une University of New England

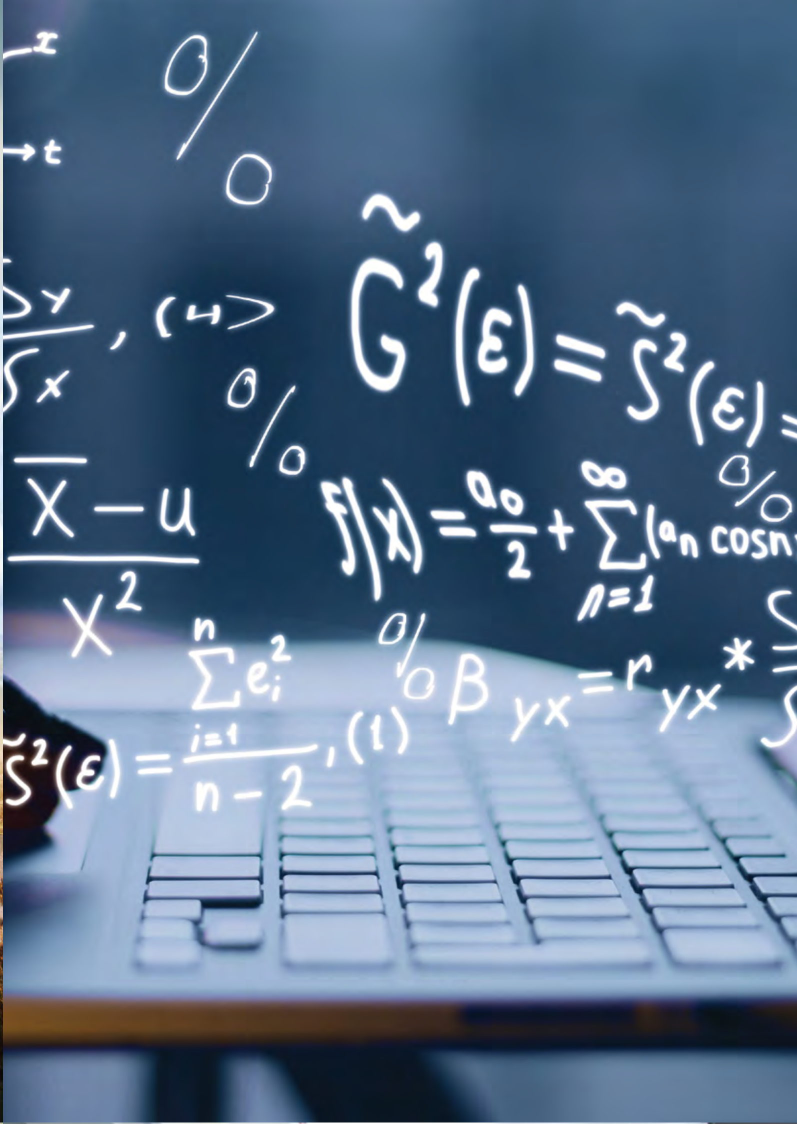
Science and Technology

School of Science and Technology

Honours Projects 2026

For majors:

- Biomedical Science
- Neuroscience
- Chemistry
- Applied Physics and Electronics
- Computational Science
- Mathematics
- Sports Science and Excercise Physiology



University of New England

Science and Technology

Projects 2026

Course Co-ordinator: Dr Nitin Chitranshi
nitin.chitranshi@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**

Project: Vaccine Design and Engineering

Supervisor: Associate Prof. Nick Andronicos

nandroni@une.edu.au | 02 6773 3394

Background: Development of vaccines to protect people against zoonotic gut pathogens is challenging. However, genomics technology has enabled the identification of antigens from gut pathogens such as gastrointestinal worms as well as the protective responses developed by the host to remove the pathogen. My group is part of an $11 million international research project that is using cutting-edge biotechnologies such as transcriptomics, proteomics to define the host responses associated with protective immunity that expels the parasite.

For these projects students will have access to transcriptomics and/or proteomics datasets to analyse using state-of-the-art bioinformatics software. Students will also perform wet lab experiments to validate conclusions from these omics' datasets.

Note: *The bioinformatic analysis components of these Honours projects may be performed off campus. However, students will have to perform the validation PCR and Western blot laboratory experiments on the UNE Armidale campus.*

UNE Staff Project:

Dr Sinead Henderson Sinead.Henderson@une.edu.au

Dr Amy Burns Amy.Burns@une.edu.au

Pre-requisite Knowledge: Students need to be able to work in a biomedical sciences laboratory and a sound knowledge in subjects related to biomedical sciences. Subject areas could include a combination of basic biochemistry, cell biology, physiology, microbiology and immunology. Experience working in a laboratory and or students completing SCI 395 will be considered favourably.

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, as well as bioinformatic analysis techniques.

Research Partners:

Moredun

University of Glasgow

Biotechnology Project: Development of a nematode cell expression system

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

nandroni@une.edu.au | 02 6773 3394

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.

Immunological Complications Associated with Post Streptococcal Infectionsp

FOR code(s) – 320211; 320499; 320203
Applicable research flagship(s) – OneHealth

Project Description: The University of New England Programme on Post-streptococcal Immune Complications (UNEpic) brings together academics, researchers, clinicians, and students within the School of Science & Technology at UNE, in collaboration with partner institutions across Australia, the USA, Canada, and New Zealand. Our research focuses on developing models to elucidate the immunopathological mechanisms that cause complications following streptococcal infections. The laboratory models characterised by our team have enabled the determination of early events that lead to Rheumatic Heart Disease (RHD) and Poststreptococcal Glomerulonephritis (PSGN) providing a platform for potential development of detection (biomarkers), treatment (immunotherapy and repurposed small molecule therapy) and intervention strategies (vaccine development). The multidisciplinary projects span Infectious Diseases, Microbiology, Immunology, Physiology, Pathology, Medicine and Public Health and can be tailored according to the interest and experience of the candidate.

Staff Members involved:

Dr Rukshan Rafeek rmohame3@une.edu.au

Dr Robert Hart rhart7@une.edu.au

Professor Natkunam Ketheesan nkethees@une.edu.au

Pre-requisite Knowledge: Students need to be able to work in a biomedical sciences laboratory and a sound knowledge in subjects related to biomedical sciences. Subject areas could include a combination of basic biochemistry, cell biology, physiology, microbiology and immunology. Experience working in a laboratory and or students completing SCI 395 will be considered favourably.

