The University Of Queensland
AUSTRALIA

CREATE CHANGE

Chemistry & Molecular Biosciences

Introduction to Research, Honours & Masters research projects

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The images included on the cover are submissions to the 2019 and 2020 SCMB Art of Science Competition by Gauri Nair and Xiao Wen Chen. The annual competition is coordinated by the School's Coursework Students Advisory Group.

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Australian Institute for Bioengineering and Nanotechnology – AIBN

Australian Centre for Water and Environmental Biotechnology – ACWEB

Centre for Advanced Imaging – CAI

Centre for Clinical Research – UQCCR

Frazer Institute

Institute for Molecular Bioscience – IMB

Queensland Alliance for Agriculture and Food Innovation – QAAFI

Queensland Brain Institute – QBI

EXTERNAL INSTITUTIONS

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QIMR Berghofer Medical Research Institute – QIMR Berghofer

Mater Research

PROFESSOR JAMES DE VOSS

HEAD OF SCHOOL

It is my great pleasure to provide a brief introduction to the School of Chemistry & Molecular Biosciences 2024 Research Projects Book. Within these pages you will find highlights of the many excellent research opportunities available to students wishing to undertake research projects within our School.

SCMB is a research-intensive School covering a diverse range of disciplines. The School is particularly known for its unique cross-disciplinary expertise in chemical and molecular life sciences. The School is recognised nationally and internationally for its research quality and output including publications and patents, for its commercialisation of discoveries and for the success of its staff in attracting research fellowships, grants, prizes and awards.

Becoming part of this dynamic research environment will be a highlight of your student experience.

Many of the group leaders you see in this book will be familiar to you; maybe you have met them when they have been lecturing or coordinating a course, or running a practical or PBL. These pages provide a window into the science that drives them, research that they don't normally talk about in their lectures. Most importantly, these are cutting-edge research programs that you can become a part of, either through the Introduction to Research course, an Honours year, or a Postgraduate Coursework degree.

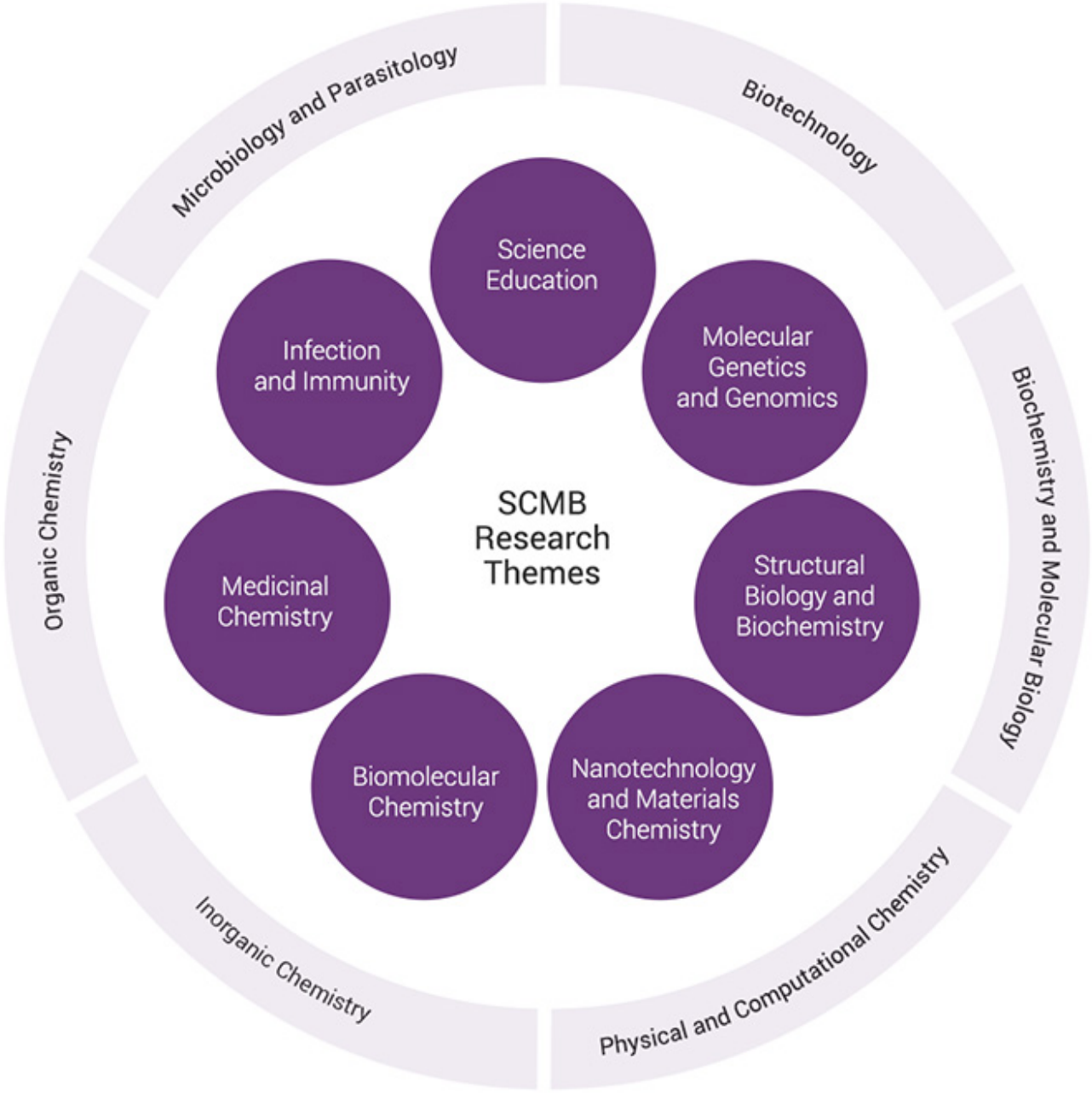
We believe a substantive research experience is a key part of an excellent science education. The lessons and experiences that come from undertaking a research project with one of our research groups include fostering creativity, learning how to balance individual and collaborative team work and developing independence, problem-solving and critical thinking as well as communication skills. All of these attributes will be invaluable to you regardless of your subsequent career path. If you are thinking of a research career, then undertaking a true research experience is your chance to take the next step and begin the transition from a student who is learning about science into being a scientist yourself.

