultant in the USA and Adelaide civil engineers]

### Kriging and co-Kriging

Kriging is spatial interpolation, and co-Kriging allows for additional predictor variables. The project is to assess load-bearing capabilities of consolidated clay in the Adelaide area. Data are available. [in collaboration with Mark Jaksa in Civil Engineering]

### Multivariate extreme values

The project is to fit various extreme value distribution models for multivariate data to flood data from Namibia. [in collaboration with Peter Adamson, Visiting Research Fellow]

### Dynamic response of a small ship

The dynamic response of a small ship is expected to vary with its heading relative to the waves. We have data from such a ship sailing an octagonal course, and there is also scope for a theoretical discussion based on a literature review [data from Professor GE Hearn, University of Southampton].

### Comparison of ANN and regression models

Artificial neural networks (ANN) are often considered to be over-parameterised. But, they seem to give good results when they are fitted to large data sets and used for interpolation. The aim of the project is to investigate the pros and cons of using ANN, rather than standard regression models, in a

hydrological context. Data are available for the Mekong and the objective is to predict the low level flow from the annual flood. Prediction of the low flow is important because farmers use it to decide whether or not to plant a third rice crop [data from Peter Adamson, Visiting Research Fellow].

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## Professor Michael Murray

I am happy to supervise Honours projects in any of the following areas.

- differential geometry
- mathematical physics
- algebraic topology
- differential geometry and statistics
- Lie groups and Lie algebras
- gauge theories
- Bogomolny monopoles
- twistor theory
- bundle gerbes

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## Dr David Parrott

I am happy to supervise students in the following areas, with some recent Honours topics listed as examples.

- **Finite group theory**
  - Constructions of the Leech Lattice
  - The Conway groups
  - Extended Sylow Theorems
- **Lie algebra**
  - The classification of the semi-simple complex Lie Algebras
- **Logic and computability**
  - Computability and Decidability
  - Computability, Turing Machines and Complexity Classes
- **History of mathematics**
  - The History and Development of Number Systems
  - The Development of Calculus
- **Mathematics education**
  - Secondary School Mathematics in South Australia

## Associate Professor Matthew Roughan

My research interests are in the area of measurement, modelling and management of data networks. Some example projects are listed below, though I am happy to talk about anything in this area.

### Non-Gaussian fractal traffic models.

Internet traffic modelling is a key ingredient in many network design, and management tasks. In recent years, there has been much research showing that Internet traffic has fractal characteristics. Typical traffic models which incorporate such features are Gaussian processes, with long-memory, such as fractional Gaussian noise. Such processes are now frequently applied, but Internet traffic, while fractal, does not always have a Gaussian marginal distribution. One can distort the marginal distribution to better fit real traffic, but this alters the fractal characteristics of the traffic in a non-linear manner, related to Hermite polynomials. This project would determine methods for approximating particular marginal distributions through non-linear transformations of a Gaussian process, while maintaining the desired fractal characteristics in the traffic.

### Network value at risk

Network reliability is a key issue for most large Internet Service Providers (ISPs). Providers aim to have downtimes of the order of a few minutes a year. Unfortunately, individual network components have nowhere near this level of reliability. Reliability is obtained through redundancy, though at a high cost in terms of duplication. Reducing the cost, while maintaining reliability is therefore a key goal for most ISPs. Interestingly, in the Internet, there are not even good ways of quantifying overall network reliability. Most metrics that one might apply are limited in some respect. For instance, it is clearly more important to maintain high reliability on core backbone links, than tiny access links, but metrics rarely distinguish the impact of failures at varying levels. Similarly, when a single failure occurs, alternative routes can often be used to transmit traffic, but not in the case of multiple failures.

The aim of this project is to extend ideas from the financial community to this task. In the financial world, there are concepts such as the "value at risk", and "conditional value at risk", which describe the potential damage that is possible to a stock portfolio, given certain stochastic assumptions. In extending these ideas to networks, we might then design a minimum cost network, with a constraint on value at risk.