Laboratory skills gained during this project:

- Rodent experimentation/sampling
- Cloning, protein purification, cell culture
- Enzyme Immuno assays (ELISA/Western blot)
- Fluorescence microscopy
- Flow cytometric assays

On Campus/Online Commitment: These projects can be completed only as on-campus offerings with the possibility of partly working in laboratories of external collaborators in other universities and collaborating research institutions.

The Microbiome

Supervisor: Dr Gal Winter
gwinterz@une.edu.au | 02 6773 5821

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.

Native Plants of Australia/Bush Medicines

Supervisor: Dr Vanu Gulati
vgulati@une.edu.au | 02 6773 5246

Project 1: Anti-oxidant, anti-inflammatory potential of Australian native plants as Medicines

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.

Project 2: Fermented foods as Nutritional Medicines

Traditional foods have served as essential sources of nutrients and medicines throughout human history. 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.

Project 3: Role of simple lifestyle strategies in managing stress levels

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.

Project 4: Anti-microbial activity of essential oils

With the rising prevalence of Anti-Microbial Resistance (AMR) in foodborne pathogens, it is causing a challenge in food safety context. Many control points in the food supply chain are vulnerable to microbial contamination but do have limitations of conventional antimicrobial strategies. Therefore, there is a greater need for a novel, sustainable antimicrobial approach. Essential oils are natural antimicrobials and have a history of usage and ethnobotanical significance. Examples include clove oil, tea tree oil, honey myrtle, and serve several advantages over synthetic alternatives such as biodegradability, multi-target activity, and consumer acceptance. This project will explore the antimicrobial efficacy of essential oils against a diverse panel of foodborne microorganisms.

Learning Objectives:

- Advanced knowledge of indigenous plants, traditional medicines and their global significance
- *In vitro* assays and cell culture laboratory techniques for screening biological activities
- Critical analysis of pathways
- Experimental design and scientific writing

Due to multi-disciplinary qualifications and experience, various projects can be developed around nutrition, foods, diet, and plants utilizing biochemistry, microbiology, and physiology mechanisms. Please don't hesitate to contact Dr. Vanu Gulati and discuss your interest.

There is also an option to do the chosen projects in collaboration with other colleagues and universities (Swinburne University of Technology and/or Deakin University) Melbourne.

Neuroinflammation and Early Biomarkers of Glaucoma

Supervisor: Dr. Nitin Chitranshi

UNE Staff profile: www.une.edu.au/staff-profiles/science-and-technology/nitin-chitranshi

RUNE Research Profile: rune.une.edu.au/entities/person/8b971ed0-3a49-43da-b4ed-39116898e7ed

Project Summary: Glaucoma is a leading cause of irreversible blindness, yet early diagnosis remains difficult. This project investigates neuroinflammatory changes in the retina and optic nerve to identify early molecular biomarkers. Students will examine cytokines, glial activation markers, and apoptotic pathways using immunohistochemistry, qPCR and protein assays. There is also scope to explore bioinformatics approaches for analysing published glaucoma datasets.

What the student will learn:

- Advanced laboratory techniques used in vision and neuroscience research
- Critical analysis of neurodegeneration pathways
- Experimental design, imaging analysis and scientific writing
- Experience working within an active translational research group

Ideal for students interested in: Neuroscience, neurodegeneration, ophthalmology, molecular biology, and careers in research or clinical science.

Drug Repurposing for Neuroprotection: Evaluating Small Molecules in a Retinal Degeneration Model

Supervisor: Dr. Nitin Chitranshi

Project Summary: This project explores whether existing FDA-approved compounds can be repurposed for neuroprotection in retinal degeneration. Students will test selected small molecules on retinal cell cultures and evaluate outcomes such as cell survival, oxidative stress, mitochondrial function and apoptotic signalling. The project contributes to an emerging research area aimed at accelerating treatment development by leveraging known drug safety profiles.

What the student will learn:

- Cell culture techniques and drug-treatment assays
- Methods for assessing cell viability, ROS production and mitochondrial health
- Data analysis, troubleshooting and experimental optimisation
- How drug-repurposing pipelines work in biomedical research

Ideal for students interested in: Pharmacology, drug development, neuroprotection, translational research and careers in biotech or clinical trials.

How Does Taking Weight-Reducing Drugs Affect Emotions, Feelings, and Eating Behaviour?

Primary Investigator: Mansi Dass Singh (PhD)/ Registered Nutritionist/Clinical nutritionist

mdasssin@une.edu.au | 02 6773 5353
www.linkedin.com/in/mansi-dass-higheracademic

Project Overview: The rapid proliferation of GLP-1 receptor agonists for weight management has revolutionised obesity treatment, yet their psychological and behavioural impacts on relationship with food remain poorly understood. This research investigates the complex interplay between pharmacological weight loss interventions, emotional wellbeing, and eating behaviours.

Research aims: To investigate the psychological and behavioural effects of weight-reducing medications on emotional wellbeing, eating patterns, and food relationships

Methods: Mixed-methods design

What skill you will learn?

- Design and administer longitudinal surveys
- Psychometric assessments
- Record and analyse food and dietary intakes
- Interpret blood/saliva analytic/reports from nutrition perspective
- Design and administer semi-structured interviews exploring lived experiences
- Thematic analysis of qualitative data.

Flexibility in work: Some lab work and travel for allied health collaboration is required. The project can be taken part time on campus and can be completed as an HDR (3-6 months) or Masters project [full time (two years) or part time (4 years)].

Prerequisite knowledge and skills: Perseverance, organisation and people skills.

Expected Outcomes: Findings will inform practicing clinicians through empathetic understanding of clients about their overall wellbeing, social functioning, and life satisfaction. It will contribute to development of nutritional guidelines.

Career prospects: Potential to apply these skills in the pharmaceutical industry, digital health startups, academic positions, further research, public health policy, and private consulting.

If you are interested to research on any other topic relation to food science and clinical nutrition, and supplemental interventions for disease prevention feel free to contact me.

