Welcome to Honours! Honours is an additional year in which you study selected mathematical and/or statistical topics in depth. There is a change of emphasis from the preceding undergraduate years: courses tend to be more focused on a specific problem or class of problems, rather than attempting to give a broad coverage of a branch of Mathematics or Statistics as was done in your earlier undergraduate years.

Also in your Honours year, there is the possibility of a project in which you investigate some problem with the assistance of a member of staff. Depending on the nature of the problem, this may involve literature searches in the library, the use of various computing packages (for example MATLAB, MAPLE or R) on the school’s computing system, resources on the internet, or even proving new theorems. At the end of the project, you produce a written report and give an oral presentation.

Who should think about Honours? If you view Mathematics and Statistics as more than a means to an end, then the Honours year will be a year well spent. The Honours year provides that additional mental edge, as well as some specific technical and (in the project) presentational skills that potential employers find valuable. If you intend to proceed on to graduate work, Masters or PhD, then Honours is a good stepping-stone.

To enter Honours in Mathematics, you will need at least 60 points from MATH310-399, plus at least 30 points from 300-level MATH, STAT or other approved courses. For Honours in Statistics, you need at least 60 points of 300-level STAT courses and another 30 points from 300-level STAT, MATH or other approved courses. Normally you should have maintained at least a B+ average in these papers. Precise details are given in the University Calendar. There is also a joint Mathematics and Statistics Honours degree (see UC enrolment handbook).

The School offers both B.A.(Hons), B.Sc.(Hons) and a P.G.Dip.Sc. programs. The most appropriate program is best decided on a case-by-case basis. If you decide that you are interested in Honours, you should see the Head of School, Prof. Jennifer Brown, or the Honours Coordinator Dr Mark Hickman to discuss your options. You should do this before the enrolment week next year.

Courses are packaged in modules that will run at two lectures a week for a semester. Any proposed programme of study for Honours requires the approval of the Head of School. It is highly unlikely that any proposed programme that has a high workload in one semester will be approved, so you should try to construct a programme that balances your workload evenly over both semesters. Courses at the appropri-
ate level from other departments may be included in an approved program. In addition there are a number of joint programs between the School of Mathematics and Statistics and other departments at the university.

**B.Sc.(Hons)**

In the Science faculty, Honours may be completed in Mathematics, Statistics, Mathematics and Statistics, Mathematical Physics, Computational and Applied Mathematics (CAMS), Mathematics and Philosophy or Economics and Mathematics. Students enrolled for a B.Sc.(Hons) in Mathematics and/or Statistics are required to complete eight 400-level courses, as well as a project which is worth the equivalent of two courses. If you are interested in the:

- Mathematical Physics programme, see Prof. David Wiltshire (Physics).
- CAMS programme, see Prof. David Wall or Assoc. Prof. Rick Beatson.
- Mathematics and Philosophy programme, see Prof. Douglas Bridges or Dr Clemency Montelle.
- Economics and Mathematics programme, see Prof. Douglas Bridges or Dr Seamus Hogan (Economics).

**B.A.(Hons)**

In the Arts faculty, Honours may be completed in Mathematics or in Statistics. A B.A. (Hons) has the same requirements as a B.Sc.(Hons).

**P.G.Dip.Sci.**

A Post Graduate Diploma in Science (P.G.Dip.Sci.) can be obtained by completing eight 400-level papers in one year. These courses normally do not include the honours project (MATH/STAT449). Entry requirements are as for a B.Sc.(Hons) except that you are not required to have a B+ average. It is very strongly recommended that your average grade in your majoring subject at stage 3 is at least a C+. A P.G.Dip.Sci may be used as the first part of an M.Sc.

