



THE UNIVERSITY  
*of* ADELAIDE

School of Mathematical Sciences

# Possible Honours Topics 2017

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## Considering Honours in 2017?

The School of Mathematical Sciences is proud to present a range of honours topics. You will find some descriptions of projects or areas of staff interest. These are suggestions only and I encourage you to contact individual academics to make a time to find out more about the opportunities for carrying out an Honours Project with them. If you are still unsure of who to contact, please make a time to come and see me. As the Honours Coordinator, I can recommend potential supervisors suited to your areas of skill and interest. The Honours year is an exciting one and I wish you all the best as you consider this pathway for your future.

A/Prof. David Clements  
Honours Coordinator (Semester 1)  
[david.clements@adelaide.edu.au](mailto:david.clements@adelaide.edu.au)

Dr Danny Stevenson  
Honours Coordinator (Semester 2)  
[daniel.stevenson@adelaide.edu.au](mailto:daniel.stevenson@adelaide.edu.au)

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## A/Prof. Sanjeeva Balasuriya

Discipline: Applied Mathematics

Email: [sanjeeva.balasuriya@adelaide.edu.au](mailto:sanjeeva.balasuriya@adelaide.edu.au)

I am happy to offer honours projects in areas related to dynamical systems, differential equations, fluid dynamics and mathematical modelling. Projects which lie in a broad spectrum from highly applied to fairly theoretical are possible.

The following is a list of more specific topics:

- Chaotic mixing in fluid flows
- Optimising transport in microfluidic devices
- Stable and unstable manifolds in time-varying flows
- Methods for locating time-varying transport barriers in fluids
- Flame speeds of reaction-diffusion combustion waves
- Invasion speeds of flora and fauna based on reaction-diffusion models
- Differential equations models for solid tumour spreading
- Modelling phytoplankton blooms
- Modelling pollution; environmental modelling
- Other applications of ordinary differential equations
- Stochastic perturbations to differential equations
- Minimum flux surfaces/curves in fluid flows

The above list is not exhaustive; please feel free to contact me if you have any ideas which seem related.

## Dr David Baraglia

Discipline: Pure Mathematics

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I am happy to supervise topics in differential geometry and in related areas of geometry, topology and mathematical physics. Differential geometry is such a diverse subject with ties to many other areas, so there is no shortage of interesting honours projects to choose from. My research interests include the following from which topics could be drawn:

- Riemannian geometry and holonomy groups
- Complex manifolds
- Generalized geometry, T-duality and mirror symmetry
- Geometric structures related to the exceptional Lie groups
- Higgs bundles
- Mathematical aspects of physics including string theory

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Dr Sue Barwick

Discipline: Pure Mathematics

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I can supervise projects in the area of Finite Projective geometry.  
The best pathway into this topic is the course Finite Geometry III.  
Following are brief descriptions of two potential projects in these areas.

#### **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 of  $k$ -arcs, and generalisations of  $k$ -arc. Some of the questions to be answered are: what is the largest  $k$  for which a  $k$ -arc exists? There are several different paths that can be followed in this topic, and the student can choose the one they are most interested in.

#### **The Bruck-Bose Representation**

The field plane  $PG(2, q^2)$  has an interesting representation in 4-dimensional projective space,  $PG(4, q)$ . Points of  $PG(2, q^2)$  correspond to points of  $PG(4, q)$ , and lines of  $PG(2, q^2)$  correspond to certain planes of  $PG(4, q)$ . This project will study this representation in detail. It involves a survey of the literature regarding the characterisation of certain sets in  $PG(2, q^2)$  using the  $PG(4, q)$  representation.

Prof. Nigel Bean

Discipline: Applied Mathematics

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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 Luke Bennetts

Discipline: Applied Mathematics

Email: [luke.bennetts@adelaide.edu.au](mailto:luke.bennetts@adelaide.edu.au)

### **Waves in random and complex media**

What affects the way that waves (sound, light, etc) travel through a particular medium? I study “scattering” produced by variations in the medium. An example that we see everyday is the Rayleigh scattering of sunlight by particles in the atmosphere, which is responsible for the blue colour of the sky.

In many applications it is necessary to consider how a wave travels through a vast number of scatterers — so many that it’s beyond the ability of a computer to solve the problem directly and mathematical ingenuity is required. These techniques are used to design “metamaterials” with properties not found in nature, used to cloak objects (stop them from being “seen” by radar, etc.), soundproof vehicles, protect buildings from earthquakes, and many more applications.

