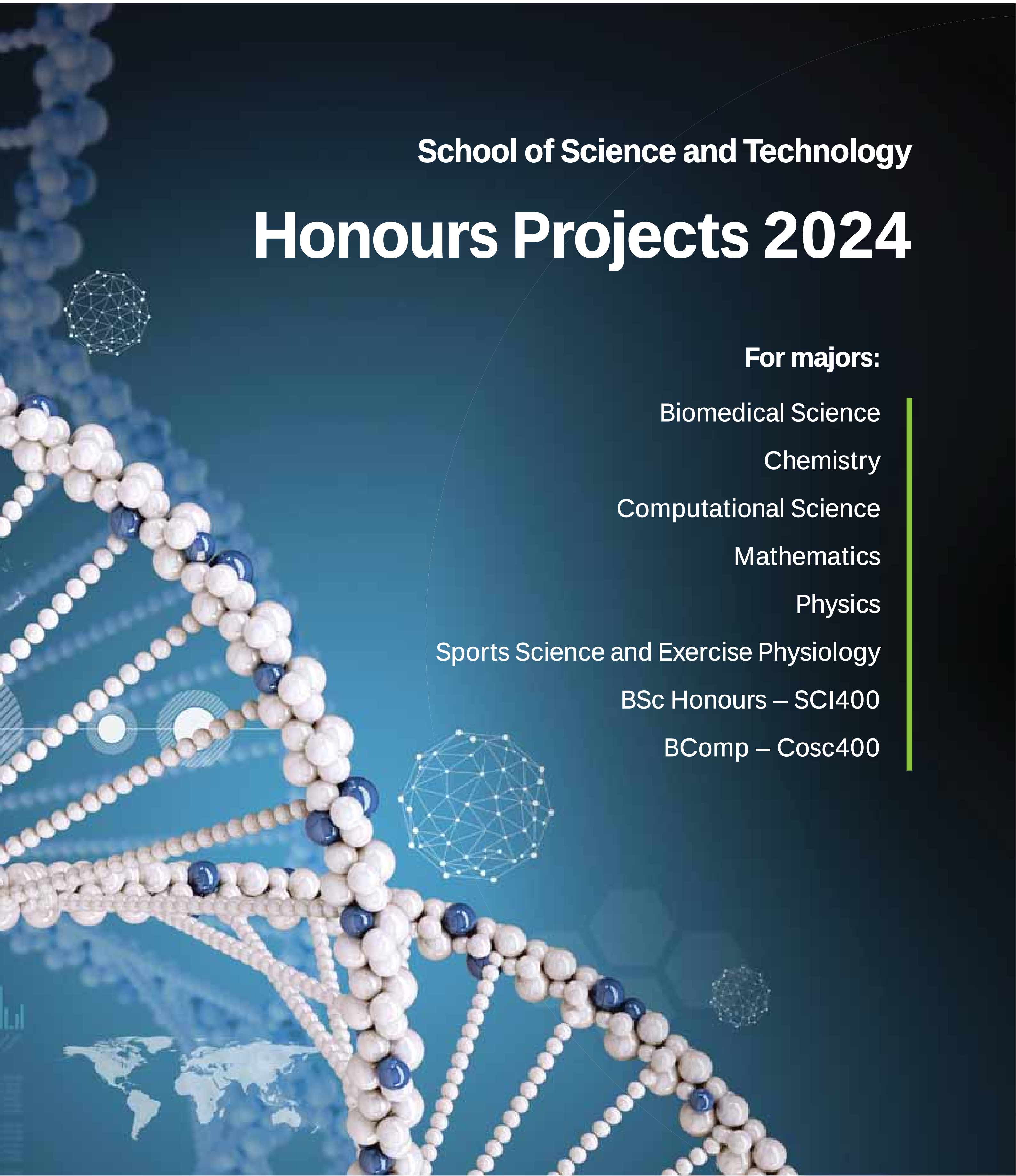
une University of New England

Science and Technology



School of Science and Technology

Honours Projects 2024

For majors:

Biomedical Science

Chemistry

Computational Science

Mathematics

Physics

Sports Science and Exercise Physiology

BSc Honours – SCI400

BComp – Cosc400




une University of New England

Science and Technology

Projects 2024

Contact: BSc Honours SCI400
Course Co-ordinator: Dr Adam Harris
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Contact: BCompSci Honours COSC400
Course Co-ordinator: Dr Peter Loxley
ploxley@une.edu.au

Contents

Projects are grouped broadly according to discipline. Many are collaborative across different research areas and there is flexibility in the Honours major used for enrolment. We encourage discussion of research ideas and student preferences across the disciplines.

ERS acknowledges that all our domestic projects are conducted on the traditional lands of the Aboriginal and Torres Strait Islander Peoples.

Knowing how the human body works and understanding methods and techniques to diagnose, analyse and treat disease.

Biomedical Science

Discipline contact Gal Winter: gwinterz@une.edu.au

Vaccine Engineering Biochemistry

Supervisor: Associate Prof. Nick Andronicos

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Background: Barbervax is a protein antigen vaccine that is used to vaccinate sheep against barber's pole worm (*Haemonchus contortus*). Sheep infected with Barber's pole worms die from haemonchosis. A major symptom of this disease is anaemia caused by sheep infected with the blood feeding barber's pole worm. The barbervax vaccine protein antigen is the H-gal-GP protease enzyme complex, which is located in the intestinal wall of this parasite. This enzyme complex enables the barber's pole worm to digest host haemoglobin thereby causing anaemia in sheep with a high barber's pole worm infection burden. Vaccination with Barbervax vaccine produces an antibody response in the sheep that inhibits H-gal-GP enzyme activity thereby protecting sheep from anaemia and starving the parasite which kills the worm.

Gap-in-knowledge: The catalytic sites of H-gal-GP have not been mapped.