## Search games

In computer science, one of the most common tasks is a search. For example, one might wish to search a list for a particular element. The binary search is well known to provide a very good solution, when searching a sorted list. However, there are problems where the search involves risks. For example, in network traffic engineering, we may wish to find a routing solution that balances traffic over multiple paths, while satisfying the constraint that we don't send any path more traffic than it can support. Traditionally, such problems are treated as optimization problems, with constraints. However, in some problems, we don't know the constraints initially. These must be estimated by performing the search, for instance, by sending traffic along the paths, and receiving feedback about congestion levels. Unfortunately, in doing so, you may loose traffic to congestion. Thus, we have two objectives in probing -- firstly to gain information in our search for a viable solution, and secondly, to avoid losing too much traffic to congestion. Thus one has a game, in many respect similar to Poker, where one must choose how much to bet, to elicit particular information from other players (about the strength of their hand), while simultaneously placing value at risk. A solution is to generalize the binary search algorithm to the space of possible solutions. We have developed several algorithms that perform such a search, for the traffic-engineering problem. An interesting question, which this project would address, is how widely these methods may be generalized to other problems.

## Joint models of traffic and topology

In Internet modelling, two major efforts are proceeding in parallel - the first to model Internet traffic, and the second to model the network topology. Despite great strides in both areas, there has been little understanding of the fact that these two features of a network are strongly related. As network routing changes, so changes the traffic, but also, networks are designed around the traffic they carry, and so are highly correlated to this traffic. There is a strong analogy here to hydrological modelling. For instance, if one examines hydrological data (for instance stream flow rates), one observes self-similar, or fractal behaviour. Such behaviour is also observed in Internet traffic flows. Another parallel is drawn when one considers catchments. The rainfall within their catchment determines river flows, whereas network traffic flows result from traffic generated by users within a catchment. Similarly, the water flows over time can alter the shape of a catchment through erosion, resulting in fractal like landscapes. In the Internet, changes in the traffic flows result in network

redesigns that then alter the catchment shapes. Again, much of the recent work on network modelling has noted fractal structure in the design of networks, so the analogy is quite strong.

In the geological world, the changes made to terrain happen over long timescales of hundreds to thousands of years. In the Internet, changes happen overnight, by comparison. Hence, by applying techniques used to model hydrological processes, we may be able to gain some highly practical insights that lead to better models for the Internet.

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## Professor Tony Roberts

**Modelling floods:** floods are turbulent and flow over complex terrain. We use dynamical systems methods to seek models that account for the small scale turbulent structures while describing the large scale ebb and flow across the land.

**Multiscale modelling:** technologies for engineering systems at the micro and nano scales are rapidly emerging. Currently we are developing mathematical frameworks and software infrastructure for the integration of heterogeneous models and data over the wide range of scales present in most physical problems. Our fundamentally new mathematics is beginning to address the challenges of multiscale simulation.

**Noisy PDEs:** noise in real spatial systems is encoded mathematically as stochastic partial differential equations. Their numerical models are very delicate. Dynamical systems theory supports an holistic approach to generate discrete models of such stochastic systems. The resulting models will be much more faithful to the original physical system.

**Detect fractal geometry:** the world around and within us is best described as fractal. Yet the tools we have for detecting fractal nature are biased. Applications, such as detecting abnormalities in neuronal cells, desperately need new effective methods of analysis and characterisation. We pursue a program using the information in all the inter-point distances in the object under study.

**Predict pattern formation:** the classical explanation of the stripes on a tiger or the spread of a disease are based upon reaction diffusion equations. Yet births induce spatial correlations that also may generate patterns. The motion of so-called Brownian bugs is an introductory example. We need to learn how to model systems where such spatial correlations are maintained for significant times. Science needs to develop techniques to discriminate between whether

reaction diffusion models are appropriate or whether long lasting correlations are the key mechanism.

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## Professor Patty Solomon

I am happy to supervise Honours Projects in any areas of biostatistics, bioinformatics, statistical methodology and applied statistics. My current research areas include the analysis of gene expression data, microarray informatics, proteomics, survival analysis, epidemiology, the design and analysis of clinical trials, and components of variance.