### **Modelling the Cryosphere**

The Cryosphere is the name for the parts of the Earth cold enough to freeze water. I develop mathematical models of: (i) The retreat of the frozen ocean surface in the Arctic — known as sea ice — due to climate change, which is driving global temperatures even higher. (ii) Disintegration of the giant ice shelves surrounding the Antarctic continent, again due to warming temperatures, which is driving global sea level rise.

## Dr Ben Binder

Discipline: Applied Mathematics

Email: [benjamin.binder@adelaide.edu.au](mailto:benjamin.binder@adelaide.edu.au)

### **Quantifying and modelling yeast growth**

Yeasts are single cell fungi organisms, familiar to most for their use in the baking of bread and brewing of alcoholic drinks. One of the most significant issues related to yeasts today is their causation of pathogenic infections in humans (e.g. oral and vaginal thrush). Moreover, a persistent problem is in their formation of biofilms on medical devices such as catheters, placing patient populations at risk of infection in our major hospitals. The real and varied impacts that yeast’s have on our everyday lives is one of the reasons why it is one of the most studied organisms in modern biology today. Project work on this important problem includes developing both spatial statistics and mathematical models (continuum and discrete) for the yeast growth processes.

### **Three-dimensional water waves over topography**

The purpose of this project is to study water waves and how they interact with bottom topography. One reason for doing this is to provide a means for using surface observations (of the ocean surface, for example) to infer the shape and structure of the water-bed. Of particular interest to this project is the potential formation of localised three-dimensional waves, which decay in the far-field away from the topographic forcing. Progress will be made on this by studying solutions to the Kadomtsev-Petviashvili equation. More challenging will be the study of such structures for the fully nonlinear equations, and this will be tackled using boundary integral methods.

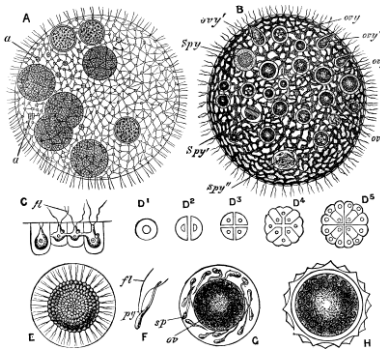
Dr Andrew Black

Discipline: Applied Mathematics

Email: [andrew.black@adelaide.edu.au](mailto:andrew.black@adelaide.edu.au)

My research interests are broadly in the area of **stochastic modelling** applied to problems in **epidemiology** and **evolution**. Below are two examples of projects in these areas, but I am happy to discuss other ideas with prospective students.

### Evolutionary transition from unicellular to multi-cellular organisms



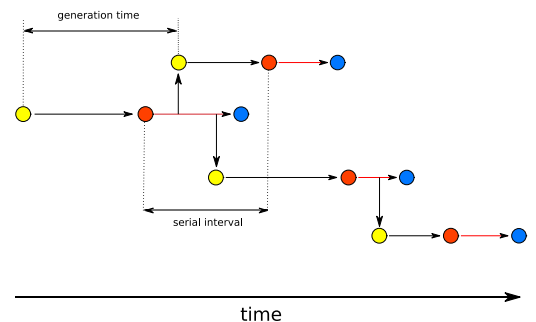
The evolution of multicellular organisms from unicellular ones is one of the best-known examples of the creation of a new level of biological organisation. The fundamental questions surrounding this transition are to do with how simple groups of cells form and then start to acquire the properties needed for natural selection to act on them. The most important of these is the ability to reproduce with heritable variations in fitness. Reproduction is taken for granted in standard evolutionary models, but here is something that must be emergent from our models.

Mathematical modelling is vital for understanding how both cell and group-level processes have driven this transition. These are multi-level stochastic models that couple both ecological and evolutionary dynamics; both analytical and computational techniques are needed for their analysis. This is interesting, highly applicable, mathematics, and will also further our knowledge of the fundamental evolutionary processes that have build the world of which we are a small part.

### Computational methods for stochastic epidemic models

Stochastic modelling is now an integral part of epidemiology. In recent work we have been interested in the spread of disease though smaller populations, such as households, which can be modelled using Markov chains. These models are now being applied to understand pandemic influenza, and more recently Ebola, the results of which will inform government policy.