A systematic review on role of dietary intakes and patterns on climacteric symptoms & health status during post menopause life stage

Primary Investigator: Mansi Dass Singh (PhD)/ Registered Nutritionist/Clinical nutritionist

Project Overview: Menopause represents a critical transition in women's health, characterized by decline of ovarian estrogen levels that may alter metabolism, body composition, cardiovascular function, bone density, and mental wellbeing. Climacteric symptoms like vasomotor symptoms palpitations, mood disturbances, depression, and insomnia are experienced by many women with varied severity and frequency. These symptoms create substantial psychological burden, compromising work productivity and quality of life for affected women and their families. Research data indicates that postmenopausal women are at higher risk of developing chronic conditions including type 2 diabetes, coronary heart disease, hypertension, and sleep disorders.

Research aim: To systematically evaluate the associations between dietary patterns, nutrient adequacy, and health outcomes among postmenopausal women.

What skills will you learn?

- Conducting a systematic review following evidence-based guidelines
- Screening and critically appraising research literature
- Data extraction and synthesis (with the option to explore meta-analysis)
- Understanding ethical considerations in research
- Developing research communication skills, including academic writing and dissemination.

Programs of Study for this project: NO lab work or travel is required. The research can be taken part time on or off campus as part of a three to six months HDR project.

Prerequisite knowledge and skills: Patience and attention to detail.

Expected Outcomes: Opportunity to publish and present at conferences. The findings will inform nutrition practicing guidelines.

Career prospects: Potential to apply for opportunities in the digital health, women's health organisation, research assistant or further future research like PhD.

If you are interested to research on any other topic relation to women health and nutrition, feel free to contact me.

International Collaboration Opportunity:

This project also offers the opportunity to collaborate with the University of Aberdeen, supporting cross-institutional skill development and exposure to global perspectives in women's health research.

Nutrient analysis of plant-based foods

Primary Investigator: Mansi Dass Singh (PhD)/ Registered Nutritionist/Clinical nutritionist

If you are considering learning or refining your lab skills – Join a 3-month hands-on research project analysing fatty acids and/or amino acids in plant foods.

Background: Plant-based diets have gained popularity for health and sustainability reasons, hence there is a need to understand their complete nutritional composition for optimising dietary recommendations.

Research Aims: To assess protein quality (essential amino acid profiles), and lipid composition (omega-3/omega-6 ratios, saturated/unsaturated fat content), and compare nutritional value across different plant sources.

What skills will you learn?

- Sample preparation
- Nutrient extraction
- Fatty acid methylation (FAME preparation)
- Gas Chromatography-Mass Spectrometry (GC-MS)
- Quantification against known standards

Programs of Study for this project: Laboratory work on campus-HDR/masters project.

Prerequisite knowledge and skills: Dedication, time management, & willingness to practice.

Expected Outcomes: Report writing, opportunity to publish and present at conferences. The findings will inform nutrition reference values for diverse range of plant foods.

Career prospects: The project will prepare you to work in nutrition or food science lab and for future job opportunities as a research assistant or further future research like PhD.

There is scope for interstate university collaboration for students choosing to work in their state of residence.

Understanding the Role of Cytokine Receptor Signalling in the Tumour Microenvironment

Supervisor: Associate Professor Andrew Brooks

abrook28@une.edu.au

Background: One of the important roles of the immune system is to detect and eliminate cells that are progressing towards, or have become, cancerous. It is now well established that cancer cells develop mechanisms to evade surveillance by the immune system. Several breakthrough treatments now exist that block some of the mechanisms cancer cells use to inhibit immune cell attack. One type of treatment, known as immune checkpoint inhibitors, has shown dramatic improvements in overall survival in some cancer types, such as metastatic melanoma. Another type of cancer immunotherapy that has shown great success in some cancer types is known as CAR-T cell therapy. In CAR-T therapy, a patient's T cells are genetically engineered to attack cancer cells. Although CAR-T has been very successful in some blood cancers, it has had very limited success in solid tumours, and it is thought that this limited success is due to strong immunosuppression in the tumour microenvironment. Cytokines are important activators of immune cell function, and this project aims to investigate how cytokine signalling is inhibited in the tumour microenvironment and to develop mechanisms to overcome this inhibition to improve cancer therapies.

Investigation of Growth Hormone-Mediated Cancer Progression and Immune Evasion

Supervisor: Associate Professor Andrew Brooks

abrook28@une.edu.au

Background: Cancer cells utilise mechanisms to inhibit immune cell activation in order to avoid immunosurveillance. Blockade of the immune checkpoint proteins PD-1 and CTLA-4 has shown success in metastatic melanoma patients; however, a significant percentage of patients show resistance to this treatment, with recent studies demonstrating a 5-year survival rate of approximately 50% for combined PD-1 and CTLA-4 blockade treatment in metastatic melanoma patients. Growth hormone receptor (GHR) signalling has been shown to enhance the progression of melanoma metastases and facilitate drug resistance in melanoma. Our preliminary data shows that GHR signalling in melanoma cells induces the expression of an alternative immune checkpoint protein. This project aims to investigate the mechanisms of GH-mediated immune suppression in melanoma.

Neuroscience explores how the brain and nervous system give rise to thought, behaviour, and experience, from molecules to mind.

Neuroscience

Discipline contact Vicki Bitsika: **Vicki.Bitsika@une.edu.au**

The Choroid Plexus: A window to age-related brain and cognitive decline?

Supervisor: Dr. Rebecca Williams

rwilli90@une.edu.au

The choroid plexuses (ChP) are small secretory tissues in the brain that produce cerebrospinal fluid and are implicated in the clearance of metabolic waste and toxins. Due to recent improvements in image processing with AI, it is now possible to closely interrogate the structure and function of the ChP non-invasively with magnetic resonance imaging (MRI). This has led to recent attention being placed on these small structures (see image below: the ChP are highlighted in cyan).

Importantly, there has been a plethora of research indicating that changes in the shape and function of the ChP might be an early indicator of Alzheimer's disease (AD). However, these changes do not appear to be specific to AD, with my recent work indicating that the same changes are also observed in healthy ageing adults (Becker et al., 2025). It is therefore critical to characterise changes in the ChP that are specific to AD, and those that represent the typically ageing brain.