**Proposed Courses for 2015**

The proposed courses for 2015 are outlined in this booklet. The final decision about which courses are to be offered will depend on the availability of staff and on student interest. The School reserves the right to cancel any course that does not attract four or more students. It is also possible (and in some cases desirable) to include in your Honours programme appropriate courses from other departments or 300-level courses from Mathematics or Statistics. In the latter case, extra work is usually required to bring the paper to a level consistent with other 400-level courses. Note that, subject to having the required background, any STAT courses may be included in a Mathematics degree and vice versa.

**Proposed Projects for 2015**

A broad range of possible projects is outlined in this booklet. However, this list is not exhaustive and other possibilities for
projects are certainly possible. Project supervision is by mutual agreement of the supervisor and student. You should arrange your project by the end of the first week of term in 2015. It is suggested that you seek out possible supervisors during the enrolment week (or before if you have a clear idea of what sort of project interests you). You will hand in a written report on September 14; part of your project assessment will be an oral presentation in Term 4.

400-LEVEL COURSES

All 400-level courses are offered subject to sufficient student demand and staff availability, which will be determined at the beginning of each semester. For an up-to-date view of the School’s current offerings, please see the School’s web page, which is located off the main University web page.

MATHEMATICS

MATH401 15 points
Dynamical Systems 1
MATH401-15S1 (C)

Dynamical systems is a rapidly developing branch of Mathematics with growing applications in diverse fields from traditional areas of applied mathematics to numerical analysis, biological systems, economic models and medicine.

It is often difficult or impossible to write down an exact solution to systems of nonlinear equations. The emphasis in this course will be on qualitative techniques for classifying the behaviour of nonlinear systems, without necessarily solving them exactly. Both main types of dynamical system will be studied: discrete systems, consisting of an iterated map; and continuous systems, consisting of nonlinear differential equations. Topics covered will include: chaotic behaviour of simple 1D maps; period-doubling bifurcations; phase portrait analysis; methods for determining stability of fixed points and limit cycles; centre manifolds; and symbolic dynamics.

Enquires: Rua Murray

MATH406 15 points
Mathematical Models in Biology
MATH406-15S1 (C)

How did the leopard get its spots? Why should children be vaccinated against measles? This course will try to answer these (and other) questions by using mathematical models to examine biological phenomena. In the achieving this we will study: Biochemical reactions, reaction diffusion, cellular homeostasis, membrane ion channels, excitability and nonlinear wave propagation.

Some knowledge of dynamical systems and a familiarity with MAPLE (or MATLAB) are useful pre-requisites to this course.

Enquires: David Wall

MATH407 15 points
Special Topic in Mathematics
(Stochastic Processes)
MATH407-15S2 (C)

Stochastic processes, in other words processes that contain some randomness, are all around us: the price of petrol; a gambler at the casino; a supermarket checkout queue; the weather; world population
growth; evolution. This course will look at a variety of stochastic processes and ways in which these can be used to describe the real world. Courses that may be useful include MATH302, MATH363, STAT211.

Topics to be chosen from: Poisson processes; birth-death processes; coalescent and branching processes; random walks; gambler’s ruin; first hitting times; Markov chains; queuing theory; martingales.

**Enquires:** Michael Plank

**MATH412**  
**15 points**  
**Unconstrained Optimization**  
MATH412-15S2 (C)  
This course looks at the minimization of smooth functions of several variables. The first part of the course examines gradient based methods using line searches, including Newton, quasi-Newton, and conjugate gradient methods. A selection of other topics is then introduced, including trust region methods and methods for constrained optimization. Demonstration software is used to illustrate aspects of various algorithms in practice.

**Enquires:** Chris Price

**MATH420**  
**15 points**  
**Hilbert Spaces**  
MATH420-15S2 (C)  
The theory of Hilbert spaces is fundamental in many areas of modern mathematical analysis, having a clear and easy-to-grasp geometric structure, just like Euclidean spaces. However, unlike Euclidean spaces, Hilbert spaces may be infinite dimensional. The course will be self-contained, introducing important spaces (especially $L^2(m)$), operators on them, and basic spectral theory. Prior exposure to MATH343 would be an asset, but is not mandatory.