For any model to be useful for public health purposes we must be able to parameterise it. This is usually done through some sort of Bayesian analysis, but this requires that we can actually solve our models efficiently. This project would develop new ways of numerically solving Markov chain models efficiently and compare these to existing methodologies. These methods can then be used in statistical inference using real world data.



Dr Nicholas Buchdahl

Discipline: Pure Mathematics

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I am happy to supervise an Honours project in any interesting area of mathematics. What is “interesting” would be for you the student and me the (potential) supervisor to agree on, and I would have to feel that I have sufficient expertise to be able to provide appropriate help and supervision.

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## Dr Barry Cox

Discipline: Applied Mathematics

Email: [barry.cox@adelaide.edu.au](mailto:barry.cox@adelaide.edu.au)

I'm happy to offer projects in the broad area of mathematical modelling in nanoscience and nanotechnology. Possible project areas include

- Modelling nanoscaled oscillating systems
- Geometry of nanostructures
- Graphene deformation – joining nanostructures
- Conformation space for ring molecules
- Understanding the process of vapour deposition synthesis

These are just a few suggestions. I'm more than willing to discuss these or any other particular project idea on an individual basis.

## Dr Michael Eastwood

Discipline: Pure Mathematics

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**Complex projective space** is a very symmetrical manifold, second only to the sphere. This project explores all aspects of this remarkable space.

**Conformal differential geometry** is differential geometry based on angles rather than distance. This project goes through the basic constructions, curvature invariants, and beyond.

**Projective differential geometry** is differential geometry based on geodesics rather than distance. This project goes through the basic constructions, curvature invariants, and beyond.

**CR geometry** is the differential geometry inherited by a smooth real hypersurface in a complex manifold. This project goes through the basic constructions, curvature invariants, and beyond.

**Integral geometry** is the key to medical imaging and other modern scanning machines. This project investigates some theoretical aspects, especially kernel and range questions for the X-ray transform.

**Invariant differential operators** are everywhere in mathematics and physics. This project looks at how to define, build, and classify them.

**Elliptic curves** are the simplest Riemann surfaces after the Riemann sphere. This project considers their construction and applications, for example in plane geometry or cryptography.

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Dr Ed Green

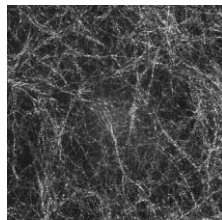
Discipline: Applied Mathematics

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My research interests are in the general areas of mathematical biology, mathematical modelling, and fluid mechanics. Below are some suggestions for projects, although I would be happy to discuss other ideas.

### **Mechanics of transversely isotropic fluids / Interactions of cells with the extracellular matrix**

Tissue engineers aim to be able to grow tissues in the laboratory, which could be used for such applications as drug testing, or, in the future, to replace tissues in the body that have been damaged by injury or disease. In the body, cells are supported on a 'scaffolding' called the extracellular matrix, which can be made up of a variety of components, with the protein collagen being one of the most important. When grown in the laboratory, cells are often seeded within gels such as collagen gel, in an attempt to mimic their natural environment and promote the formation of useful tissue. The interactions between the cells and the fibrous microstructure of the gel in which they reside have a significant effect on the architecture of the tissue. Mathematical models can be used to gain more insight into these processes, which will eventually help tissue engineers tailor their culture methods to the tissue they aim to grow. Projects in this area might include models for the mechanics of the gel itself, since this needs to take account of the changing orientation of the fibres – this type of material, with a single 'preferred direction' (the fibre direction) is called transversely isotropic. (Similar problems also arise in the manufacturing of fibre-reinforced plastics.) Models of cell-gel interaction could also be developed and studied. These projects would combine fluid mechanics and reaction-diffusion equations, and would involve both analytical and numerical work.



The microstructure of a collagen gel (the region shown is approx. 70 microns across)



Decreasing Matrigel concentration

Effect of changing gel composition on the pattern of cell growth (fibrous gels produce elongated 'ducts', whilst in isotropic gels cells grow in clusters (acini))

### **Interactions in and between swarms and other biological aggregations**

The collective behaviour of animals in swarms, or cells in tissues, is governed by the interactions between individuals in the group. We can use mathematical models to understand how different types of inter-individual interaction lead to different arrangements of cells in tissues, or movements of swarms. These models can be computational agent-based models, in which individual cells or organisms are represented, or systems of two or more partial differential equations for the densities of each species, which can be investigated using a combination of analytical and numerical methods. The student is welcome to choose whichever approach best suits their interests.