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## Dr Yvonne Stokes

My research Interests include:

**Fluid Mechanics,** in particular very viscous flows, free-surface flows and computational fluid dynamics.

**Industrial and Biological Mathematics,** in particular modelled by differential equations involving mass and/or heat transfer.

Some possible project topics are indicated below but feel free to discuss other ideas with me.



### Viscous extensional flows

These are flows that, like honey dripping from an up-turned spoon, exhibit, elongation, necking to form a drop suspended by a thin filament, and, finally, pinch-off of the drop and further break-up of the filament. Important application areas include fibre spinning, ink-jet printing, blow moulding, and rheometry. Despite much research over the last century, the mechanism(s) that govern where and when drop pinch-off occurs are still not fully understood. Simplified one-dimensional models as well as computational simulation may be used to examine these types of flow.

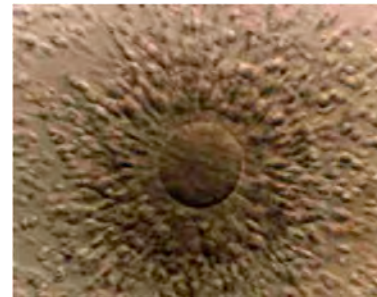
### Sagging of viscous sheets under the influence of gravity

Gravity sagging of viscous fluid sheets is used in the manufacture of car windscreens and optical lenses; glass sheets or discs are heated so that they melt and flow under their own weight. Mathematical modelling and numerical simulation can be used in place of experiments to determine what shape results

from some initial geometrical set-up and for some given temperature distribution. Mathematical modelling is even more useful for solving the even more challenging "inverse" problem of determining mould shape and/or temperature distribution to yield a required product shape.

### Nutrient supply to eggs and embryos

Oxygen and nutrient supply to mammalian eggs (see picture below) and embryos affect their ability to develop to full maturity and give rise to healthy living offspring. Knowledge of the nutrient requirements of eggs and embryos is particularly important for improving the success of assisted reproduction technologies and mathematical models are required to determine these from experimental data. Projects in this area involve diffusion equations and their analytic and/or numerical solution.



### Flow in spiral channels

Spiral-channel flow is important in a number of industrial separation processes, such as helical-coil distillation of petroleum products, separation of liquids of different densities (e.g. oil from seawater), and particle segregation and concentration in spiral separators used by the mineral processing industry.



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It also has relevance to flows in rivers. Flows in such curved channels consist of two components: a primary axial flow and a secondary cross flow. The fluid depth is, typically, small making experimental investigation difficult. Mathematical models are

therefore of great value for determining how such flows are influenced by fluid properties and geometrical parameters. This project involves thin film mathematics and computational fluid dynamics.

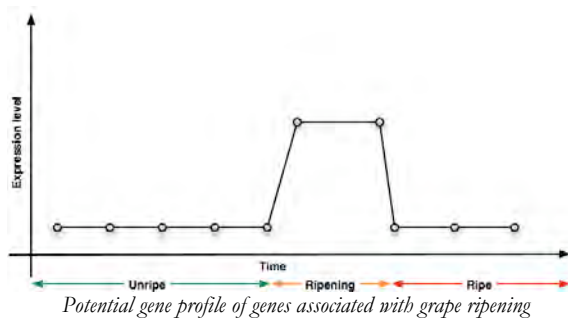
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## Mr Jono Tuke

### Gene profiling in the wine industry

The CSIRO is researching the interaction between genes and environmental factors on the quality of grapes. In a designed experiment undertaken by the CSIRO, grape vines have been grown under a range of environment conditions. At various time points, cellular samples have been taken and analysed using microarray technology. These analyses measure the expression levels of thousands of genes.

A goal of the research is to isolate genes that have a pre-specified gene profile. For example, Figure 1 shows a potential gene profile for genes associated with grape ripening.