**Enquires:** Maarten McKubre-Jordens or Hannes Diener

**MATH426**  
**15 points**  
**Differential Geometry**  
MATH426-15S1 (C)  
Have you ever wondered why you can roll a piece of paper into a tube but cannot bend the paper tube to form a torus without wrinkling or breaking the paper or how a ‘flat being’ can decide whether it lives on a 2-sphere or a torus? There are physical reasons to the first question but differential geometry also provides a mathematical answer.

The principal objects of interest in differential geometry are differentiable manifolds, like spheres or a torus, that may be equipped with additional structures, like a metric, which leads to Riemannian geometry, and one investigates their intrinsic properties and invariants. In so doing one encounters many ideas which are not only beautiful in themselves but are basic for both advanced mathematics and theoretical physics.

The course gives an introduction to classical differential geometry including the basic theory of manifolds, vector fields, geodesics and intrinsic invariants like curvature.

**Enquires:** Gunter Steinke
Matroids (combinatorial geometries) are precisely the structures that underlie the solution of many combinatorial optimization problems. These problems include scheduling and timetabling, and finding the minimum cost of a communications network between cities. Given this, it is perhaps surprising that matroid theory unifies the notions of linear independence in linear algebra and forests in graph theory as well as the notions of duality for graphs and codes. This course is an introduction to matroid theory.

Enquires: Charles Semple

Graph Theory

In a nutshell, graphs are mathematical structures which model relationships between objects. Graph theory is the branch of combinatorics concerned with their study, and has grown to become a very rich and diverse discipline in its own right. It has applications in almost every scientific field, from analysing the spread of epidemics to modelling social networks.

In this self-contained course we will explore a range of topics from graph theory, considering both theory and applications. The course is intended for students majoring in Mathematics or Computer Science. Does not require MATH120 or MATH220.

Enquires: Jeanette McLeod

Topics in Algebra

This course in modern algebra. See MATH321.

Enquires: Gunter Steinke
Topics in Applied Mathematics  
MATH442-15S2 (C)
This course will cover techniques of applied mathematics which are key tools of researchers in applied mathematics. These are likely to include dimensional analysis and the Buckingham-pi theorem, analysis of PDEs, the delta function and the theory of distributions, asymptotic analysis, boundary layer theory, the method of multiple scales, and numerical experimentation.

Enquires: Miguel Moyers-Gonzalez or Phil Wilson

Metric, Normed and Hilbert Spaces  
MATH443-15S1 (C)
This course introduces those parts of modern analysis that are essential for many aspects of Pure and Applied Mathematics, Physics, Economics, Finance, and so on. For example, if you want to understand the convergence of numerical algorithms, approximation theory, quantum mechanics, or the economic theory of competitive equilibrium, then you will need to know something about metric, normed and Hilbert spaces. See MATH343.

Enquires: Hannes Diener or Ngin-Tee Koh

Summer Research Project  
MATH491-15SU2 (C)
This 150-hour course provides students with an opportunity to develop mathematical research skills and to extend and strengthen their understanding of an area of mathematics.

Enquires: Gunter Steinke

Independent course of study  
MATH475-15S1 or MATH475-15S2 (C)
This course allows a student to perform directed reading of a particular topic under a Mathematics lecturer. The topic choice is by mutual arrangement with the lecturer. Students should ensure these arrangements are in place before enrolling in the course.

Enquires: Any Mathematics Lecturer

Project  
MATH449-15W (C)
A whole year research project in mathematics (see Honours projects).