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## Dr Peter Hochs

Discipline: Pure Mathematics

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I would be happy to supervise an honours project in geometry and analysis on manifolds, Lie group theory and representation theory, or  $C^*$ -algebras and  $K$ -theory. One of my main interests is the interaction between these areas via index theory.

An index theorem is an equality

$$\text{a-index} = \text{t-index}$$

of numbers, group representations, or other objects. Here a-index is an analytic quantity, such as the dimension of the solution space of a differential equation on a manifold  $M$ . On the right hand side, t-index is a topological quantity, related to the geometry of  $M$ . An example is the Gauss-Bonnet theorem, which states that the average scalar curvature of a compact surface equals  $2\pi$  times its Euler characteristic.

Index theorems are powerful links between different areas in mathematics and physics, which help us to understand these areas better. Such possibly unexpected links are what interests me the most. But I am open to discussing any topic a student may be interested in and I know enough about to supervise an honours project.

## Prof. Finnur Larusson

Discipline: Pure Mathematics

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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 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. There are many other options, including complex analysis in higher dimensions, algebraic geometry, 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, complex analysis, and topology; a project on one dimensional complex tori, also known as elliptic curves; a project about category theory and toposes of graphs; a project on the so-called Oka principle, which mixes homotopy theory and complex geometry; a project on Belyi's famous theorem, characterising the compact Riemann surfaces that can be defined over a number field; and a project on 20<sup>th</sup> century generalisations of the Riemann mapping theorem.

If you are interested in honours in pure mathematics, feel free to talk to me.

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## Dr Thomas Leistner

Discipline: Pure Mathematics

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I am happy to supervise honours projects in differential geometry that are related to holonomy groups, transformation groups, general relativity, and conformal geometry. Differential geometry is an area of mathematics that studies curved spaces (manifolds) that are equipped with further geometric structures such as a metric which allows to measure distances. Differential geometry has many applications in theoretical physics, mainly in general relativity and string theory. It is full of interesting topics on the analytic as well as on the algebraic side of mathematics, for example:

- 1) Holonomy groups: The holonomy group is the group of parallel transports along loops. It describes how curved a space is. Possible projects are related to the classification of holonomy groups.
- 2) Symmetries and symmetric spaces: Some spaces have a large group of symmetries that allows to describe them by algebraic tools and relates them to certain model spaces, such as the sphere or hyperbolic space. Analysing quotients of these model spaces is a classical problem in differential geometry that has many modern variants that can be studied in an honours project
- 3) Geodesic completeness: Geodesics are the shortest paths in manifolds. For many spaces that are relevant in general relativity, geodesics are incomplete, which means that they cannot be extended beyond a singularity. Completeness and incompleteness for specific manifolds can be studied in an honours project.
- 4) Conformal geometry: In conformal geometry, a metric on a manifold is only given up to a scaling function, which means that only angles but not lengths can be measured. Possible topics in conformal geometry are related to the conformal Einstein equation and the conformal ambient metric construction.

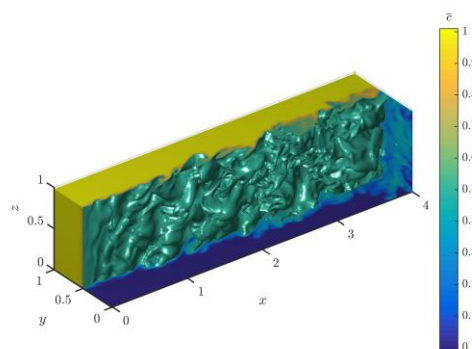
## Dr Trent Mattner

Discipline: Applied Mathematics

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### Large-eddy simulation of turbulent mixing

Turbulent flows are characterised by unsteady three-dimensional fluid motion over a wide range of spatial and temporal scales. Turbulence occurs in many flows of scientific and technological interest, such as flow past a wing, mixing of pollutants, oceanic and atmospheric circulation and combustion, to name a few. The aim of this project is to predict turbulent mixing and particle transport using large-eddy simulation.