We encourage you to review the exciting research opportunities available to you in SCMB and to talk to as many current students and staff as you can.

We do hope to see you as one of our research students in the future!

SCMB RESEARCH THEMES

The School of Chemistry & Molecular Biosciences is a diverse and powerful research grouping with unique expertise in the chemical and molecular life sciences. Research income exceeds $30 million per year and the School is recognised internationally for its research quality and output and for commercialisation of discoveries.



SCMB has seven identifiable research themes (inner circles) within a number of recognised discipline areas.

SCIENCE EDUCATION

Our theme members work to build new educational experiences and examine how well they work for students and academics.

Our research projects use a combination of quantitative and qualitative methods to examine the development, implementation, stakeholder experience and outcomes of educational activities.

Working directly with educators, employers and other students at UQ and further afield, our research students:

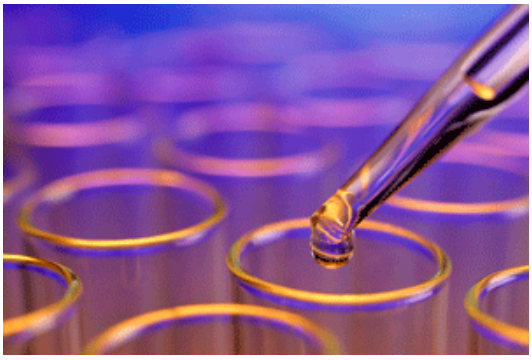
- conduct surveys and interviews
- examine student outputs
- analyse feedback from multiple sources
- work directly on creative teaching media such as online learning tools, video productions, student magazines, radio programs and podcasts.

Theme members also collaborate with other academics in local, national and international contexts to evaluate and improve educational practice.

Theme members:

Andrew Allsebrook	Development of technology and alternative methods to aid student learning and skill development in the Chemistry laboratory.
Effie Kartsonaki	Develop flexible modes of high-order thinking activities and support in large, diverse groups of chemistry learners.
Gwen Lawrie **(Theme Leader)**	Students' awareness of their own conceptual models in chemistry and their motivation to apply formative feedback in their learning.
Justin Ridge	How students learn key research skills and how to assess this. Teaching core biochemical, microbiological and molecular biology knowledge to students of the health professions.
Philip Sharpe	The barriers to student success in the chemistry laboratory and how to maximize their learning. Mathematical foundations for Chemistry study.
Jack Wang	Integration and evaluation of undergraduate research experiences, and assessment/feedback practices in large undergraduate microbiology courses.