Enquires: Mark Hickman
**STATISTICS**

**STAT445** 15 points  
*Multivariate and Financial Time Series*  
STAT445-15S2 (C)

**Enquires:** Marco Reale

**STAT446** 15 points  
*Generalised Linear Models*  
STAT446-15S1 (C)

How do you analyse data that does not fit the standard methods such as ANOVA and regression? How do you deal with data that are very non-normal, are counts rather than measurements, are correlated and have interdependencies? In this course we introduce you to the very useful toolbox of Generalised Linear Models (GLMs). This is a natural progression from understanding ANOVA, regression and multivariate techniques. We will learn about the general framework for GLMs, and how to use GLMs for analysing data. We will introduce you to the package R, and will use this software throughout the course. Some background in statistical analysis methods is necessary, and useful courses to have completed are STAT220, STAT212 and STAT315. No experience in R is necessary. See STAT319.

**Enquires:** Jennifer Brown

**STAT447** 15 points  
*(Official Statistics)*  
STAT447-15S2 (C)

This course provides an overview of the key areas of Official Statistics. Topics covered include data sources (sample surveys and administrative data); the legal and ethical framework of official statistics; an introduction demography; the collection and analysis of health, social and economic data; data visualisation including presentation of spatial data; data matching and integration; the system of National Accounts.

**Enquires:** Jennifer Brown

**STAT449** 30 points  
*Project*  
STAT449-15W (C)

A whole year research project in Statistics (see Honours projects).

**Enquires:** School of Mathematics and Statistics Reception

**STAT450** 15 points  
*Advanced Statistical Modelling*  
STAT450-15S1 (C)

This course provides an introduction to a range of statistical techniques used in the analysis of spatial data. It will cover the basic concepts and techniques of spatial data analysis (SDA) and provide a wide range of applications examples from various fields such as geology, demographics, epidemiology and environmental sciences. A comprehensive lab programme uses a variety of software packages (including ArcGIS, Geoda, geoR and WinBUGS) to explore and analyse spatial data using the techniques taught in the course.

**Enquires:** Elena Moltchanova
STAT455 15 points
Sampling Methods
STAT455-15S1 (C)
This course looks at practical methods for gathering new data, the raw material of Statistics. See STAT312.

Enquires: Carl Scarrott

STAT456 15 points
Time Series and Stochastic Processes
STAT456-15S2 (C)
Here we explain some techniques to model observations taken sequentially over time. This kind of data is very common in Biology, Environmental Sciences, Economics and Finance. Time series methods are widely used for forecasting. This course is application oriented, and computers are used to analyse real time series data. See STAT317.

Enquires: Patrick Saart

STAT460 15 points
Extreme Value Statistics
STAT460-15S1 (C)
This course aims to develop the theory and methods for modelling the extremes of random processes. Extreme value theory moves away from more traditional statistical techniques where the aims are to model the usual (or in some sense average) behaviour, to consider the unusual or rare events. It has received wide application in many fields where the risk associated with rare events are of concern, e.g. finance/economics, hydrological modelling, climate change, engineering (structural design) and material science (material fatigue/failure).

The course will cover the mathematics underlying extreme value models, statistical inference using likelihood and applications to real data, with implementation in the software package R. Recommended preparation includes second year Statistics (preferably STAT214) and at least full first year Mathematics (MATH103 or EMTH119 or equivalent).

Enquires: Nate Wichitaksom

STAT461 15 points
Bayesian Inference
STAT461-15S2 (C)
This course explores the parametric Bayesian approach to Statistics by considering the theory, methods for computing Bayesian solutions, and examples of applications. The key advantage of the Bayesian approach is that it naturally provides probabilistic measures of uncertainty along with the inference. Topics that may be covered include: Theoretical foundations of Bayesian Statistics, choice of prior distributions, Bayesian estimation and credible regions, Bayesian tests and model selection, methods for computing Bayesian solutions, hierarchical models, and applications to linear models. Students should have a sound mathematical background and a good foundation in Statistics and Probability, at least up to the level of STAT213 or STAT214. See STAT314.

Enquires: Nate Wichitaksom

STAT462 15 points
Data Mining
STAT462-15S2 (C)
Data mining refers to a collection of tools to discover patterns and relationships in
data, especially for large databases. It involves several fields including database management, statistics, artificial intelligence, and machine learning, and it has had a considerable impact in business, industry and science.