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Dr Lewis Mitchell

Discipline: Applied Mathematics

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I would be happy to supervise honours projects in areas related to computational social science, data assimilation, sentiment analysis, data science, or some combination of each. Projects will depend on the specific interests and strengths of the student, but will better suit students with interest and capability in computational mathematics. Below are brief descriptions of two potential projects in these areas; many other project topics are possible, these are just to give a sense of some of the general themes.

### **Exploring the interactions between climate and influenza transmission**

There exists evidence that there is a relationship between influenza transmission and climate variables such as temperature and humidity, but the exact nature of this relationship is not well understood. This project will combine climate and influenza data sets from Australia with epidemiological models and new methods for model fitting to ascertain the nature of this relationship. The ultimate aim will be to make better real-time predictions of influenza outbreaks across Australia. This project will require some programming in MATLAB or similar, and is joint with A/Prof Joshua Ross.

### **A social network Bechdel test for movies**

The Bechdel test measures the male/female balance in a work of fiction by asking whether or not at least two female characters have a conversation about something other than a male character; modern films have a spectacular failure rate. This project will look at extending the Bechdel test to a social network analysis: by constructing the social network of character interactions in a large corpus of film scripts, we will analyse how central different characters are to the story. This will involve tools from network science, natural language processing and statistics, and will require programming in R, Python or similar. Project is joint with Dr Jono Tuke.

### **Trends in scientific self-promotion and hedonometrics**

Recent [work](#) has suggested that usage of positive words and self-promotion is [increasing](#) in science. This project will test this hypothesis rigorously using natural language and sentiment analysis techniques applied to a large corpus of texts from scientific articles over the past century. As well as measuring trends in positivity, we will take the next step and look at how self-promotion relates to success through a paper's citation count. Other questions involving topic modeling and network science will be explored. This project is joint with Dr Jono Tuke, and involves programming in R, Python or similar.

### **Real-time population monitoring through open social media**

There has been an explosion in recent years of the application of simple mathematical algorithms to huge, novel data sets such as social media to infer population-level characteristics such as health, mobility, even happiness. There exists great potential to use such data to study human behaviour quantitatively, giving rise to new exciting fields such as “culturomics” and computational social science. This project will blend Australian social media with traditional data sources to answer diverse questions such as: Can election outcomes be predicted? What drives successful conversations? What effect do our surroundings have on our happiness? We will build real-time monitoring and prediction tools for answering these and other questions.

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## Data assimilation for epidemiological forecasting

Forecasting the peak timing and intensity of infectious disease outbreaks (eg. seasonal influenza) is of great importance to public health officials each year, and is an active area of applied mathematical research. Recently there has been significant interest in improving predictions by borrowing techniques from numerical weather prediction such as data assimilation, which fuses information from predictive numerical models with observational disease surveillance data (eg. the work of Shaman et al on influenza forecasting). This project will look at important questions such as model error — how to make the best prediction when both the data and forecast model have inherent deficiencies? We will investigate ways to improve models, observations (potentially through the use of “Big” open data), and the mathematical techniques for blending the two.

**Prof. Michael Murray**

Discipline: Pure Mathematics

Email: [michael.murray@adelaide.edu.au](mailto:michael.murray@adelaide.edu.au)

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

- Differential Geometry
- Mathematical Physics
- Gauge Theories
- Twistor Theory
- Lie Groups and Lie Algebras
- Differential Geometry and Statistics
- Algebraic Topology
- Bundle Gerbes
- Bogomolny Monopoles

**Dr Giang Nguyen**

Discipline: Applied Mathematics

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I'm happy to supervise projects on applied probability and stochastic modelling. Below are three possible projects. However, students are welcome to discuss with me other topics.

### **Explode or Extinct?**

Branching processes are mathematical models used to describe and analyse how populations evolve over time, with applications in many areas such as biology, epidemiology, computer science and image processing. Students can study the effects of initial starting points and growth rates on the eventual size of the population, via algorithms and/or probabilistic analysis.

### **What does the Apollo spacecraft and Wall Street have in common?**

Diffusion processes played an important role in estimating the trajectories of the Apollo spacecraft on its way to the Moon and back, as well as in building the myriad of intricate models that is today's financial world. Students can study the effects on key properties of diffusion processes when we impose boundary constraints on these models.

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## How likely is *that*?