Aim: Therefore, the aim of this project is to:

1. Define the in vitro catalytic activity of H-gal-GP for different protein substrates.
2. Use XL-LC-MS/MS to define the structure of H-gal-GP complexed with bovine haemoglobin.

This project is part of an international collaboration with Scottish researchers at the Moredun Research Institute.

Methods:

- Protein purification
- Native and SDS-PAGE
- Protease inhibitor assays
- LC-MS/MS epitope mapping
- Proteomics and 3D protein modelling

This project is ideally suited for students wanting a career in the biomedical or veterinary research sectors. You will learn essential lab techniques used in a biochemistry research lab, including LC-MS/MS proteomic and bioinformatic techniques.

Development of a Gut Leukocytes Cryopreservation Protocol

Supervisor: Associate Prof. Nick Andronicos

nandroni@une.edu.au | 02 6773 3394

Background: Reverse vaccinology is an effective vaccine design strategy. In a larger project, we will use reverse vaccinology to design prototype vaccines to protect sheep from gut parasites such as scour worms (e.g., *T. colubriformis*). To be effective, a vaccine needs to elicit both cellular and humoral immune responses, very similar to the immune response the scour worm pathogens elicit. Worms activate gut leukocytes, and therefore the parasite induced activation state of gut leukocytes must be determined. However, before their activation states can be assessed, we need to define a protocol to rapidly preserve gut tissues, extracted from parasitised sheep, such that the viability of mucosal leukocyte immune cells is maintained when these cells are extracted from cryopreserved gut tissues. These mucosal leukocytes include lymphocytes, macrophages/dendritic cells and granulocyte cell types. However, the granulocyte populations (tissue neutrophils, eosinophils and mast cells) usually die during the isolation process..

Aim: To define a protocol that optimises the viability of mucosal leukocyte populations isolated from the gut of sheep.

This project is part of an international collaboration with Scottish researchers at the Moredun Research Institute.

Methods:

- Live sheep experimentation/post-mortem sampling.
- Hybridoma cell culture to produce leukocyte ID monoclonal antibodies.
- Fluorescent Immunohistochemistry.
- Flow cytometric CD marker and apoptosis assays.

This project is ideally suited for students wanting a career in the biomedical or veterinary research sectors. You will learn high-end lab techniques used in an immunology research lab, including flow cytometric assays.

Development of a parasite epithelial cell co-culture model for parasite development

Supervisor: Associate Prof. Nick Andronicos

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Background: Reverse vaccinology combines bioinformatics and in vitro models to design effective vaccines. In a larger project, we will use reverse vaccinology to design prototype vaccines to protect sheep and eventually humans from gut parasites such as scour worms (e.g., *T. colubriformis*) which will require the development of biologically relevant in vitro models. To be effective, a vaccine needs to elicit both cellular and humoral immune responses, very similar to the immune response that a natural infection of scour worms will elicit. The various developmental stages of the parasite worms will activate gut leukocytes differently with stage-specific antigens thereby enabling the worms to "effectively hide" from the host immune system as they develop. However, to determine the mechanism of host leukocyte activation by the different parasitic worm developmental stages, an in vitro culture needs to be established that effectively mimics the in vivo environment of the host gut for worms to promote natural worm development. We have previously established such a system for the 3rd larval stage of the gut parasite *T. colubriformis* (Andronicos et. al., 2012).

Gap-in-knowledge: We want to use this parasite-epithelial cell co-culture model technology to induce the development of the gut parasite *T. colubriformis* to the next larval stage (L4) which is hypothesised to be more immunogenic in the host than the L3 larval stage.

Aim: To define a protocol that optimises the in vitro development of *T. colubriformis* parasites from larval stage 3 to larval stage 4 using a parasite-epithelial coculture system that was previously developed.

This project is part of an international collaboration with Scottish researchers at the Moredun Research Institute.

Methods:

- Live sheep experimentation/post-mortem sampling
- Primary cell culture development
- Quantitative reverse transcriptase PCR (qRT-PCR)
- Fluorescence microscopy
- Flow cytometric apoptosis assays

This project is ideally suited for students wanting a career in the biomedical or veterinary research sectors. You will learn high-end lab techniques used in an immunology research lab, including in vitro mammalian cell culture, qRT-PCR and flow cytometry.

Infection, Inflammation & Immunity Group

Supervisor: Prof. Natkunam Ketheesan

nkethees@une.edu.au

Ketheesan's research group focuses on investigating the interactions between selected bacterial pathogens and the human host, to enable the development of strategies to better identify and treat these infections and their complications including the development of vaccines against some of these infections. Their work on pre-clinical laboratory models to understand the complex mechanisms that enable the pathogen to survive within the human host has been internationally recognised.

Professor Ketheesan is currently accepting expressions of interest from suitably qualified undergraduate students who are interested in conducting their Honours and students from within Australia and overseas who are keen to undertake Higher Degrees by Research (MSc or PhD).

He has an extensive network of collaborations and has ongoing projects on streptococcal infections and their neurological, cardiac and renal complications, infections complicated by metabolic syndrome and Q fever. During their project students will learn a variety of techniques including but not limited to cell culture, antibody assessment by ELISA, determination of cell medicate immune activation by FACS, gene cloning and protein expression and purification, bioinformatics and scientific presentation skills. Since most of the projects are conducted in collaboration with other research institutions and universities both national and international, UNE students also get the opportunity to work within a larger research team.

The Microbiome

Supervisor: Dr Gal Winter

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The term microbiome is a collective name for the entire microbial population within a specific environment. My group studies the influence of the microbiome on the host and their dynamic interaction in both human and plants environments. Special are-microbiome axis, and the plants roots microbiome, the rhysobiome. An additional area of focus is antibiotic resistance and its effects on the microbiome.

The methodologies used include classic and molecular microbiology as well as bioinformatics and next gen sequencing.

Interested students are invited to contact me for more details on the different projects available.