This course provides an introduction to the principal methods in data mining: data preparation and warehousing, supervised learning (tree classifiers, neural networks), unsupervised learning (clustering methods), association rules, and the dealing with high-dimensional data (PCA, ICA, multidimensional scaling). Students will see applications from various fields, such as commerce (fraud detection, product placement, targeted marketing, assessing credit risk) and medicine (diagnostics). We will use data mining software to illustrate methods with data sets from these fields.

Students must (i) do problems that are assigned throughout the term and (ii) research an area and write an account of it; the instructor will give suggestions for topics in class. See STAT/three.pnum/one.pnum/eight.pnum.

Enquiries: Marco Reale

STAT463 15 points
Multivariate Statistical Methods
STAT463-15S1 (C)

Multivariate statistical methods extract information from datasets which consist of variables measured on a number of experimental units. The application of these methods is blooming with the availability of large datasets from a wide range of scientific fields, combined with the advent of computing power to implement them. Examples abound in fields as diverse as bioinformatics, internet traffic analysis, clinical trials, finance and marketing. This course will cover the theory and applications of various multivariate statistical methods. See STAT315.

Enquiries: Daniel Gerhard

STAT470 15 points
Special Topics in Statistics
(Advanced Time Series Methods)
STAT470-15S2 (C)

In many applications, in particular in finance and economics, observed data series often exhibit a behaviour which cannot be modelled with linear time series models (i.e. ARMA processes). Thus alternative models allowing for a nonlinear behaviour are called for and are successfully used. For instance, Robert Engle was awarded the Nobel Prize in 2003 for introducing the so-called (G)ARCH model. In this course we will first review some materials on linear time series methods, then consider and analyse several classes of nonlinear time series models, such as GARCH, Markov-switching as well as threshold autoregressive time series models. We study their common probabilistic and statistical concepts and theory (Markov chains with uncountable state space, stochastic recurrence equations, ergodicity and mixing). Finally, we will derive and apply estimators for the model parameters.

Enquiries: Patrick Saart

STAT472 15 points
Special Topic in Statistics
(Advanced Data Analysis and Statistical Consulting)
STAT472-15S1 (C)

In most undergraduate courses, you are taught the theory behind a method and
then given neat examples to which it can be applied and software to apply it. In reality, the most common question you will hear from a non-statistician is 'how do I analyse my data? So you are the one who has to come up with the appropriate research question and choose the suitable method (and sometimes learn it quickly too). It is common in real world applications for the experiments have not been well planned and for data to be missing, which will need to be taken into account. The assumptions underlying the statistical model (e.g. homoscedasticity and normally distributed) often do not hold and you will have to know what to do. Finally, your fellow scientists, laymen and policymakers are all interested in different aspects of the research question and that is rarely the statistical significance of your ANOVA: you have to know how to communicate your results clearly, correctly and efficiently and how to defend your choices in data analysis and collection.

This course is about the reality of being an applied statistician. Besides covering the above points in class, individual statistical consulting session will provide you with hands-on experience.

Good knowledge of multivariate statistical methods, GLMs, and basic sampling theory expected. Working knowledge of R is recommended or forecasting methods. It provides extensive training in forecasting and modelling techniques such as smoothing, dynamic regressions, multivariate autoregressions, state space models, and neural networks with a wide range of applications.

Enquires: Elena Moltchanova

STAT475 15 points
Independent course of study
STAT475-15S1 or STAT475-15S2 (C)
This course allows a student to perform directed reading of a particular topic under a Statistics lecturer. The topic choice is by mutual arrangement with the lecturer. Students should ensure these arrangements are in place before enrolling in the course.

Enquires: Any Statistics Lecturer

STAT491 15 points
Summer Research Project
STAT491-15SU2 (C)
This 150-hour course provides students with an opportunity to develop statistical research skills and to extend and strengthen their understanding of an area of statistics.