Natural disasters, financial crises, large-scale accidents and system breakdowns are examples of phenomena with extreme consequences that occur with non-negligible frequencies. Heavy-tailed models are able to capture adequately the behaviour of this type of phenomena but are often intractable. Students can study a class of models associated with infinite-phase-type distributions that can replace heavy-tailed models, from numerical and/or theoretical perspectives.

## Prof. Tony Roberts

Discipline: Applied Mathematics

Email: [anthony.roberts@adelaide.edu.au](mailto:anthony.roberts@adelaide.edu.au)

### 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.

### 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 a holistic approach to generate discrete models of such stochastic systems. The resulting models will be much more faithful to the original physical system.

### 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.

### 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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## A/Prof Joshua Ross

Discipline: Applied Mathematics

Email: [joshua.ross@adelaide.edu.au](mailto:joshua.ross@adelaide.edu.au)

My research interests are in Applied Probability, Computational Statistics, and Mathematical Biology. I am happy to discuss projects in any of these areas. Possible example projects are:

### Which came first: symptoms or transmission?

An important determinant of the impact of an infectious disease, and of our ability to control it, is the timing of symptom onset in an individual relative to their ability to transmit the disease. A project could build models of these competing scenarios, investigate the impact of the timing of these features, and develop statistical methods to infer the order of these features from different types of epidemic data.

### Saving the pangolin: New methods for combating illegal wildlife trade

Illegal wildlife trade poses a significant challenge to the global conservation of biological diversity. Novel mathematical and statistical methods are urgently required to combat this illicit transnational activity. A project could aid the development of such methods, including building models, solving optimisation problems, and/or developing statistical methods.



## Prof. Matthew Roughan

Discipline: Applied Mathematics

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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.

### 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 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.

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## 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 lose 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 which 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.

## Statistics of h-indices

The h-index is a measure of the success of someone's publications. Roughly, a scientist has index h, if at least h of his/her papers have at least h citations. There is a rough idea that it should increase linearly with the length of career (as opposed to the citation counts themselves). For more details, see <http://en.wikipedia.org/wiki/H-index>

This project proposes to try out several models for the way citations grow for a scientist, examine the linearity of the growth, and to determine the affect of various parameters of a scientist h-index.

## Internet Mapping

The Internet was conceived as a network that used distribution and redundancy to be attack resilient. Recent events have demonstrated it is not. The problem is that shared infrastructure (fibre conduits, IXPs, carrier hotels and so on) reduce this redundancy so that there are critical points where a failure can widely disrupt service.

The objective of this project is to work on techniques to create a high-quality map of network infrastructure to allow accurate risk assessment. It doesn't just require coding -- there is a basic requirement to develop mathematical algorithms to help infer links (where they are hidden), and we also need to use techniques from statistics to assess the accuracy and completeness of the data. In the past we have trialled methods from biology -- specifically the capture/recapture protocol -- to assess numbers of hidden items, and the goal of this project would be, in part, to extend these ideas. Internet Mapping sound interesting to you? Check out the article below on our work:

<http://www.newscientist.com/article/mg21829125.700-map-of-the-internet-could-make-it-stronger.html>



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## Dr Danny Stevenson

Discipline: Pure Mathematics

Email: [daniel.stevenson@adelaide.edu.au](mailto:daniel.stevenson@adelaide.edu.au)

I am happy to supervise projects on topics in the following areas

- Algebraic topology (especially homotopy theory)
- Category theory (especially higher category theory)
- K-theory
- Lie groups and Lie algebras
- The theory of bundle gerbes.

## Prof. Patty Solomon & Dr Tyman Stanford

Discipline: Statistics

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**1. Improving patient outcomes with statistics:** Longitudinal data arise when repeated measurements are made on patients over time, and the modelling and analysis of these data represents an important area of medical statistics. In this research project you will collaborate with clinicians to analyse data on patient outcomes from knee and hip replacement surgery conducted at the Royal Adelaide Hospital. The first aim of the study is to develop a model which predicts post-operative patient pain and function using individual patient multi-morbidity data. The research will then develop a predictive tool for surgeons to determine in advance the potential benefits of knee and hip replacement surgery for individual patients. The project will involve general regression modelling in R using cross-validation to develop the best predictive model and novel machine learning techniques for obtaining a diagnostic algorithm.