Interested students are invited to contact me for more **details on the different projects available.**

Visual Neuroscience: Identify the mechanisms driving neuronal death in inherited retinal degeneration

Supervisor: Dr Kirstan Vessey

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Background: Inherited retinal degenerations are a caused by a single gene mutation and result in the gradual loss of the light sensitive neurons in the retina, photoreceptors. This leads to vision loss and eventual blindness. These diseases occur in around 1:5500 people, but 1:50 are carriers. We are examining the mechanisms of photoreceptor death and whether specific treatments ameliorate or slow the loss of photoreceptors. Understanding how photoreceptors die is of relevance to diseases such as Age-Related Macular Degeneration (AMD), which is one of the leading causes of blindness especially in older people. Our ultimate goal is to develop ways of slowing photoreceptor death and also to investigate ways of replacing lost photoreceptors.

Aims:

- To determine why photoreceptors die during retinal degeneration, including inherited disorders like retinitis pigmentosa (RP) and complex diseases like Age-Related Macular Degeneration (AMD).
- Find therapies to slow photoreceptor death in retinal degenerations.

The project: Help us understand the mechanisms leading to photoreceptor death in inherited retinal degeneration. In this project you will have the opportunity to develop valuable bioinformatics skills in analysing transcriptome data (RNAseq) from the retina of retinal degeneration and control samples from a pre-clinical model at critical stages of the degeneration process. You will uncover the molecular pathways that drive photoreceptor death and confirm your findings by assaying protein changes using western blot and immunohistological techniques. These results will be invaluable in identifying molecular targets for treatments to slow photoreceptor loss in not only inherited retinal degeneration but also age-related macular degeneration.

Techniques:

- Bioinformatic analysis of RNAseq data
- Quantitative PCR
- Western blot
- Immunohistochemistry

This project would be of interest to students who would like to pursue their passion for a role in biomedical research, biomedical industry, health and/or medical science.

Traditional plants as Medicines

Supervisor: Dr Vanu Gulati

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Plants have always been a vital source of nutrients and medicines since time immemorial. Plants play a significant role in the discovery of chemicals in the development of novel therapeutics. Nearly 80% of the population in developing nations still rely on medicinal plants for their primary healthcare needs as estimated by the World Health Organization (WHO). This project will explore the therapeutic properties of native plants of Australia to find out the mechanism of action such as anti-microbial, anti-inflammatory, antioxidant, anti-diabetic using simple biochemical analysis.

Fermented foods as Nutritional Medicine

Supervisor: Dr Vanu Gulati

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Traditional foods have always been a vital source of nutrients and medicines since time immemorial. Foods are the major source of macronutrients as well as micronutrients such as vitamins and minerals and play a significant role in the maintenance of health. Foods can directly modulate gut microbiota and its metabolites and can alter the metabolism of nutrients and thus can initiate the disease process. This project will explore the prebiotic and probiotic effect of traditional fermented foods and can draw the comparative analysis of traditional home fermented foods versus commercial fermented foods using simple chemical, nutritional and microbiological analysis.

Role of simple lifestyle strategies in managing stress levels

Supervisor: Dr Vanu Gulati

vgulati@une.edu.au | 02 6773 5246

Effect of psychological stress and physiological changes in the human body became extremely important since COVID19. Stressful situations activate HPA (hypothalamic-pituitary-adrenocortical) axis that can further alter cortisol secretion. This project will explore the use of simple lifestyle strategies that can manage stress hormones in an effective way. Salivary cortisol analysis will be done to assess the stress levels.

Due to multi-disciplinary qualification and experience, various projects can be developed around nutrition, biochemistry, microbiology and physiology. Please don't hesitate to contact Dr. Vanu Gulati and further discuss your interest.

Eating disorders and nutritive imbalance among young Australians

Supervisor: Dr Mansi Dass Singh

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Background: Approximately 4% of the population in Australia is living with a type of eating disorder. According to the American Psychiatric Association people with the eating disorders (EDs) have food, weight and body shape concerns. EDs are categorised as severe psychiatric disorders. Bulimia nervosa (BN), Anorexia nervosa (AN) and binge eating disorder (BED) are the most prevalent diagnoses among the main ED categories.

Recent advancement in human neurobiology indicates that ED is characterised with inappropriate compensatory weight control mechanisms and dietary restriction that leads to impaired physical and mental health-related quality of life, and poor psychosocial functioning. The alterations in the secretion of neuroendocrine and -peptides for example., leptin or ghrelin produced by our gut mucosal cells, can stimulate or dampen brain dopamine response and subsequently affect food approach of people reported to have AN and BN.

While EDs can affect people of all ages, body weights, and genders, they often appear during the teen years or young adulthood. This period during a lifespan requires optimal nutrition for a healthy adulthood. Hence, it is important to understand nutritional imbalances among young adults who are suffering from these conditions.

Aim: The aim of this observational study is to study the nutritional imbalance among young Australians with eating disorders.