Enquires: Gunter Steinke
Honours Projects

A range of possible projects are outlined. However, this list is not exhaustive and other possibilities for projects are certainly possible.

Project supervision is by mutual agreement of the supervisor and student. You should arrange your project by the end of the first week of term in 2015. It is suggested that you seek out possible supervisors during the enrolment week (or before if you have a clear idea of what sort of project interests you).

You will hand in a written report on the project by Monday September 15, 2015; part of your project assessment will be an oral presentation during Term 4.

Projects in Mathematics

Algorithms for tangent plane continuous surface fitting
Rick Beatson

This project considers the fitting of tangent plane continuous surfaces to points and normals data sets. The end goal is to efficiently model underground rock formations, and other blobby shapes, occurring in applications. The project will build on an existing algorithm which uses quintic Bezier elements.

There are diverse aspects that could be considered. An algorithmic aspect is to consider and experiment with some local optimisation steps, which would be used to improve a given fit when the normals are noisy.

Another aspect is to recast the current theory in terms of a different parametrisation of the Bezier elements. This would quite probably give rise to a cleaner theory, and probably a more efficient implementation.

Finally, on the implementation end, a core task in the current code is to solve a sparse semi-definite system. The current solver is crude. The theory and implementation of a more efficient solver would be an interesting task for someone who enjoys numerical analysis, and wants to experiment with parallel algorithms.

Arithmetic of Elliptic Curves
Brendan Creutz

An elliptic curve is a geometric object with a rich algebraic structure. There is a natural way to ‘add’ two points on the curve to get a third, resulting in an algebraic group. One of the most prominent open problems in mathematics seeks to obtain a better understanding of the structure of such groups (cf. The Birch and Swinnerton-Dyer Conjecture at http://www.claymath.org/millennium-problems).

These groups have also begun to play an increasing prevalent role in cryptography, as they provide cryptosystems that are more secure and efficient than traditional systems based on integer factorization or discrete logarithms in finite fields.

This project will introduce the student to the theory of elliptic curves by first investigating the classical geometry of elliptic curves over the real or complex numbers. Depending on student interest, the project will then explore the situation over the rational numbers, function fields, or finite fields, as well as investigating potential applications.
Computing the Infinite  
Hannes Diener

Since most mathematical objects are ideal/infinite, but computers can only ever deal with discrete/finite objects, it seems that we almost always have to confine ourselves to using approximations and shadow types (such as ‘float’ instead of the reals, or ‘int’ instead of the natural numbers) when transferring mathematical ideas to a computer.

Surprisingly though, it is possible to compute with (a large class of) infinite subsets of natural numbers, real numbers, and so on, not just as approximations, but as the actual objects. In this project a student should investigate some of the mathematical background of such an approach, and ideally implement some of the ideas. Depending on the student’s background the project can either focus on the theoretical mathematical foundations, or on the practical implementation. For the first a background in logic is welcomed (for example MATH130, 230, or 336), for the second some familiarity with a programming language which allows elements of ‘functional programming’ (such as Python, Haskell, C++) is useful.

History of Mathematics  
John Hannah

The second half of the 19th century and the first half of the 20th century saw the introduction and development of several quite abstract branches of mathematics. Examples include abstract algebra (groups, fields, rings, ideals, modules), functional analysis, topology, and category theory. In this project you will follow this development in a topic of your own choosing, and in the process you will both learn some new mathematics, and try to discern the influences (mathematical, philosophical or cultural in origin) which led to these developments.

Lax Pairs  
Mark Hickman

Given a non-linear differential equation, a Lax pair is a pair of linear differential operators $L$, $M$ whose commutator vanishes only on solutions of the differential equation. A Lax pair allows one to potentially solve the differential equation by reducing the problem to an eigenvalue problem (if the operator $L$ is second order, this is a Sturm-Liouville problem) and a time evolution of the eigenfunction; the so-called inverse scattering method. If $L$ is first order then the Lax pair gives a conservation law of the differential equation. In this project, we will be looking at a method to compute the Lax pair of prescribed order for a differential equation (if it exists). This will involve Maple and would suit a student who has completed MATH302.