This project will leverage cognitive, lifestyle, and MRI data collected in healthy ageing participants, and in participants diagnosed with AD, to determine which characteristics of the ChP specifically represent early disease processes.

Reference: Becker, J., MacDonald, M.E., Vessey, K.A. & Williams, R.J. (2025). Choroid plexus volume and its association with cognitive performance across the lifespan: Links to sleep quality and healthy brain aging. *Neurobiology of Aging*, 156, 40-49. https://doi.org/10.1016/j.neurobiolaging.2025.08.003

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

Supervisor: Dr. Kirstan Vessey

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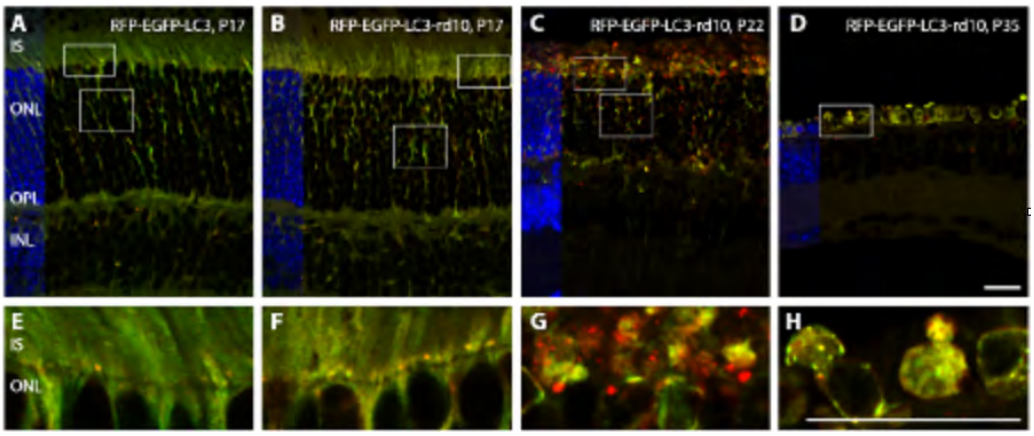
Background: Inherited retinal degenerations are a caused by a single gene mutation and result in the gradual loss of the light sensitive neurons in the retina, photoreceptors. This leads to vision loss and eventual blindness. These diseases occur in around 1:5500 people, but 1:50 are carriers. We are 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.

Image below shows how changes in intracellular waste management occur during retinal degeneration. The outer nuclear layer (ONL) is the photoreceptor layer and it is lost during retinal degeneration (rd10). At the same time intracellular waste (red and green dots) is accumulating in the dying cells. One goal of our work is to test novel therapies to enhance intracellular waste processing to slow neuronal death, with application not only for retinal degeneration but also diseases like dementia.



Analysis of visual evoked potential changes in depression

Supervisors: Dr. Kirstan Vessey
Prof Chris Sharpley

Background: Depression is characterised by a range of changes in the brain. In this project you will have the opportunity to determine whether changes in the electrical signals in the brain's visual region can be used as an objective biomarker for depression. Major depressive disorder (MDD) currently relies on subjective diagnostic scales and clinical interviews, which are time-consuming and prone to inter-rater variability. Electroencephalography (EEG) offers a non-invasive, cost-effective approach to capture neurophysiological alterations associated with depression. Recent advances in machine learning have demonstrated that EEG-based classifiers can achieve diagnostic accuracies exceeding 95% for MDD detection, highlighting the potential of electrophysiological biomarkers. Visual evoked potentials (VEPs) represent the brain's electrical response to visual stimuli and reflect the integrity of visual processing pathways. Alterations in VEP parameters, including P100 latency and amplitude, have been reported in various neuropsychiatric conditions, suggesting that visual cortex function may be a read out for neurological disorders. However, the specific utility of VEPs as a standalone biomarker for depression remains underexplored. By examining VEP characteristics in individuals with MDD compared to healthy controls, this study aims to establish whether objective, quantifiable changes in visual cortex electrophysiology can serve as a diagnostic tool for depression.

This project aims to:

- Characterise VEP parameters (P100 latency, amplitude, and waveform morphology) in individuals diagnosed with MDD compared to age-matched not depressed controls.
- Determine the diagnostic accuracy of VEP-derived features in distinguishing between depressed and non-depressed individuals.
- Evaluate the feasibility of VEP testing as an objective, accessible biomarker for depression screening in clinical settings.

Exploring associations between EEG patterns and social responses in autistic children

FoR Code: 320903

Research Unit: UNE Brain-Behaviour Research Group

Research Team: Professor Vicki Bitska and Dr. Ian Evans

Background: Autism Spectrum Disorder (ASD) refers to a group of neurodevelopmental conditions characterised by atypical socialisation and communication (cluster 1), in conjunction with restricted and repetitive behaviours (cluster 2). Investigations into Cluster are of particular relevance to understanding how autistic children detect, interpret and respond to the social stimuli they encounter in home, school, and community contexts. This project will examine the responses of autistic children to a series of graded social stimuli during an EEG experiment. Behavioural and EEG data will be used to understand the interconnections between brain functions and autism-related responses to basic verbal (e.g., greeting) and non-verbal (e.g., facial expression) social cues.

Pre-Requisite Knowledge: Knowledge on Autism Spectrum Disorder and the procedures for observing recording behaviour. Basic computer literacy and data entry/ manipulation skills

Clinical Skills Gained: Methods for coding and analysing behavioural outputs. Exposure to (and execution of) EEG processing techniques and data analysis.