BIOMOLECULAR CHEMISTRY



Our research in biomolecular chemistry includes the structure, reactions and synthesis of biologically important small molecules and chemical investigations of proteins and enzymes.

Members of this research theme are brought together by their common approach to understanding the structures and mechanisms of biologically relevant organic and inorganic molecules at a molecular level, which informs their role in nature and their potential applications.

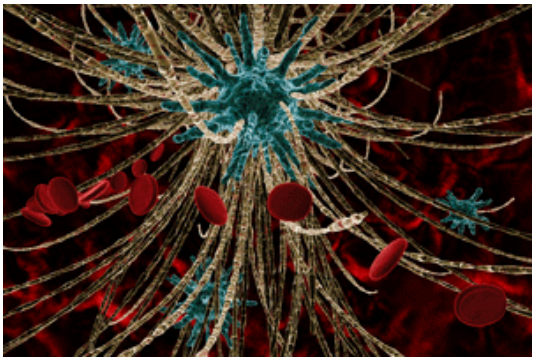
Theme members:

Paul Bernhardt	Inorganic Chemistry - Coordination chemistry
James De Voss	Biological and synthetic chemistry
Lisbeth Grondahl	Biomaterials for bone repair and regeneration
Elizabeth Krenske **(Theme Leader)**	Physical and computational chemistry; organic chemistry
Gary Schenk	Physical Chemistry - Structure, function, mechanism and pharmaceutical potential of metalloenzymes
Craig Williams	Organic Chemistry - Synthesis and isolation of complex natural products, method development, medicinal and physical organic chemistry

Affiliate theme members:

Mary Fletcher	Organic and analytical chemistry – analysis and identification of toxins affecting livestock

INFECTION AND IMMUNITY



Our infection and immunity research encompasses the study of microbial pathogens and the response to infection by their hosts. Specific areas of interest include molecular virology, bacterial pathogenesis, fungal pathogenesis, parasitology and innate immunity.

Theme members represent a core group within the Australian Infectious Diseases Research Centre, a multidisciplinary network encompassing more than 80 research groups at UQ and the QIMR Berghofer Medical Research Institute.

Theme members:

Keith Chappell	Vaccine development and the understanding of medically and environmentally significant viruses
James Fraser	Sex virulence and evolution in pathogenic fungi
Ulrike Kappler	Microbial physiology and biochemistry of metalloenzymes
Alex Khromykh **(Theme Leader)**	Molecular mechanisms of flavivirus replication and virus-host interaction
Graham Leggatt	Immunotherapy of non-melanoma skin cancers
Mark Schembri	Bacterial Pathogenesis
Kirsty Short	Influenza virus pathogenesis
Kate Stacey	Cellular response to foreign nucleic acids
Daniel Watterson	Virology and rapid generation of treatments for viral diseases
Nick West	Tuberculosis microbiology and pathogenesis
David Muller	Virology
Natalee Newton	Molecular virology and structure of flaviviruses
Jody Peters	Mosquito-borne viruses and vaccine/diagnostic platforms

Afiliate theme member:

Matt Sweet	Infection and innate immunity

MEDICINAL CHEMISTRY

Medicinal chemistry is a multidisciplinary science involving molecular design, chemical and enzymatic synthesis and bioassays followed by modifying compound properties for pharmaceutical applications.

Medicinal chemistry thus combines organic chemistry with biochemistry, physical chemistry, microbiology, pharmacology, structural biology, enzymology, computer modeling, molecular biology and *in vitro* and *in vivo* examinations.

Theme members:

Joanne Blanchfield	Drug development and delivery
Vito Ferro **(Theme Leader)**	Organic Chemistry - Glycoscience, drug discovery and biotechnology
Michael Monteiro	Living polymers
Avril Robertson	Drug discovery (inflammation, cancer, pathogenic fungi), medicinal chemistry
Istvan Toth	Novel drug delivery systems
Anitha Sudheesh Kumar	Nano drug delivery systems for therapeutic proteins and anticancer drugs

Affiliate theme members:

David Fairlie	Chemistry and human therapeutics

MOLECULAR GENETICS AND GENOMICS

Our molecular genetics and genomics research encompasses the application and analysis of targeted and high-throughput approaches to better understand all domains of life.