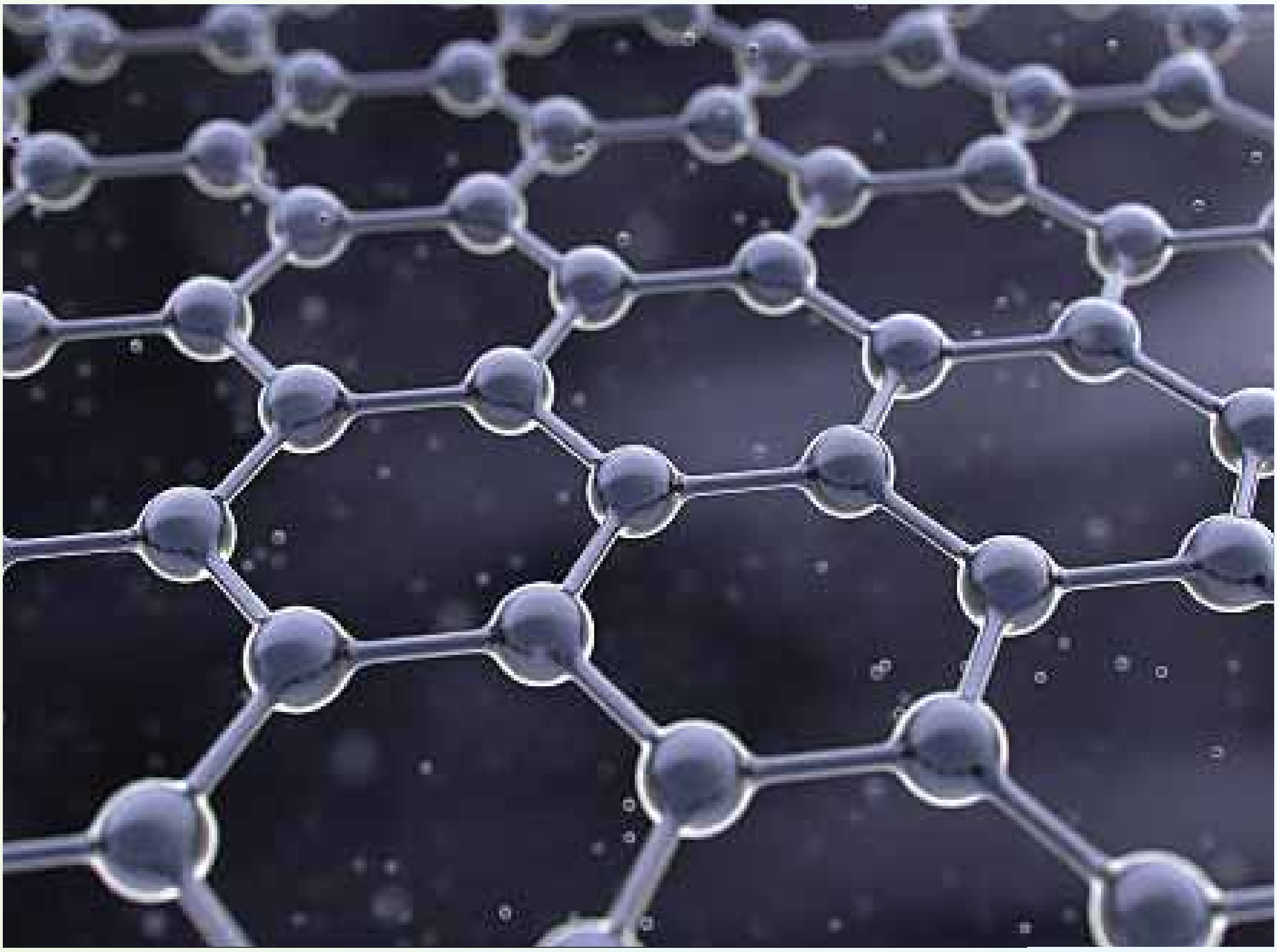
Method: The study will use a dietary assessment tool to analyse dietary pattern, and types of foods consumed by young Australians living in regional areas. The data will analyse quality and quantity of macronutrient content and micronutrient content. The data on participant's signs, symptoms, general health, herb, nutrient, and medicinal use will also be collected and analysed for correlation with the diet quality.

Interested learners are encouraged to contact me for this and related projects.

The science of elements and compounds: their properties, composition, structure, transformations and the energy used in these processes.

Chemistry

Discipline contact Brendan Wilkinson: Brendan.Wilkinson@une.edu.au



3D Printing and its Biomedical Applications

Supervisor: Dr Ali Bagheri

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My main interests are in the 3D printing of drug delivery systems (DDSs) for personalized medicine, a field that has revolutionised the modern world. This field continues to be an inexhaustible source of new applications and exciting chemical problems.

3D printing technology intersects with personalised medicine as it can create bespoke DDSs that take each patient's individual variabilities into account.

The U.S. Food and Drug Administration approval of the first 3D printed drug SPRITAM for the cure of epilepsy (marketed by Aprecia Pharmaceuticals in 2015), has prompted increasing interest in using 3D printing in personalized medicine. Thus far, 3D printing technology has showed great promise in pharmaceutical manufacturing processes, especially for oral solid dosage, transdermal delivery and drug eluting implants. Nevertheless, the use of 3D printing in personalized medicine is still in its early stage of development and there are several challenges on its path to mainstream adoption. One of the foremost challenges (prior to regularity clearance and clinical trials) is the *selection of appropriate 3D technologies and formulations* suitable for the pharmaceutical product.

Therefore, the objective of this project is to develop biocompatible and 3D printable formulations that can undergo radical polymerization in a layer-by-layer 3D printing process. Subsequent to the development of suitable formulations, on-demand DDSs (e.g., drug eluting implants or scaffold) with precise geometry, size, drug dosage and customizable release profiles will be printed based on a range of 3D models.

This project will help the students to develop practical laboratory skills in the synthesis and handling of materials that is useful in both academia and industry. Moreover, students will gain skill sets associated with use and application of common equipment and instrumentation in chemical science and engineering.

The project will involve collaboration with Dr Brendan Wilkinson at UNE and A/Prof Chris Fellows from the Desalination Technologies Research Institute in Saudi Arabia.

Computational Chemistry and Chemical Education

Supervisor: Associate Prof. Erica Smith

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Computational Chemistry:

Research in this area involves use of molecular dynamics simulations, scientific programming, data analysis, high-performance parallel computing, and applied statistical mechanics. Computer simulation provides a direct route from microscopic details of a system to macroscopic properties and with the advent of more powerful and cheaper computing, the use of molecular simulation to gain atomic level understanding of important chemical and biological systems is rapidly increasing. Dr Smith is currently working on a range of questions, such as: behaviour of industrial polymers in solution; stabilization and disruption of phospholipid membranes by antifreeze and antimicrobial peptides; design of antifreeze peptides and antifreeze glycoproteins for ice growth inhibition.