Ecological Networks  
Alex James

From the Amazon rainforest to the Okeover stream species interact with each other in complex systems. These interactions come in many forms: competitive - they both compete for the same resource, predator-prey - eat or be eaten, mutualistic - both benefit from the relationship. How does the architecture of these interactions affect the behaviour of the system? Should a species interact with as many others as possible? Should they form groups or cliques? Is there a conflict between good for an individual and good for the system?
Useful pre-requisites for this project could include dynamical systems, discrete maths and some Matlab or other computer programming. An interest in ecology is also helpful.

I also have other projects available that combine maths and ecology. Please contact me to find out more.

**Modelling Collective Cell Movement**
Mike Plank

This project will build mathematical models of cell invasion based on random walks. In this type of model, individual cells move stochastically, for example by selecting a movement direction at random. Despite the unpredictability of an individual cell’s movement, the model can be used to predict the emergent behaviour of the population as a whole, for example the number of cells at a particular location, with a surprising degree of accuracy. The main goal of this project is to develop and solve a PDE to describe how the average cell density changes over space and time and to compare this with new experimental data from the wet lab to see how well the model matches reality. This project will require some knowledge of PDEs and experience of a computer programming language, e.g. MATLAB.

**Smaller Fish to Fry?**
Mike Plank

Modern fisheries management is almost universally based on the principle of protecting small fish from capture and targeting large fish. Fisheries that do not conform to this dogma, such as small-scale African fisheries, are seen as destructive. But mathematical modelling and empirical experience has shown that, actually, these fisheries can be more sustainable than you might expect. The aim of this project is to investigate the optimal size of fish to catch from the point of view of an individual fisher. This is a game theoretical problem, because the choices made by one fisher can affect the fish population, and therefore the outcomes for other fishers. Of primary interest is the question: if each individual fisher behaves so as to maximise his/her own yield, what does the aggregate fishing pattern look like across the whole fishery? Are regulations needed to stop the fishers driving the fish population to extinction and/or driving each other to economic penury? Or can a self-organising group of individual fishers be ecologically and economically sustainable? This project will require some knowledge of PDEs and experience of a computer programming language, e.g. MATLAB.

**Is it Mathematical Biology or Biological Mathematics?**
Charles Semple

One typically thinks of physics as the science that interacts most with mathematics. However, this perception is rapidly being challenged with the ever increasing interactions between biology and mathematics. In this project, we sample a taste of these interactions from the viewpoint of evolutionary biology and ecology, and discrete mathematics.

**Tutte’s 5-flow Conjecture**
Charles Semple

Network flow problems are an important class of problems in combinatorial optimisation and represent a large variety of real
world occurrences. A particular type of network problem gives rise to Tutte’s 5-flow conjecture, the most outstanding conjecture in graph theory today. In this project, we investigate this conjecture and its connections to other areas of combinatorics. To whet your appetite, the Four Colour Theorem says that every planar graph without isthmuses has a 4-flow. While some prior knowledge of graph theory would be helpful, it is not a prerequisite for the project.

\textbf{p-adic numbers}

Gunter Steinke

The real numbers are the completion of the rationals $\mathbb{Q}$ with respect to the usual absolute distance $d(x, y) = |x - y|$ between rational numbers $x$ and $y$. In a similar way, $p$-adic numbers, where $p$ is a prime, are obtained as the completion of $\mathbb{Q}$ with respect to a different distance $d_p$: two integers are close if their difference is divisible by a high power of the prime $p$. There is also a purely algebraic definition of $p$-adic numbers.

The $p$-adic numbers $\mathbb{Q}_p$ have many interesting properties: $\mathbb{Q}_p$ is a non-archimedian field, and it is locally compact but not connected. One can do analysis on $p$-adic numbers, form the algebraic closure, and they are useful in solving, for example, Diophantine equations.