**2. Modelling variation in Australia's climate change data:** The Bureau of Meteorology maintains several important datasets as part of its climate science programme. One important dataset is the Australian Climate Observations Reference Network - Surface Air Temperature dataset (ACORN-SAT) of daily temperature records dating back more than 100 years. The purpose of ACORN-SAT is to monitor climate variability and change in Australia. There are however numerous sources of temporal and spatial variability which impact on the accuracy and precision of the daily temperature measurements in ways that are not yet fully understood or quantified. This research project aims to address this problem by firstly investigating the sources of variability then developing new hierarchical statistical models and other approaches to describe the observed uncertainty and its impact on the temperature records. The analysis will be conducted in R and will use K-fold cross validation of training and test datasets to validate the statistical models.

**3. How big should your big-data classification study be?:** An important part of study design is estimating the required size of the study to be conducted to reasonably answer the scientific question(s) being asked. Having the appropriate number of observations ensures there is sufficient statistical power to detect the real biological effects of interest. Sample size calculations for microarray and proteomics studies present special challenges however, owing to the special features of the technologies and the high-dimensional nature of the data. To date, most study size calculations have concentrated on detecting the significance of individual gene expression levels or adjusting for multiple comparisons. This research



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project will develop study size calculations for discriminating between classes of observations, in particular, cancer versus non-cancer groups, based on tens of thousands of predictor variables. The techniques used will employ simulation studies in R and the analysis of proteomic gastric cancer data, and statistical power will be assessed by the proportion of studies reaching pre-specified levels of correctly classified observations. Omics datasets also suffer from missing data and the techniques to be developed will accommodate missingness in the data.

## A/Prof Yvonne Stokes

Discipline: Applied Mathematics

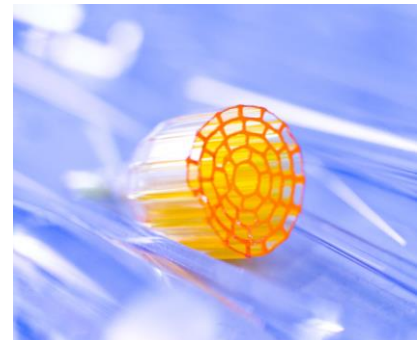
Email: [yvonne.stokes@adelaide.edu.au](mailto:yvonne.stokes@adelaide.edu.au)

I am broadly interested in mathematical modelling using differential equations. Specific research interests include **mass and heat transfer with application to industrial and biological problems**. The major research projects on which I am currently working concern **viscous fluid mechanics with free and moving boundaries**.

Possible project topics are indicated below. Each involves model derivation and solution using both analytical and computational methods. You are welcome to discuss other ideas with me.

### Viscous extensional flows

An everyday example is honey dripping from an up-turned spoon. The fluid stretches to form a thin filament from which a drop is suspended. Given sufficient time the filament may break. An important application area of interest to me is the 'spinning' of microstructured optical fibres whereby a macroscopic preform having a complex internal geometry is heated and stretched in a drawing tower to form a long fibre with a diameter of 100-200 $\mu\text{m}$  (see picture at right). Obtaining the desired internal structure in the fibre is a key problem that requires mathematical modelling. Perturbation methods, exploiting the slenderness of the geometry, yield coupled 1D and 2D models of the stretching and cross-plane flows, respectively, which are accurate and very computationally efficient compared to solution of the full 3D problem.

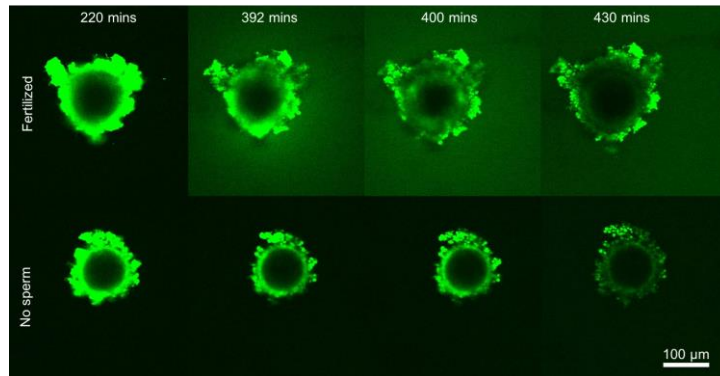


### Flow in spiral channels and ducts

The study of flow in spiral channels and ducts has application to many natural and industrial flows. My research is motivated by (i) spiral particle separators used in the mineral processing industry to separate valuable minerals from ore and (ii) spiral microfluidic sorters, a new idea for separating tumour cells from other cells in a blood sample. In both applications the fluid depth is small and perturbation methods yield a simplified flow model which enables examination of the influence of fluid and geometrical parameters on the flow. The spiral particle separator features gravity-driven flow in an open helically-wound channel (see picture at left) in which the flow has a free surface. The microfluidic sorter features pressure driven flow in a closed spiral duct.