Expertise in programming, modelling and big data analysis can lead to careers as diverse as international finance and the stock market, theoretical physics, novel material design, sport science, genetic modelling, and management consulting. The opportunities are literally endless!

Chemical Education:

The scholarship of teaching and learning of teaching can include research on teaching practice or understanding how students learn. I am particularly interested in self-efficacy in first year students, transition to university study, equity in education, online teaching and learning, and using computational chemistry in chemical education. Research in this area will be of interest to educators who want to improve educational outcomes for students of chemistry.

Novel Carbohydrate materials as vaccine adjuvants and cryoprotectants

Supervisor: Dr Brendan Wilkinson

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Background: D-Trehalose is an abundant non-reducing disaccharide that is expressed many cold- and drought-tolerant organisms as an adaptation to anhydrobiotic and cryobiotic stress, including plants, microorganisms, yeast, and fungi. Owing to its potent osmoprotectant and bio-stabilisation properties, it is widely used in research and industry as a stabiliser for biomacromolecules, a potential therapy for the treatment of Alzheimer's disease, drug delivery, as well as extracellular cryopreservation. The development of novel trehalose materials is an active and fruitful area of research, which has revealed dramatic enhancement in the bio-protection/stabilisation, and therapeutic efficacy towards inhibition of fibril formation – a key step in the onset of Alzheimer's disease. Furthermore, lipophilic derivatives of trehalose have been shown to be potent stimulators of the innate immune system through activation of the pattern-recognition receptor, Mincle. As such, they show tremendous promise as Th1 promoting immunoadjuvants for vaccines targeting viral infections, TB, and certain cancers. Finally, trehalose-based compounds have been shown by our group to display dramatically enhanced cell penetrating properties and thus hold significant promise as non-toxic replacements for conventional (and toxic) cryoprotectants like DMSO. Our group has numerous exciting honours projects available in the following areas:

- Trehalolipid vaccine adjuvants: We will design, synthesise, and characterise novel trehalolipids as novel immunoadjuvants and inhibitors of cancer metastasis (with A/Prof Bridget Stocker, Victoria University, Wellington, NZ).
- Novel trehalose-based cryoprotectants (CPAs): In collaboration with Professor Gary Bryant, RMIT (Melbourne), a leading expert in cryopreservation, we will synthesise new trehalose analogues, including fluorinated derivatives, glycopeptides, and cell-penetrating peptide conjugates as potential cryoprotectants.
- New trehalose nanomaterials as novel bioprotectants, delivery agents, and therapeutics. We will design, synthesise and characterise new nano-scale materials including supramolecular 1D nanofibres, PAMAM and HPG trehalose dendrimers. We will also investigate the synthesis of amphiphilic trehalose denrdons for the self-assembly of complex liposomes for RNA/gene delivery applications.
- Synthesis and physical characterisation of light-responsive surfactants. In addition to our research program in trehalose materials, we are also active in the area of colloid science and surfactant chemistry. In particular, we are exploring the self-assembly and phase behaviour of visible and NIR light-switchable surfactants, particularly their physical properties in ionic liquids and deep eutectic solvents (DES). This is part of an ongoing and exciting collaboration between our research group and Prof Michael Gradzielski (TU Berlin).

Methods:

- Organic synthesis (handling of air and moisture-sensitive chemicals, Schlenk skills, purification skills including recrystallisation, liquid-liquid and dry extraction techniques).
- Chromatography, including silica gel (flash), HPLC (analytical and preparative, LC-MS, ion-xchange).
- Advanced spectroscopic techniques for compound characterisation, including NMR, IR, CD, etc.
- UV-vis spectrophotometry and fluorescence spectroscopy.
- Advanced scattering techniques (e.g. SANS, SAXS – both at the ANSTO/Synchrotron).

These projects are ideally suited to students with a strong interest in applied organic synthesis, particularly materials and medicinal chemistry. Graduates can expect to acquire a broad set of skills and attributes including (but not limited to) those listed above, with career prospects in the pharmaceutical industry, academia and soft materials engineering.

Synthesis, Structure and Reactivity of Anomeric Amides

Supervisor: Dr Adam Rosser

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Background: Anomeric amides are a novel class of amides, featuring a pyramidalised amide nitrogen. This structural change reduces their 'amide character', allowing them to react in unusual ways, including the HERON reaction, discovered and named right here at UNE.

Projects in this area will allow students to develop a well-rounded chemistry skillset as we synthesise novel anomeric amides and explore their structure and reactivity in the laboratory and computationally. If you're looking to build upon your undergraduate chemistry skills in a challenging and rewarding area of chemistry, please get in touch.

The convergence of mathematical modelling, advanced computing and data analysis for understanding and solving of complex real-world problems.

Computational Science

Discipline contact Dr Peter Loxley: ploxley@une.edu.au

Explainable AI for education

Supervisor: Associate Prof. William Billingsley

wbilling@une.edu.au

As AI and machine learning become more central to computer science, they begin to pose an issue for the computational thinking. Though we now regularly teach schoolchildren to code, more and more of the digital infrastructure in the world is trained rather than directly programmed. “Explainable AI” is the part of the field that looks at how humans can understand what the AI is doing (what caused it to misclassify a cat as a dog).

Can we take this further and build machine learning models and visualisations that are explainable to beginners?

Classifying behaviour in groupwork

Supervisor: Associate Prof. William Billingsley

wbilling@une.edu.au

There now thousands of open source software projects across GitHub and Gitter, producing public data on how different kinds of projects operate. Across both the commit behaviour (git), issue activity, and conversation streams (e.g. gitter) how can we (automatically) classify the different roles that people take within projects based on their behaviour, and how they move between those roles.