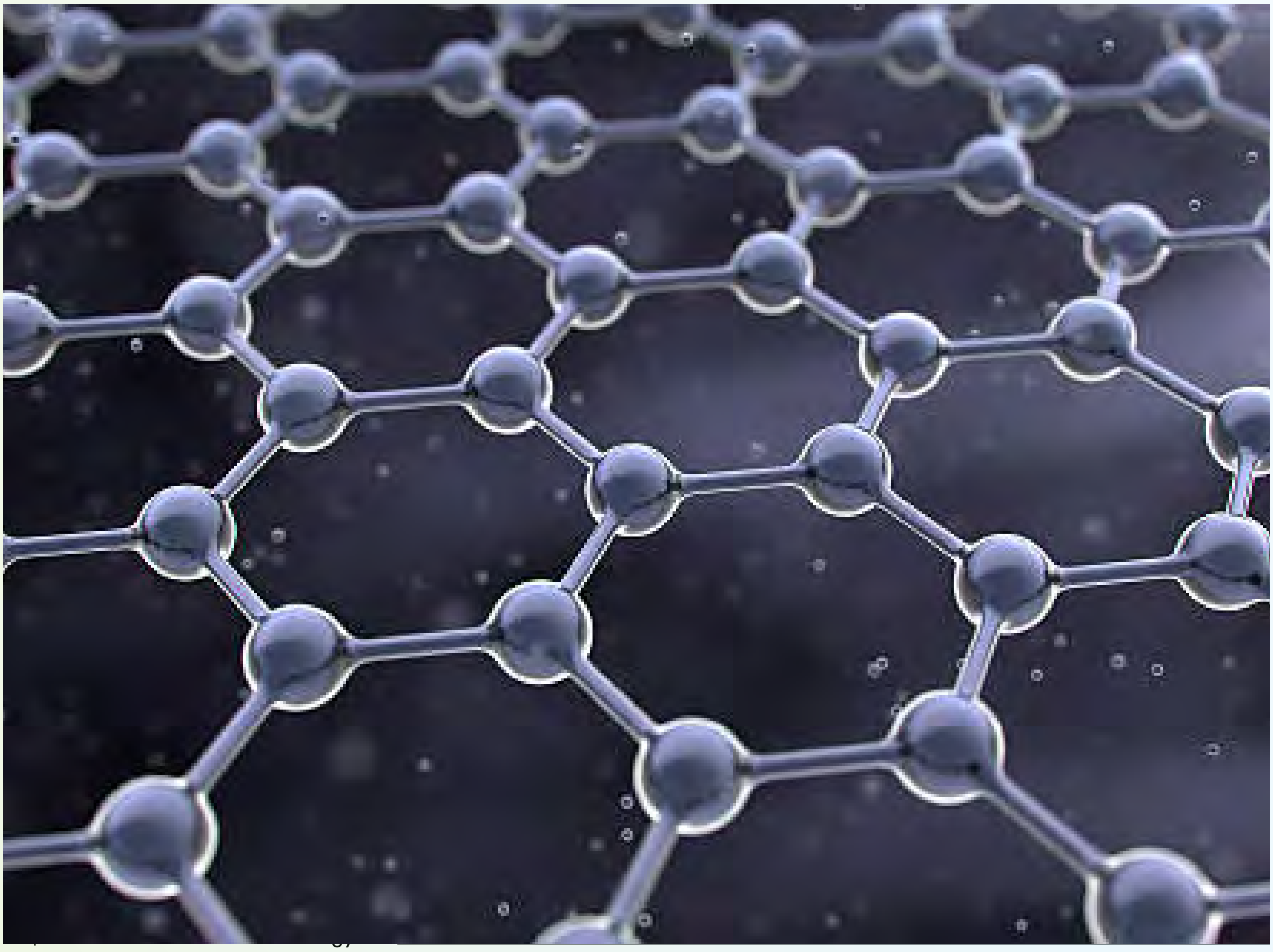
On Campus/Online Commitment:

This research project can be undertaken primarily online with some requirement for face-to-face activities at the university which will be negotiated with applicants prior to their commencement.

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

Ali.bagheri@une.edu.au | 02 6773 2470

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

erica.smith@une.edu.au

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

brendan.wilkinson@une.edu.au | 02 6773 5653

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, hydrogels, and cell-penetrating peptide conjugates as potential cryoprotectants.
- **New trehalose nanomaterials**: We will design, synthesise and characterise new nano-scale materials including supramolecular 1D nanofibres, low molecular weight hydrogelators, PAMAM and HPG trehalose dendrimers with diverse applications in therapy and diagonistics and drug/gene delivery.

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 diverse career prospects in R&D, government and policy, and intellectual property law to name a few.

Phosphorus in eucalypts: chemistry for koala nutrition

Supervisor: Dr Adam Rosser

arosser3@une.edu.au

Area: Natural products / analytical chemistry

Mode: On-campus (with local fieldwork)

Background: Koalas rely on eucalyptus leaves as their main food source, but not all leaves are nutritionally equal. This project will investigate the phosphorus content of eucalyptus species in New England koala habitats to better understand the nutritional quality of their diet.

You will collect leaf and soil samples from selected sites, prepare and process them in the lab, and quantify phosphorus using ^{31}P NMR spectroscopy and other analytical methods. You will then compare phosphorus levels between species and/or locations and discuss possible implications for koala nutrition and habitat quality.

Skills/techniques: Analytical chemistry, field sampling, sample preparation, 31P NMR, analytical data analysis.

Who it suits: Students who enjoy the environment and hands-on laboratory work.

Engaging chemistry: how universities can better support regional schools

Supervisor: Dr Adam Rosser

arosser3@une.edu.au

Area: Chemical education

Mode: Online or on-campus

Background: Across Australia, fewer students are choosing Year 12 Chemistry, with regional schools often most affected. This project asks: how can universities better support regional primary and secondary teachers to deliver engaging chemistry?

You will work with teachers to understand their needs, using surveys and interviews to identify key barriers and opportunities for support. Drawing on this evidence, you will help design practical outreach resources or program ideas (for example, simple experiment kits, curriculum-aligned activities, or professional-learning concepts) suitable for regional contexts.

Skills/techniques: Qualitative and quantitative data analysis, survey design, interview methods, ethics processes for human research, design of teaching and engagement outreach resources.

Who it suits: Students interested in teaching, science communication, or chemical education. Suitable for online or on-campus enrolment.

Testing AI-based DFT Functionals for Quantum Chemistry

Supervisor: Professor Amir Karton

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Background: Density Functional Theory (DFT) is the workhorse of modern computational chemistry, but its accuracy is limited by approximations to the exchange-correlation (XC) functional. Recently, Microsoft Research developed 'Skala' a revolutionary new XC functional based on deep learning. Trained on an unprecedented dataset of nearly 80,000 high-accuracy quantum chemical calculations (many of which were generated by our group), Skala promises to deliver the accuracy of computationally expensive methods at a fraction of the cost.