Vertebrates, plants, insects, microorganisms and microbial communities are subject to cutting-edge methodologies to elucidate evolution, ecology and function at the genetic and regulatory levels.

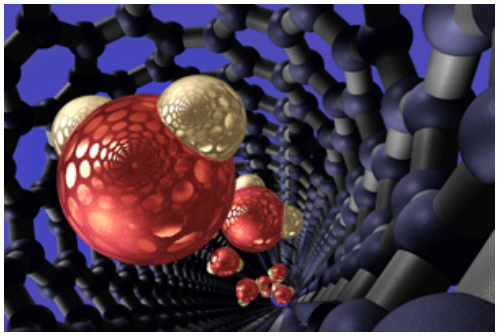
Theme members:

Stephen Barker	Evolutionary genetics and genomics of parasitic arthropods
Scott Beatson	Molecular pathogenomics
Mikael Boden	Bioinformatics (analysis, modelling and integration of biological data)
Bernie Carroll	Molecular genetics of gene expression and development
Cheong Xin (CX) Chan **(Theme Leader)**	Genomics, computational and evolutionary biology
Marina Fortes	Genetics and reproductive biology in mammals
Phil Hugenholtz	Microbial ecology & evolution
Paul Evans	Metabolism and genomics of methanogenic microorganisms
Miloš Tanurdžić	Molecular genetics and genomics of plant developmental plasticity
Anne Sawyer	RNA vaccines as sustainable alternatives to chemical pesticides
Rochelle Soo	Non-photosynthetic cyanobacteria and marsupial microbiomes

Affiliate theme members:

Rick Sturm	Melanogenics and skin cancer

NANOTECHNOLOGY AND MATERIALS CHEMISTRY



Organic, inorganic, physical, and computational chemistry underpins our Nanotechnology and Materials Chemistry theme.

This theme draws together expertise in synthesis (including self-assembly), characterisation (including spectroscopy, colloid and surface science) and computational modelling, and applications (optoelectronics, clean energy generation and storage, separation technologies, biomaterials, nanomedicine, molecular recognition) of organic, inorganic, and composite materials from small molecules to macromolecular structures including polymers, dendrimers, frameworks, gels, and nano-porous structures.

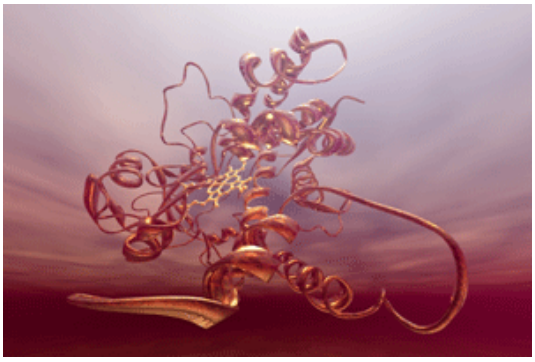
Theme members:

Debra Bernhardt	Materials chemistry application
Paul Burn	Organic opto-electronics
Jack Clegg	Metallo-supramolecular chemistry
Ian Gentle	Energy materials
Lawrence (Shih-Chun) Lo	Functional opto-electronic materials design, synthesis and characterisation
Evan Moore	Lanthanide metal ions properties
Paul Shaw **(Theme Leader)**	Photophysics of organic semi-conductors
Matt Trau	Nanoscience, Nanotechnology and Molecular Diagnostics
Jos Kistemaker	Preconcentrators for vapour detection of explosive material

Affiliate theme member:

Andrew Whittaker	Polymer chemistry, nanotechnology, photolithography, biomaterials science, magnetic resonance

STRUCTURAL BIOLOGY AND BIOCHEMISTRY



Our Structural Biology and Biochemistry research focuses on understanding basic processes involved in cell regulation and disease at a molecular level.

We use biophysical techniques such as x-ray crystallography and nuclear magnetic resonance spectroscopy, together with computer simulations and modelling techniques, to understand at an atomic level how proteins and peptides interact with themselves and other cellular components such as lipids and sugars to form functional complexes. We use biochemical and molecular biology approaches are being used to probe differences in protein expression, interactions or activity associated with different disease states.