This project investigates $p$-adic numbers and their basic properties and looks at some of their applications.

\textbf{Reflection Groups}

Gunter Steinke

Groups naturally occur as collections of symmetries of geometries or algebraic structures. Of all symmetries involutions, that is, symmetries of order 2, often play a special role, and many important groups, like symmetric groups, are known to be generated by involutions.

The project investigates groups that are generated by finitely many involutions. It should lead to a complete classification of some of the so-called Coxeter groups. Much of the information about such groups can be graphically represented in Coxeter-Dynkin diagrams. Similar diagrams also appear in seemingly unrelated areas like Lie algebras, algebraic groups and buildings. Furthermore, realisations of the finite Coxeter groups as reflection groups, that is, groups of isometries in some Euclidean space generated by reflections, should be found.

\textbf{The Mathematics of Natural Disasters}

Phil Wilson & Miguel Moyers-Gonzalez

Geologic processes can adversely impact human life and infrastructure, representing a significant risk to national security. For example, volcanic ash can choke emergency generators, pollute reservoirs, and damage hydroelectric turbines. This project will model selected aspects of natural disasters using mathematical and numerical techniques. The aim is to better understand the underlying physical processes in order to mitigate their consequent adverse effects. The project is part of a broader inter-disciplinary research group. The ideal candidate would have a good background in PDEs and MATLAB, but all applicants will be considered.
Environmental monitoring is a fast moving, and important field of research. Data on environmental processes such as changes in water quality, endangered species distribution, weed invasion, and biodiversity are used to inform and guide how we manage our environment.

One use of environmental data is to build models to predict species distribution, and to predict the effect of environmental changes. In this project we will look at different methods used to collect field data and the effect of these differences on prediction models. We will use computer simulations to model data collection and analysis.

Geospatial Analysis
Elena Moltchanova
The aim of the project will be to demonstrate application of spatial statistical techniques in practice. A suitable dataset may either be selected from the field of interest by the student or will be supplied by the lecturer. A short report should then be produced with the short description of the data, some results of the exploratory data analysis and, finally, the description of the method of choice and the results of its application.

Extreme Value Statistical Modelling
Carl Scarrott
The statistics you meet on undergraduate course typically focus on the capturing the "usual" characteristics of a process (e.g. properties of mean, median or variance). Extreme value statistics focus on understanding the unusual or rare events of a process. Extremes are of interests in all sort of different fields, for example:

1. financial risk (e.g. estimating Value at Risk for risk and portfolio management)
2. engineering (e.g. designing structures to withstand the strongest forces they could be exposed to, e.g. wind exposure on bridges or forces on buildings due to earthquakes!)
3. environment (e.g. are Christchurch’s winter air pollution extremes reducing due to government interventions?)
4. IT (e.g. can our servers and network cope with peak demand when your assignments and projects are due in?)

I have various honours projects in extreme value modelling for financial, environmental, medical and industrial applications. So if you are thinking of becoming a statistical "extremist" then get in touch.

Below are two projects which are accompanied with a $1000 stipend. Students with work with Dr Hamish Jamieson from the Otago Medical School/Canterbury District Health Board and an academic staff member from our School.

Canterbury District Health Board Dataset

PROJECT ONE
To assess the use BlueFern supercomputer at UC to analyse the a large dataset from the Canterbury District Health Board on
patient health. There are many factors that can be explored and modelled, and all are useful for the CDHB, e.g., rest home admission, mortality, hospital admissions. The dataset is part of a nationwide, and international, programme to assess health in the ageing population.

PROJECT TWO (With the Brain Research Institute)
To use the Canterbury District Health Board dataset on health in the ageing population to identify the characteristics of people with Parkinson's Disease and possible predictors of the disease. The second part of this project will look at what confounding factors influence the outcomes in patients with cognitive impairment.

For more details, please contact Jennifer Brown.