In this project, you will be one of the first researchers to put Skala to the test on a series of challenging chemical problems. You will benchmark Skala's performance for key properties such as reaction barrier heights, isomerization energies, and non-covalent interactions. Your work will help establish the reliability and scope of this next-generation AI-driven tool and provide insights into its strengths and weaknesses. This project is at the cutting edge of AI and computational chemistry and will give you hands-on experience with high-performance computing, data analysis, and state-of-the-art quantum chemical methods.

Further reading:

https://arxiv.org/abs/2506.14665

https://arxiv.org/abs/2506.14492

Designing Next-Generation Materials for Harvesting Water from Air

Supervisor: Professor Amir Karton

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Background: Water scarcity is one of the world's most pressing challenges. A promising technology to address this is atmospheric water harvesting, which uses desiccant materials to capture moisture directly from the air. Our recent work, published in PNAS (https://doi.org/10.1073/pnas.2508208122), revealed a remarkable synergistic effect where calcium ions intercalated in graphene oxide (GO) dramatically enhance its water capture ability. We found that the interplay between the calcium ion and the oxygen functional groups on the GO surface creates a highly polarized environment that strengthens the hydrogen-bond network, leading to significantly increased water uptake.

This project will build directly on that discovery. Using high-level DFT calculations, you will investigate whether other cations (e.g., Mg^{2+}, Al^{3+}, Li^{+}) could outperform calcium. You will model these new ion-GO systems, analyze their interaction with water molecules, and calculate key thermodynamic properties to predict their water harvesting efficiency. The goal is to establish design principles for creating even more effective materials, providing a computational roadmap for our experimental collaborators. This project combines fundamental quantum chemistry with a high-impact application in sustainable technology.

How are different types of salts and minerals affecting enzymes?

Supervisor: Dr Kasimir Gregory

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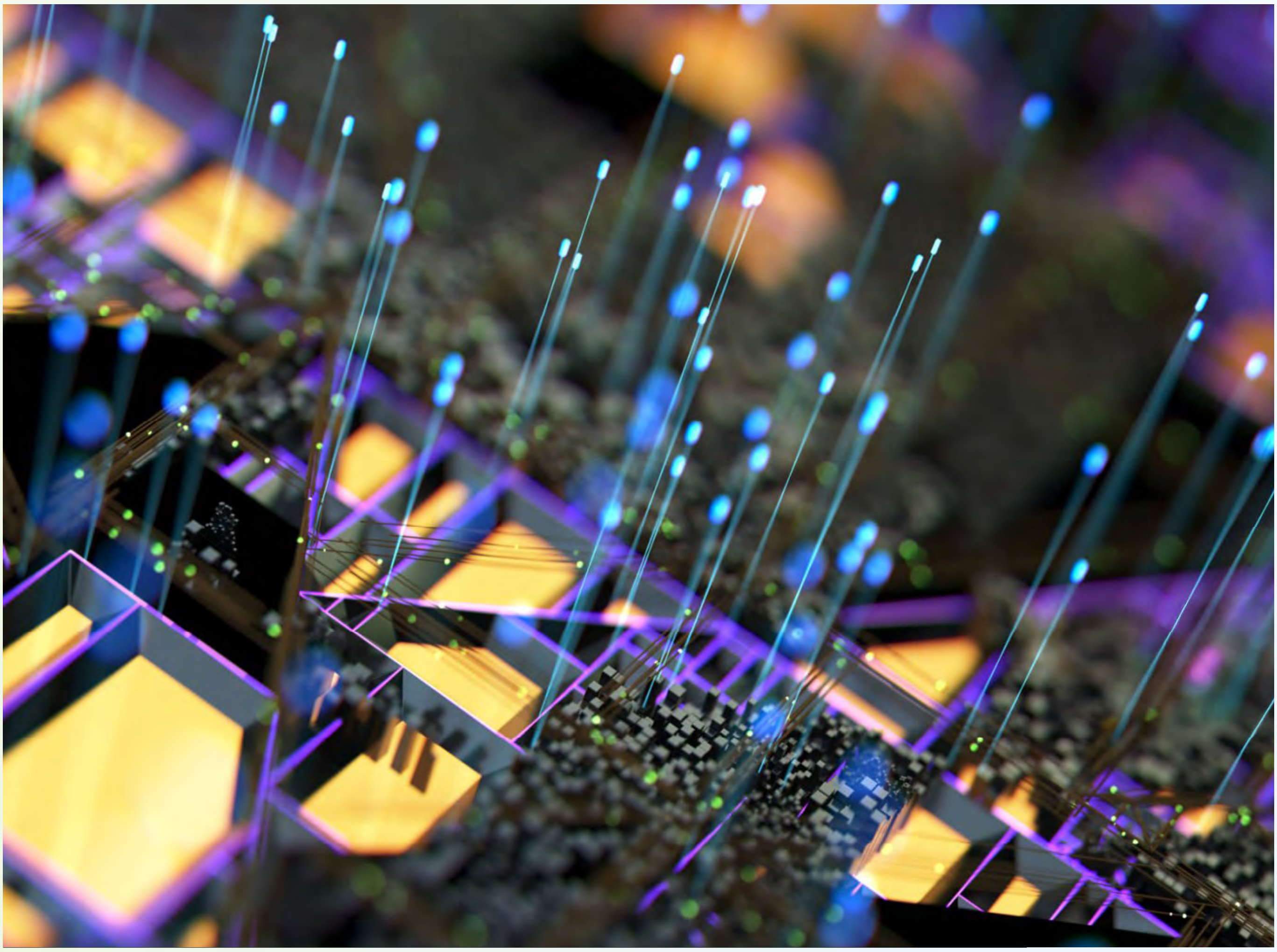
Background: Enzymes underpin nearly every biological process, acting as nature's catalysts to accelerate chemical reactions with extraordinary efficiency and selectivity. Their remarkable properties make them invaluable in industrial applications – from biofuel production and food processing to cutting-edge challenges such as the enzymatic degradation of plastics and environmental pollutants. Understanding how to control and optimise enzyme activity is therefore a powerful lever for developing greener and more efficient technologies.