Developing an architecture to translate Industry 4.0 to 5.0 standard and beyond

Supervisor: Dr Fareed Ud Din

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Fareed is a computer scientist with research interests including Artificial Intelligence, Distributed Computing, Multi-Agent Systems, Information Systems Industry 4.0, and Project Management. He received his PhD Degree from the University of Newcastle (UoN), NSW on a Non-Commonwealth Government of Australia fully-funded scholarship and completed the tenure in an exceptional timeframe. During his research at UoN in distributed computing, he received several academic performance awards, including the Best Research Paper Award, Best Technical Poster Award, Best Conference Presentation and Best Academic of the Year Award. Currently, Fareed is a Snr Lecturer in Computational Science in the School of Science & Technology, Faculty of SABL, The University of New England, NSW, Australia.

Background: Industry 4.0 or the 4th Industrial Revolution is an integration of intelligent digital technologies into manufacturing and industrial processes. It encompasses a set of technologies that include industrial IoT networks, AI, Big Data, robotics, and automation. However, Industry 5.0 refers to people working alongside robots and smart machines. It’s about robots helping humans work better and faster by leveraging advanced IoT and Big Data technologies. It adds a personal human element to the Industry 4.0 pillars of automation and efficiency.

Aim: To develop an architecture or a protocol that transforms Industry 4.0 architecture e.g., xAOSF framework into Industry 5.0 standards and beyond.

This project is ideally suited for students wanting a career in the enterprise network management or distributed computing research sectors.

Note: More details are available on request, please feel free to reach (fuddin@une.edu.au) for further discussion.

Applying Multi-Agent Systems (MAS) for real-world scenarios (open selection)

Supervisor: Dr Fareed Ud Din

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Background: In systems modelling, the multi-agent approach is used to simulate the behaviour of a complex model incorporating multiple software agents. Multi-Agent Systems (MAS) approach has been used for multiple real-world applications, for example, to predict the spread of COVID-19 worldwide. A similar approach can be used to model traffic in a city and see how it reacts to changes in traffic rules. Other areas where multi-agent systems research may deliver an appropriate approach include online trading, disaster response, target surveillance and smart factory environment etc.

Aim: To develop a simulation to experiment the agent coordination and negotiation to increase the overall utility of the system.

This project is ideally suited for students wanting a career in the AI industry, software development or MAS research sectors.

Note: More details are available on request, please feel free to reach (fuddin@une.edu.au) for further discussion.

Information theory, dynamic programming, and sparse codes

Supervisor: Dr Peter Loxley

ploxley@une.edu.au

The concept of entropy was first introduced in physics to describe the macroscopic properties of thermodynamic systems such as steam engines, chemical reactions, and black holes. When the atomic structure of matter was proposed by Boltzmann, he gave entropy a statistical meaning in terms of the microscopic states of matter. Shannon later formulated entropy in terms of information content when he considered reliable communication over a noisy channel and optimal data compression. Around the same time, Lindley used Shannon's ideas to propose the amount of information given by an experiment. These ideas of entropy and information are still relevant today, and have been extended into the quantum realm to describe entanglement and quantum computing.

Project 1: Following on from Lindley, we have recently proposed a dynamic programming algorithm to determine an informative sequence of measurements. This approach extends existing greedy methods by using the method of sequential optimization (Bellman's dynamic programming) over a sequence of measurements, and has applications to path planning and active sensing in robotics. This project would involve the detailed analysis of a particular measurement problem.

Project 2: Sparse codes are important in neuroscience for efficiently encoding sensory information. I have recently shown that sparse codes can also help to solve optimal control problems when sensory inputs are correlated. This project would involve finding a sparse code and investigating its optimal control properties.

Both of these projects require strong mathematical skills and good programming skills.

Quick solutions for the Boolean satisfiability problem (SAT)

Supervisor: Associate Prof. David Paul

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I am interested in a wide variety of areas in computational science, including algorithm design, complexity analysis and network science. An example project is mentioned below, but please get in touch if you're interested in any of these areas.

Background: The Boolean satisfiability problem (SAT) asks whether the variables of a given Boolean formula can be assigned values that cause the formula to evaluate to true. SAT was the first problem proven to be NP-complete, and thus there are no known solutions that perform well in all circumstances. However, as the power of computers has increased, more sophisticated algorithms have been created that allow certain important classes of SAT instances to be solved in a reasonable period of time. This project will cover the state-of-the-art algorithms and data structures used to solve SAT problems and attempt to improve on existing algorithms for certain classes of inputs..