Theme members:

David Ascher	Modelling biological data to gain insight into fundamental biological processes
Evelyne Deplazes	Biophysical and computational chemistry
Elizabeth Gillam	Biocatalysis and molecular toxicology
Luke Guddat	Protein structure and drug discovery
Mathew Jones	Improving cancer treatment by targeting DNA replication and repair
Bostjan Kobe	Structural biology of infection and immunity
Michael Landsberg **(Theme Leader)**	Structure and function of molecular machines
Marloes Nitert Dekker	Metabolism and microbiome in pregnancy
Ben Schulz	Synthetic systems glycobiology
Simon Worrall	Mechanisms of drug-induced liver damage
Lucia Zacchi	Antibody discovery, biochemistry, protein quality control, glycobiology, and mass spectrometry proteomics

INDUSTRY PROJECTS

Would you like to undertake your research project in collaboration with industry?

- Experience a commercial workplace
- Make contacts to help you with your career
- Receive support and guidance from UQ as well as your industry supervisor

Opportunities exist in these industries and more:

- biotechnology
- chemical
- pharmaceutical
- food processing
- pathology

You may be able to undertake a research project or internship with companies with which SCMB already has a working relationship. Many academics currently offer research projects in collaboration with industry partners. This provides an excellent opportunity to gain contacts in industry and get experience in the skills they value and understand their business.

For first-hand industry placement experience, SCIE3050 – *Science Industry Placement* is a course offered over a summer semester as part of your undergraduate degree.

SCMB students have been hosted for a variety of industry projects and internships at the following companies:

- Anteo Diagnostics
- Patheon by Thermo Fischer Scientific
- Mars Petcare (Albury-Wodonga)
- Resolian Bioanalytics (Alliance)
- Neogen Australia
- OECD

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Inventia Genetics Technologies Pty Ltd
Herston, Brisbane

Project Scope:

Beef cattle production benefits from selective breeding, which is the practice of selecting animals according to their genetic merit. Cows with high genetic merit are often used as oocyte donors in assisted breeding programs. In these programs, oocyte collection is followed by in vitro fertilization (IVF) and embryo transfer so that each donor cow is able to have dozens of offspring in one year (instead of one). In partnership with Inventia Genetic Technologies (IGT), an Australian cattle breeding company, we aim to understand the requirements of the developing embryo to improve assisted breeding. Current IVF protocols were developed using *Bos indicus* breeds and may not be ideal for *Bos taurus* cattle. Our research aims to investigate the differences in *Bos taurus* and *Bos indicus* breeds during oocyte maturation and early embryo development. Specialised culture medias will ultimately reduce cellular stress and optimise cellular function, improving embryo quality and therefore pregnancy rates. The aim of this research is to optimise current IVF protocols used for oocyte maturation and embryo development to increase IVF success rates of beef cattle and to understand differences between *Bos taurus* and *Bos indicus* bovine breeds.

Summer project benefits student and Biotechnology company

Van Mai was inspired by a lecture to do an industry placement internship that led to her work being incorporated into presentations to customers by a successful Brisbane biotech company.

“Two scientists from Anteo Diagnostics gave a guest lecture in the second year *Issues in Biotechnology* course I was taking,” she said. “I found it very interesting and thought provoking.”

Course coordinator, Professor Vito Ferro, mentioned to students that an eight-week internship at Anteo was available for a student taking the course *Biotechnology Industry Placement* over the summer semester. Van applied and was chosen.

After two weeks of on-site training about company policy, equipment use, experiment design and record-keeping, Van felt well-equipped to undertake six weeks in the company laboratory.

“I worked with one of Anteo’s signature products, Mix&Go, a high performance substance for surface coating,” said Van.
“The product enables fragile biomolecules to correctly orientate and attach to a wide range of surfaces.
“Specifically, I worked on optimising protocols for plate-based enzyme linked immunosorbent assays.”

Shaun Cooper of Anteo Diagnostics supervised Van’s project and said that Van was asked to use the underlying theory of Anteo’s novel ligand-metal coordination chemistry to determine its utility in improving sensitivity of an immunoassay in a format were low surface area traditionally limits performance.

“Van identified the performance differences of the product in high and low surface area plate formats,” he said.
“Her data demonstrated that sensitivity differences can be observed with the application of Mix&Go and that improvements are greater in the lower surface area format.
“Some of her data was incorporated into technology overview presentations given by the company’s chief scientific officer to prospective customers and partners.”