A key, yet often under-appreciated, factor governing enzyme behaviour is **specific ion effects**. Beyond general ionic strength, different salts and mineral ions (e.g., Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, Cl^{-}, SO_4^{2-}) can profoundly alter enzyme structure, stability, solubility, and reaction rates. These Hofmeister-type effects can dramatically shift activity by modulating hydration shells, altering electrostatic landscapes, stabilising or destabilising intermediates, and even reshaping protein conformational ensembles. Experimental studies have shown cases where small changes in ionic composition enhance or inhibit enzyme function.

This project will use computational chemistry to uncover the molecular origins of these ion-dependent behaviours. By integrating quantum mechanics (to characterise active-site chemistry), molecular dynamics (to capture solvent, ion and conformational effects), and/or artificial intelligence (to learn structure–function patterns and predict optimal ionic conditions), we can build a multi-scale, mechanistic understanding of how salts and minerals tune enzyme performance. This unified approach has the potential to guide enzyme engineering, improve industrial biocatalysts, and accelerate the development of sustainable solutions such as plastic-degrading enzymes.

Applied Physics and Electronics harness fundamental physical principles to design, analyse, and innovate the electronic systems and technologies that underpin modern life.

Applied Physics and Electronics



Atomic-scale design of functional materials for hydrogen storage

Supervisor: Associate Professor Tanveer Hussain

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Background: Hydrogen (H_2) is poised to play a central role in the next generation of clean-energy technologies. With the highest gravimetric energy density of any fuel and zero carbon emissions at the point of use, hydrogen offers a compelling pathway toward decarbonising transport, industry, and power systems. However, the major barrier to large-scale deployment is the lack of safe, efficient, and high-capacity storage technologies suitable for real-world applications. Conventional storage methods, high-pressure cylinders and cryogenic liquefaction- are energy-intensive, expensive, and introduce significant engineering and safety constraints. These limitations have accelerated the search for material-based hydrogen storage, where engineered nanomaterials can reversibly adsorb hydrogen under practical conditions. This project focuses on using quantum mechanical simulations (DFT) to design, model, and evaluate advanced nanostructured materials for hydrogen storage. Students will investigate how hydrogen interacts with functionalised 2D surfaces, analyse key performance metrics (binding energies, charge transfer, electronic structure), and identify promising candidates for next-generation energy systems. By completing this project, students will develop high-level computational skills, a deep understanding of nanomaterials for clean energy, and experience with cutting-edge simulation tools that underpin modern materials research.

Aims of the Project:

- Design and screen advanced 2D nanomaterials using DFT to identify structures with strong, reversible hydrogen adsorption.
- Analyse hydrogen-material interactions through binding energies, charge transfer, electronic density, and structural stability.
- Evaluate storage performance against key criteria such as adsorption capacity, ideal binding energy window, and operating conditions relevant to practical hydrogen technologies.
- Assess the impact of functionalisation and metal decoration on improving hydrogen uptake and tuning electronic properties.

Further reading:

- doi.org/10.1016/j.ijhydene.2025.152597
- doi.org/10.1021/acsaem.5c01746
- doi.org/10.1016/j.est.2025.115970
- doi.org/10.1002/aesr.202500154
- doi.org/10.1016/j.ijhydene.2024.10.347

Computational Design of Next-Generation Electrode Materials for Sustainable Metal-Ion Batteries

Supervisor: Associate Professor Tanveer Hussain

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Background: Metal-ion batteries are at the forefront of global clean-energy storage, powering everything from portable electronics to large-scale renewable energy systems. While lithium-ion batteries (LIBs) currently dominate the market due to their high efficiency, long cycle life, and broad applicability, rising costs, uneven geographic distribution, and limited long-term availability of lithium pose significant constraints on future energy expansion. These challenges have driven intense interest in next-generation metal-ion batteries that rely on earth-abundant, low-cost, and sustainable alternatives such as sodium, potassium, magnesium, and calcium. Each of these systems offers unique advantages, ranging from improved safety to higher theoretical capacities yet their performance ultimately depends on discovering high-quality electrode materials capable of fast ion mobility, structural stability, and favourable redox behaviour. This honours project uses state-of-the-art quantum mechanical simulations (DFT) to design and evaluate advanced electrode materials for sodium-ion (NIBs), potassium-ion (KIBs), magnesium-ion (MgIBs), and calcium-ion (CaIBs) batteries. We will investigate ion adsorption, diffusion mechanisms, electronic properties, and structural stability to identify materials with strong potential for next-generation energy storage. Through this project, students will gain specialised computational materials science skills, deepen their understanding of battery chemistry and electrochemical mechanisms, and contribute to the scientific development of sustainable energy technologies.

Aims of the Project:

- Use quantum-mechanical modelling to explore and optimise potential electrode materials for sodium-, potassium-, magnesium-, and calcium-ion battery systems.
- Characterise ion uptake and storage behaviour, focusing on adsorption energetics and overall capacity to pinpoint promising high-performance candidates.
- Map ion migration routes and calculate diffusion barriers to evaluate how efficiently ions can move through the material during charging and discharging.
- Examine electronic characteristics and redox activity to assess structural robustness, charge transport capability, and long-term cycling stability.
- Build specialised expertise in computational electrochemistry, applying DFT tools to understand how atomic-scale features govern battery performance.

Further reading:

- doi.org/10.1016/j.jpowsour.2025.238592
- doi.org/10.1016/j.mtchem.2024.102429
- doi.org/10.1016/j.jallcom.2024.175665
- doi.org/10.1016/j.carbon.2024.119537
- DOI: 10.1039/D3CP01608K

Computational Screening of 2D Nanosensors for Environmental Monitoring and Early Disease Detection

Supervisor: Professor Amir Karton

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Background: Pollution is one of the most urgent global challenges, impacting both environmental quality and human health. According to the World Health Organization (WHO), around 7 million people die prematurely each year due to indoor and outdoor pollution, and this figure is expected to double by 2050. In Australia, premature deaths linked to air pollution carry an annual economic burden estimated between $11 billion and $24 billion. At the same time, the global sensor market is expanding rapidly, growing at 13.3% per year and projected to reach $323.3 billion by 2024, reflecting the increasing demand for accurate, real-time monitoring technologies. In response to these challenges, this project focuses on developing advanced nanosensors capable of detecting toxic and hazardous pollutants with high sensitivity and reliability. Using computational materials modelling, the project will explore nanostructured materials and their interactions with a range of target molecules to identify promising candidates for next-generation sensing devices.