## Travelling waves and chemical signalling

Researchers in the School of Paediatrics & Reproductive Health recently discovered that immediately after fertilisation of a mammalian egg a signal seems to propagate around the egg causing the surrounding cells to move away from it much like a travelling wave. Diffusion of a calcium signal released by the egg



and/or surrounding cells is believed to be the cause of the observed cell behaviour. This has motivated my interest in travelling wave solutions of reaction-diffusion equations. Such solutions have been found in other contexts which form a starting point for this study but the specific mathematical model for this problem will lead to new solutions. Comparison of model solutions and experimental measurements will yield new understanding of the biology.

## Elder Prof. Mathai Varghese

Discipline: Pure Mathematics

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I am happy to supervise projects in the following and related areas,

Dualities (Tannakain duality, T-duality,...)

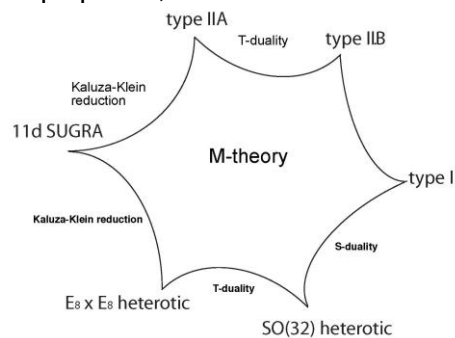
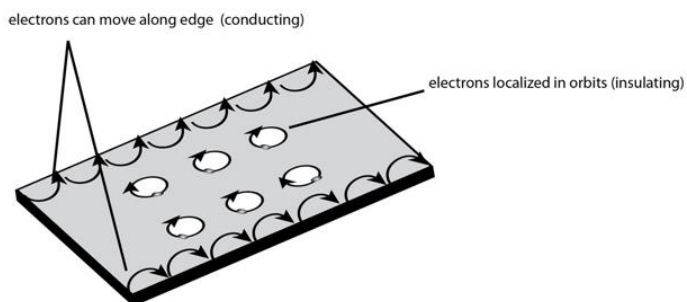
Noncommutative geometry and K-theory

Spectral theory of elliptic operators

Atiyah-Singer index theory of elliptic operators (applications and generalisations)

Aspects of mathematic physics (string theory, quantum Hall effect, topological insulators, gauge theory)

Equivariant cohomology including twisted versions and loop spaces;



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## Dr Raymond Vozzo

Discipline: Pure Mathematics

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

- Differential Geometry
- Mathematical Physics
- Algebraic Topology
- Category Theory
- Bundle Gerbes

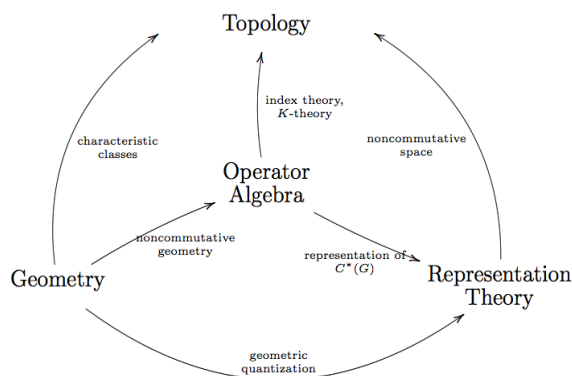
## Dr Hang Wang

Discipline: Pure Mathematics

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I am interested in supervising honours projects on index theory for invariant elliptic operators on spaces with group action, higher index, operator K-theory of group  $C^*$ -algebras and group representation.

Projects on these topics create opportunities to touch many areas such as differential geometry, algebraic topology, representation theory, number theory and to discover their connections from the point of view of operator algebra.



The possible projects are not restricted to these subjects I am working on but also depending on the interest of each student. Any students interested in Pure Mathematics are welcome to talk to me on specific problems we could work on together.