Van said that the work environment at Anteo was warm and welcoming and that the experience had taught her about the business side of scientific research, including policy, protocols and the importance of discussion and collaboration.

“It has also built my confidence,” she said.

Van is an international student who won a scholarship from the Vietnamese government to study in Australia. She was awarded Dean’s Commendations for high achievement in her undergraduate studies, worked as a peer tutor and charity volunteer, and is now completing her Honours year in materials chemistry.

She praised the quality of UQ’s teaching and learning, the range of courses, lab facilities and the beautiful St Lucia campus.

Anteo Diagnostics has hosted a number of UQ biotechnology students and is keen to host more.

“Students who undertake internships like Van’s gain not only general workplace skills, but also some insight into how Australian research contributes to commercial product realisation,” said Mr Cooper.
“Support for translational research is currently a topic of government policy debate, and projects like Van’s are a good example of the interface between research and commercialisation.

PROFESSOR DAVID ASCHER

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Research Area

Biology is increasingly becoming a data-driven science. Technological advances have led to an explosion in the amount of data being generated. This has created challenges in managing, describing and modelling these data. Our group is interested in developing and validating novel computational methods to exploit biological data through statistical and machine learning approaches, in order to provide powerful insights into biomedical questions. Our goals are to:

- Use mathematical models and statistical inference techniques to better understand biological processes and diseases;
- Integrating omics and structural biology to generate an integrated view of biological processes at molecular resolution;
- Develop computational tools to provide insights into protein structures, interactions, drug development and clinical decisions;

Treating the Person Not the Disease

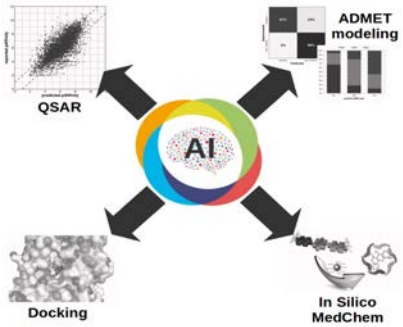
Patient treatment and outcomes can be greatly influenced by underlying genetics. We have been developing approaches to analyse these genetic differences. In this way, we can have mechanistic insights underlying diseases and phenotypes, evaluate gene function in the context of their molecular interactions, and identify molecular relationships among apparently distinct phenotypes. These tools have also enabled the interpretation of heterogeneity in clinical trial and are being used to inform treatment strategies and personalised medicine.

Discovering Sequence-Structure-Dynamics-Function Relationships

Studying the architecture, shape, and dynamics of biological macromolecules is paramount to understanding the mechanisms that drive the essential processes of all life. By applying fundamental principles of physical sciences, we are beginning to establish sequence-structure-dynamics-function relationships that enable deeper levels of discoveries, and enable *de novo* structural and functional predictions at the proteome level. We are using these insights to engineer biotherapeutics with tailor-made properties, including for nerve agent detoxification and enzyme replacement therapies.

Developing Better and Safer Drugs

Many drug candidates fail clinical trials due to issues with efficacy and safety. We are using computational approaches to guide development of better drugs. We are also developing tools to pre-emptively predict and identify likely resistance mutations, to guide the development of 'resistance-resistant' treatments, contributing to maintaining the longevity of developed treatments.



Techniques you learn in our group may include: artificial intelligence, machine learning, deep learning, python coding, statistical analysis, molecular modelling (small molecules, proteins and pathways), genomic variant characterisation (genetic diseases and drug resistance), clinical genomics, high-performance computing, bioinformatics.

PROFESSOR STEPHEN BARKER

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Parasitology

My research is cross-disciplinary in that it contributes to 2 of the 7 research themes in our school: (i) Molecular Genetics & Genomics; and (ii) Infection & Immunity. I study parasites which along viruses, bacteria and fungi are the 4 main groups of organisms that cause disease other than

My current research-focus is on the ticks of Australia, NZ, PNG and the West Pacific. Ticks are the 'pests of our times' in that many people are more concerned about the diseases from ticks than with any other infectious disease. Ticks cause disease in humans, our domestics animals, particularly dogs, and wildlife.