Areas of investigation include:

(i) Detecting common air pollutants (CO, CO_2, CH_4, NO, NO_2, NH_3, H_2S, SO_2, etc.)

(ii) Identifying contaminants in water systems

(iii) Monitoring volatile organic compounds associated with food spoilage (meat, fish, shrimp)

(iv) Recognising biomarkers for early disease diagnosis (e.g., lung and gastric cancers, Alzheimer's, diabetes, kidney disease)

(v) Sensing chemical warfare agents (e.g., mustard gas, cyanogen chloride, arsine)

(vi) Monitoring organic pollutants in agricultural environments

Through this project, students will learn how to design and evaluate nanosensor materials using quantum-mechanical simulations, develop skills in interpreting electronic and adsorption properties, and contribute to research that supports environmental safety, public health, and national security.

Aims of the Project:

- Use first-principles simulations to identify nanomaterials with strong sensitivity and selectivity toward a wide range of environmental and biological pollutants.
- Examine gas and molecule adsorption behaviour to determine how different contaminants interact with candidate sensing surfaces.
- Assess changes in electronic structure and conductivity upon molecule adsorption to evaluate real-time sensing potential.
- Compare sensor performance across pollutant classes (air toxins, water contaminants, VOCs, biomarkers, and chemical agents) to highlight versatile, high-impact materials.
- Develop computational expertise in nanosensor design, including electronic analysis, charge-transfer evaluation, and structure–property interpretation for next-generation detection technologies.

Further reading:

- doi.org/10.1016/j.apsusc.2025.164507
- doi.org/10.1021/acsanm.5c02511
- doi.org/10.1016/j.apsusc.2025.162984
- doi.org/10.1021/acs.langmuir.5c00802
- doi.org/10.1016/j.mtchem.2025.102656

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

Computational Science

Discipline contact Will Billingsley: **wbilling@une.edu.au**

Explainable AI for education

Supervisor: Associate Prof. William Billingsley

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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

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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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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.

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

Supervisor: Dr Fareed Ud Din

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Background: This project aims at utilising Machine Learning (ML) algorithms for prediction in various domains, which hold a huge potential. A robust set of ML techniques can help solve abstract problems, such as disease identification/diagnosis, bioinformatics, drug design, social network filtering, and natural language translation. ML algorithms can be applied to the existing available datasets e.g., for the Dementia/Alzheimer's/ neurocognitive decline parameters, Fire Weather Index (FWI), which is an estimation of the risk of wildfire computed based on multiple parameters. Similarly, it can be used in a vast variety of areas e.g., to predict the severity of Intensive Care Unit (ICU) patients, predict the success of projects in IT, Financial Technology (FinTech) or students' success in university.

Information theory, dynamic programming, and sparse codes

Supervisor: Dr Peter Loxley

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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**

Applied Probability, Data Science, Mathematical Modelling

Supervisor: Dr Robert Cope

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

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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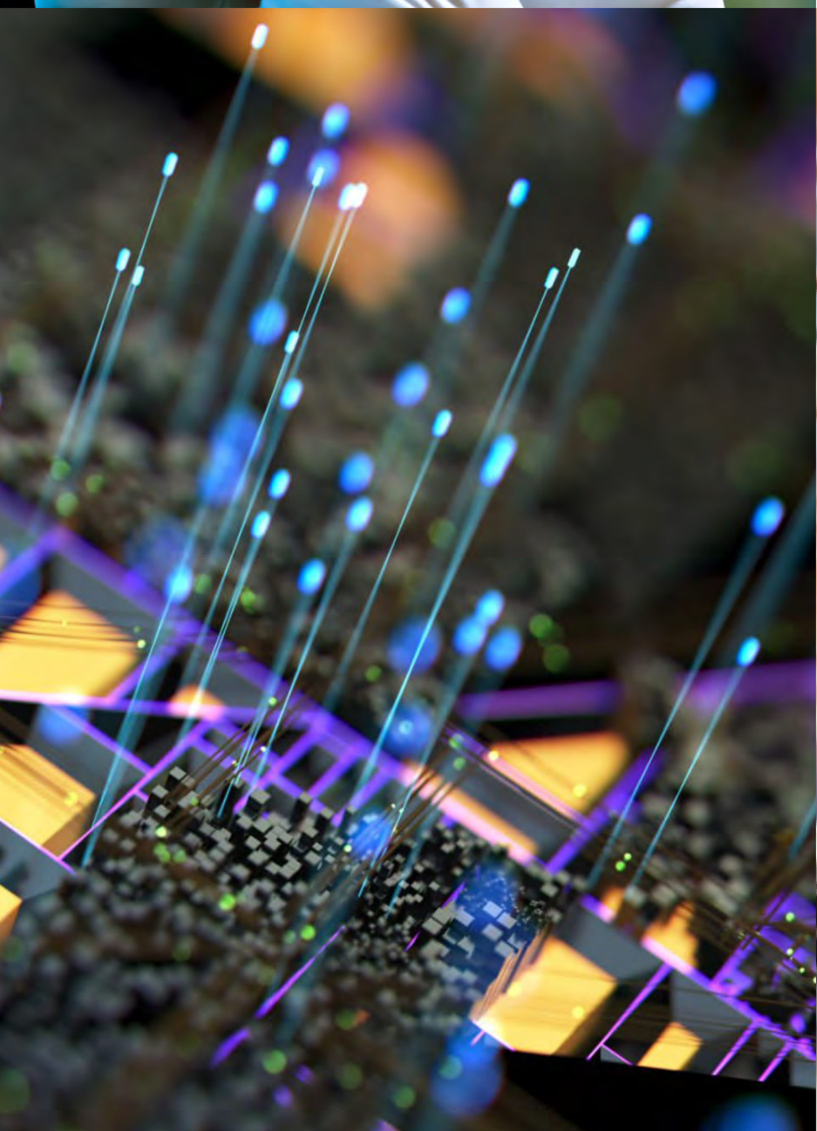
Background: CR geometry. You may be familiar with the Cauchy Riemann equations in Complex Analysis. CR structures (where CR stands for Cauchy Riemann) are geometric objects with complex and real features for which Cauchy Riemann equations can be defined. The study of CR structures requires methods from 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.

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**





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