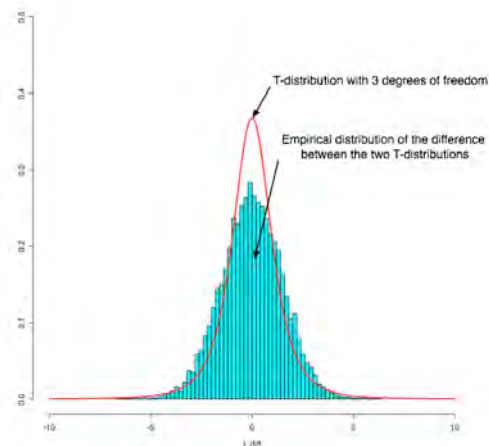


Gene profiling has been developed by Jonathan Tuke, Dr Gary Glonek and Assoc. Prof. Patty Solomon at the University of Adelaide to look for gene profiles in stem cell data. The project would involve applying gene profiling to the grape vine data. This will entail learning how microarray technology works; learning the theory underlying gene profiling; and developing computer code to analyse the grape vine data using the gene profiling.

Approximating the difference of two T-distributions using quantile comparisons

The T-distribution is familiar to most students from their acquaintance with the T-test. It is frequently used in inference about the mean of a normal distribution and its pdf is relative straightforward. The distribution of the difference of two T-distributions is not so simple. Its pdf is complicated and not easy to use. Therefore, approximations are used. A common approximation method is moment matching where a suitable T-distribution is chosen

so that it has the same variance and kurtosis as the empirical distribution of the difference. This is illustrated in Figure 2 where a T-distribution with 3 degrees of freedom is used to approximate the empirical distribution of the difference of a T-distribution with 10 degrees of freedom and a T-distribution with 20 degrees of freedom. In the project an alternative approximation method will be developed and compared to the moment-matching method.



*Histogram of the empirical distribution of the difference of two T-distributions and an approximating T-distribution*

### Australian longitudinal study of aging

The Australian Longitudinal Study of Aging (ALSA) has been following a sample of aged Australians over a number of years. Various factors have been measured on each subject. This project would examine part of this large data set involving possible issues such as missing data, hidden Markov processes, logistic regression, multivariate analysis, etc.

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## Professor Mathai Varghese

I am happy to supervise Honours projects in the following areas:

- Atiyah-Singer index theory of elliptic operators and generalizations,
- Noncommutative geometry,
- Positive scalar curvature metrics - obstructions and existence,
- Spectral theory of elliptic operators and their discrete analogs,
- L2 methods in geometry and topology,
- K-theory and twisted analogues,
- Applications to the fractional quantum Hall effect and string theory.

In the past I have supervised Honours projects on:

- The proof of the Atiyah-Singer Index theorem;
- Cyclic cohomology.

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**Dr Alison Wolff**

I am prepared to supervise Honours projects in number theory, combinatorics, and applications of these to other areas.

Some past projects I have supervised are given below:

**Numerical integration with respect to Fibonacci lattice rules**

This project was done by a student doing joint Honours in Pure Maths and Computer Science. The project was on an application of number-theoretical ideas to numerical analysis, thus combining the student's favourite areas of study from his undergraduate courses.

**On Diophantine approximation**

This was a straight number-theoretical project, in which the student researched in greater depth a topic studied in Number Theory III. In particular, he investigated a fascinating sequence of numbers called the Markoff Spectrum, which is concerned with how well certain types of irrational numbers can be approximated by rationals.

**Solving large sparse singular homogeneous systems over  $\text{GF}(2)$** 

Another joint Pure Mathematics/Computer Science project is, using number theory and linear algebra, and with applications to factoring large numbers, a topic that is of interest to cryptographers.

**On the period length of pseudorandom number sequences**

The 'random' numbers used in many applications are in fact almost always elements of periodic sequences produced deterministically by algorithms known as pseudorandom number generators. Clearly a long period length is desirable, and this project was a study of the period lengths of several common types of generator. Algebraic and number-theoretic methods were used.

**Path counting and applications**

This project dealt with the combinatorial problem of counting certain restricted types of lattice paths between two points in the coordinate plane (A lattice path is one composed of steps along the integer grid lines  $x=n$ ,  $y=m$  where  $m$  and  $n$  are integers.) Applications to such diverse areas as seismography and vote counting were investigated.