Our goals are to:

1. Resolve by bioinformatics the Ixodida (tick) branches of the three-of-life from entire mitochondrial and nuclear genome sequences.
2. Find new and interesting genes in ticks that are associated with disease in humans, our domestics animals, particularly dogs, and wildlife.
3. Resolve by bioinformatics and big data the climatic requirements of the ticks of Australia and PNG and thus the potential changes to the geographic distributions and amount of disease caused by ticks, under a range of climate-change scenarios.

1. This work is the Australian contribution to an international project to resolve the tree-of-life called the Tree-of-Life Web Project (http://tolweb.org). Students will use common bioinformatics tools to mine our Illumina nucleotide sequence data & the Sequence Read Archive for mitochondrial genomes & ribosomal RNA gene-clusters. Then students will use Geneious to manipulate sequences, & other programs to predict ("reconstruct") the evolutionary tree of the ticks. Virtual time machines! Have a look at the You Tube Channel of my *Tick Mitochondrial Genome Network*: https://www.youtube.com/channel/UCnBhfhYxjC4rsJmVpBwHT0g/featured

2. Mine our Illumina nucleotide sequence data & the Sequence Read Archive for new and interesting genes in ticks that are associated with disease in humans our domestics animals, particularly dogs, and wildlife.

3. Ticks are the "pests of our times" in that the current generation of Australians & indeed people all over the world are more concerned about the diseases associated than with ticks that with any other infectious disease. This is understandable since we know so little about how the climate influences why ticks live where they live (*geographic-risk*) & why ticks are abundant in some years yet rare in other years (*variation in risk among years*). Students will use computer models to predict how the climate influences why ticks live where they live (*geographic-risk*) & why ticks are abundant in some years yet rare in other years (*variation in risk among years*); and thus the potential changes to the geographic distributions & amount of disease caused by ticks, under a range of climate-change scenarios.

Techniques you learn in our group may include: microscopy, bioinformatics, creation of DNA diagnostic tests, public health concepts and strategies.

Useful Majors/Minors: Biomedical Science / Computational Science / Genetics / Microbiology

ASSOCIATE PROFESSOR SCOTT BEATSON

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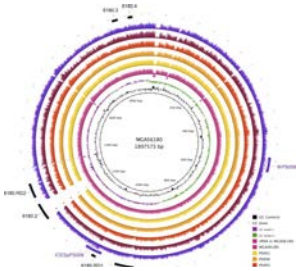
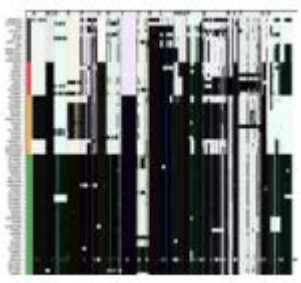
Microbial genomics



We aim to exploit next-generation DNA sequencing to better understand how medically important bacteria cause disease, become resistant to antibiotics and disseminate globally. Our major focus is the role of mobile genetic elements in the evolution of virulence and antimicrobial resistance amongst pathogens such as *Escherichia coli, Streptococcus pyogenes, Mycobacterium tuberculosis* and *Pseudomonas aeruginosa*. Our group develops new computational approaches for the rapid analysis of bacterial genome data from the latest sequencing technologies.

Genomic investigation of antimicrobial resistance.

Carbapenem resistant Enterobacteriaceae (CRE) pose an urgent risk to global human health. CRE, which include organisms such as *Klebsiella pneumoniae* and *Escherichia coli,* are resistant to almost all currently available antibiotics. Almost 50% of patients who develop bloodstream infections with these organisms die from the infection. In this project we use Pacific Biosciences Single Molecule Real-Time (SMRT) sequencing to determine the complete genomes of CRE isolated from local hospitals. Comparative genomic analysis will enable us to recognise the genetic cause of antibiotic resistance and the relationship between isolates from an outbreak. As we outlined recently (Beatson SA, Walker MJ (2014) Science 345: 1454-1455), in contrast to short-read sequencing technologies commonly used in genomic studies, SMRT sequencing allows complex antimicrobial resistance elements to be properly characterised.