Statistical and machine learning techniques to predict mango yield

Supervisor: Dr Brenda Vo

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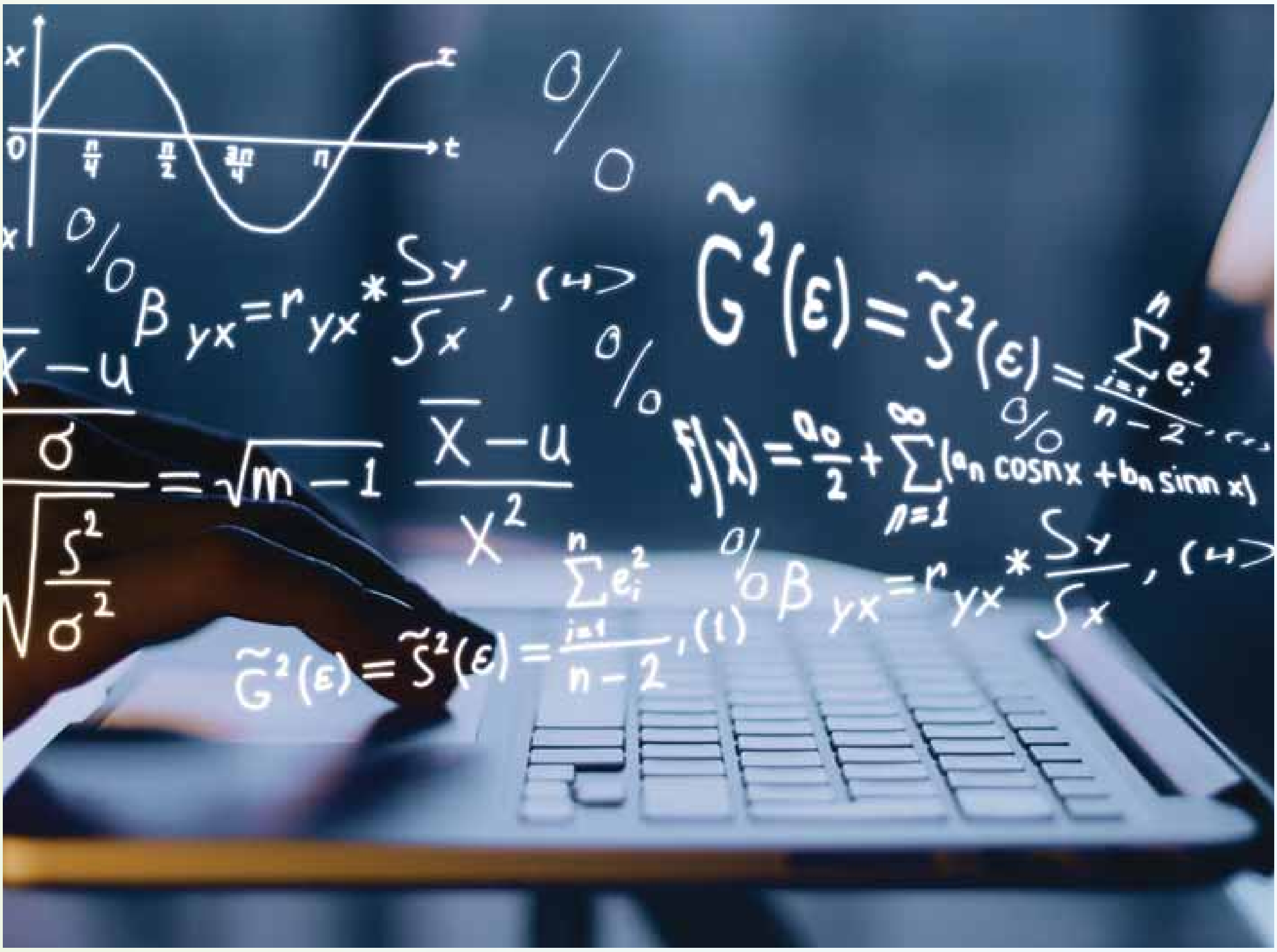
Background: Obtaining accurate pre-harvest estimations of fruit load is critical for mango farmers. However, pre-harvest yield estimation is often based on historic data and manual count of fruits from a sample of trees within the block. This project will make use of statistical and machine learning techniques to develop prediction models of mango yield using satellite remote sensing data.

The science of structure, order, and relations evolved from elemental practices of counting, **measuring, and describing the shapes of objects.**

Mathematics

Discipline contact Adam Harris: aharris5@une.edu.au



Algebraic Topology

Supervisor: Dr Bea Bleile

bbleile@une.edu.au

www.une.edu.au/staff-profiles/science-and-technology/bbleile

Background: Algebraic topology uses algebraic objects to study topological spaces up to continuous deformation or homotopy equivalence. For example, manifolds play an important role in many branches of mathematics and theoretical physics and many of their properties depend only on the homotopy type, that is, they do not change under homotopy equivalences. Poincaré duality (PD) complexes are homotopy theoretic generalisations of manifolds and Dr Bleile is using algebraic models to study PD complexes in dimension 4. There are several questions to be explored in this area and the choice of project will depend on students' background and preferences.

Applied Probability, Data Science, Mathematical Modelling

Supervisor: Dr Robert Cope

rcope4@une.edu.au

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Nonlinear partial differential equations and applications. Current research topics include theoretical as well as numerical investigations of nonlinear partial differential.

Applied Probability & Mathematical Modelling (suitable for BSc Mathematics majors): Stochastic process allow us to model phenomena that evolve randomly, including processes driven by human interactions or decision making (like in telecommunications, finance, or disease spread). To deal with the complexity of these processes, we often need to take approximations (into discrete time, or large population limits), but given appropriate assumptions stochastic models enable us to perform estimation to better understand the world, and can inform decision making under uncertainty. Honours projects in stochastic processes could either be theoretical (e.g., understanding properties of approximations), or applied (developing models for a particular scenario).

Data Science (suitable for BComp Honours): Many modern data sources produce objects that are challenging to work with, like medical scans, networks or structures organised in space, images, or text. To work with these challenging data types we can seek to simplify them / reduce dimensionality, or apply equally complex models like neural networks in the hope of extracting informative patterns from the data. The interface of complex machine learning models with modern statistical ideas presents also presents some challenges. Students interested in applied data science using challenging data, or more theoretical explorations involving simulation studies, are welcome to contact me to discuss projects.

Differential Equations

Supervisor: Prof. Yihong Du

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www.une.edu.au/staff-profiles/science-and-technology/ydu

Background: Nonlinear partial differential equations and applications. Current research topics include theoretical as well as numerical investigations of nonlinear partial differential equations (PDEs) arising from models in invasion ecology and epidemic spreading. We are particularly interested in PDEs with free boundaries, which often represent the propagation fronts in a spreading process and pose significant challenges in both the theoretical and numerical treatment of the equations. The questions we aim to answer include: Are the solutions well-defined for all future time? How do they behave as time goes to infinity? Do they predict successful invasion of the species being modelled? What is the invasion speed?

Complex Analysis and Differential Geometry

Supervisor: Dr Adam Harris

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Project 1 – Algebraic curves and Riemann surfaces

A Riemann surface is one on which complex analysis, geometry and topology all come together. They can be compact or non-compact surfaces, and can be studied via their embeddings in complex Euclidean space, or complex projective space (as algebraic curves), or without reference to any embedding. The focus of such a project can be flexible, but I'm particularly interested in the study of harmonic differential forms with singularities in this context..

Project 2 – Riemannian manifolds and curvature

As an extension to one of our coursework topics for SCI400, on the basic theory of manifolds and differential structures, we would focus on the basic properties of curvature, with particular reference to Riemannian metrics and the Levi-Civita connections associated with them.

Mathematical Physics and Complex Geometry

Supervisor: Dr Jock McOrist

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Background: The Hull--Strominger system is a set of coupled partial differential equations that derive from the study of string theory. Solutions of these PDEs have a geometric interpretation in terms of a complex manifold and a vector bundle. This project will involve studying small deformations of these solutions and understanding how these deformations relate to an auxiliary geometry known as a moduli space. It will have a large component of learning differential geometry and tensor calculus.

Functional Analysis and Mathematical Physics

Supervisor: Dr David Robertson

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Groupoids:

In the classical picture of the atom, the algebra of observable physical quantities can be read directly from a *group* of frequencies. Since the operation in the group is commutative, so too is the algebra. However, early in the 20th century, experiments indicated that in reality, one does not have a group of frequencies, but rather a *groupoid* - the subtle difference being that the sum of two frequencies may not always result in another allowable frequency. It was this realisation that led Heisenberg to replace the commutative algebra of the group with the noncommutative algebra of the *groupoid*, thus replacing classical mechanics in which observable quantities commute with his now-famous noncommutative matrix mechanics.

In general, a groupoid is a set G with a partially defined multiplication and an inverse operation. We call the set G0 = {gg^-1} the *units* of G. Groups correspond precisely to those groupoids with exactly one unit - the identity of the group. Other examples of groupoids include topological spaces and equivalence relations. The purpose of this project is to understand the definition of an abstract topological groupoids and study several interesting examples. Time permitting, we may also look at the convolution algebras of functions associated to topological groupoids.

Higher-rank graph C*-algebras:

A C*-algebra is an algebra of operators acting on a Hilbert space – think infinite dimensional matrices. The study of C*-algebras has its roots in quantum physics, where particles are represented by vectors in a Hilbert space and observables are represented by self-adjoint operators acting on the Hilbert space.

An approach to studying C*-algebras that has found success in recent years is to model the relations defining the algebra using some combinatorial data. For example, given a *directed graph* consisting of vertices and oriented edges, one may consider the C*-algebra where each edge of the graph corresponds to an isometry between subspaces of the Hilbert space. The benefit of an approach like this is that algebraic properties can be read from combinatorial properties of the graph, for example the ideal structure of such an algebra can be completely determined by looking at the set of infinite paths through the graph. The idea behind *higher-rank graphs* is to replace one-dimensional edges in the graph, with a higher-dimensional shape. This increase in complexity allows us to model many more algebras in this way

Applied Mathematics

Supervisor: Associate Prof. Timothy Schaerf

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Modelling and analysis of collective motion

Background: Grouping animals are capable of remarkable displays of coordinated collective motion, with examples ranging from starling murmurations, the toroidal milling of fish and the movements of herding animals. It is thought that the group-level patterns of movement emerge without centralised control, but rather due to repeated interactions between individuals over a scale smaller than that of the group. These interactions are sometimes referred to as "rules of interaction", and control how individuals adjust their velocity as a function of the relative positions and behaviours of neighbouring group members. Research topics in this area may be focussed on individual-based models for collective motion, methods for inferring rules of interaction and analysing group patterns of movement from experimental data, or both. The individual-based models may be formulated as systems of ordinary differential equations, or via a set of algorithmic rules. Current methods for inferring rules of interaction include force-matching, force-mapping, and equation-based methods targeted at developing data-driven models.

CR Geometry and Complex Analysis

Supervisor: Prof Gerd Schmalz

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Background: CR geometry. You may be familiar with the Cauchy Riemann equations in Complex Analysis. CR structures (where CR stands for Cauchy Riemann) are geometric objects with complex and real features for which Cauchy Riemann equations can be defined. The study of CR structures requires methods from several complex variables, differential geometry, Lie groups and algebras, differential equations and other fields of modern mathematics. My research focuses on the properties of mappings and symmetries of such CR structures. Surprisingly, some of these problems can be interpreted in terms of theoretical physics.

Physics

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Projects available in the following areas:

- Medical physics, image processing
- Solar & sustainable technology
- Computer simulation of molecules in a microwave field
- Astronomy
- High-speed digital signal processing for a group-mapping alkali metal vapour magnetometer
- Interactive visualisation of electromagnetic fields for teaching

Exploring human movement and how it applies to physical activity to optimise human performance, **fitness and health.**

Sports Science and Exercise Physiology

Discipline contact Prof. Neil Smart: nsmart2@une.edu.au

Contagiousness of stress in teams

Supervisor: Dr Ben Serpell

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Background: The aim of the proposed project is to loosely replicate the research of Dimitroff et al (2017) and explore the contagiousness of stress in teams. However, rather than measuring autonomic response of participants watching videos of people presenting with varying levels of stress, we wish to measure stress hormones of coaches prior to team meetings and stress hormone response of their athletes following meetings. We will collect saliva samples from the coach prior to team meetings to analyse testosterone and cortisol concentrations, and also collect saliva samples from players before and after the team meetings. We will measure coach stress and athlete stress response from 2-4 meetings across the season with a super rugby team.

Psycho-behavioural approaches to quantifying mental fatigue in sports and exercise

Supervisor: Dr Stephen Goodman

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Background: Mental fatigue is a suboptimal psycho-physiological state characterised by elevated perceptions of lethargy and an aversion to continued cognitive work. This phenomenon is often quantified in one of three ways during mental exhaustion; 1) Subjectively (i.e. through visual analogue scales); 2) (neuro)Physiologically (i.e. using EEG or heart rate variability); and 3) Behaviourally (i.e. declined cognitive task performance or compromised movement function).

This project will be a review paper focused on identifying the different methods used to quantify the behavioural indices of mental fatigue within the sports and exercise discipline. This project will inform researchers about the breadth of tasks available to elicit mental fatigue and determine the most effective means of implementation (both in terms of magnitude and time efficiency).

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