Phylogenomic analysis of global pandemic *E. coli.*

Escherichia coli sequence type 131 (ST131) is a globally disseminated, multidrug resistant clone responsible for a high proportion of urinary tract and bloodstream infections. By sequencing the genomes of ST131 isolates from all over the world we were able to use phylogenomic analysis to investigate the rapid emergence and successful spread of this clone (Petty, Ben Zakour et al., PNAS, 2014). In this project we will analyse the genomes of other global pandemic multidrug resistant *E. coli* clones in order to understand of the role of mobile genetic elements and antibiotic resistance in their evolution.

Novel methods to visualise bacterial genomic data.

We have previously developed easy-to-use software such as BRIG and Easyfig for visualising bacterial genome comparisons. We are seeking computationally focused students to develop novel web-based software for intuitive visualization and reporting of virulence and antimicrobial resistance gene profiles from genome data generated using Illumina or Nanopore technologies.

Techniques you learn in our group may include: Comparative genomic analysis, Phylogenomics, Bioinformatics, Python programming, Web programming; Joint projects that have both computational and "wet-lab" components may be arranged with other SCMB microbiology group leaders on request.

Useful Majors/Minors: Genetics / Microbiology / Bioinformatics / Biochemistry & Molecular Biology / Biomedical Science / Computational Science

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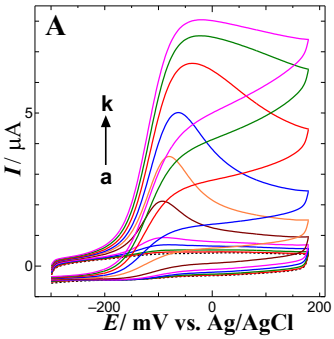
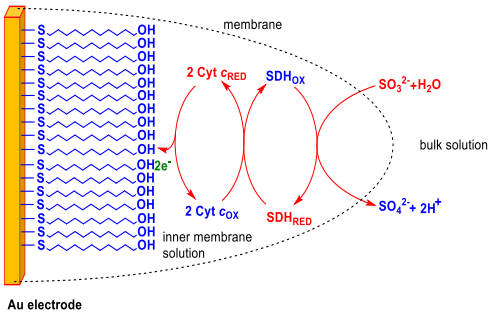
Coordination and Bioinorganic Chemistry

Our research efforts are concerned with electron transfer reactions and coordination chemistry of relevance to biology and catalysis. Students interested in any of these areas of research should contact Prof. Bernhardt for a more detailed project description.

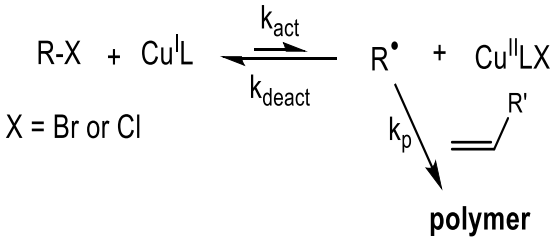


Enzyme Electrochemistry



Enzyme electrode biosensors are devices that comprise a redox active enzyme integrated with electronic circuitry to give real-time quantitative analysis of chemical compounds in biological fluids or the environment. The current that is generated by the oxidation or reduction of the substrate provides a quantitative measure of the substrate concentration. This project will involve the electrochemical investigation of metalloenzymes currently available within in our group.

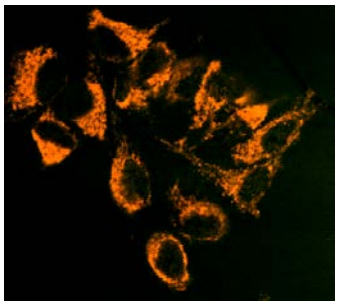
Copper complexes as catalysts for atom transfer radical reactions



Simple Cu(I) complexes (e.g. $[Cu(bipy)_2]^+$) are capable of generating organic radicals from alkyl halide precursors and have been used extensively in so called atom transfer radical polymerisation (ATRP). The mechanism by which the radical is produced remains controversial. This project will use spectroscopic and electrochemical methods to understand the reactivity of these simple but highly reactive compounds.

Imaging Metals in Cells Using Fluorescent Ligands

Within living cells transition metals may occur in various forms either tightly bound (to proteins) or weakly bound to small molecules. Identifying the cellular localisation and chemical form (oxidation state etc.) of these metals is an important goal. Due to its high sensitivity fluorescence is a popular technique for visualising molecules at low concentrations. This project will investigate the combination of the ideal metal binding properties with fluorescent tags such as fluorescein (a well characterised fluorophore) in order to develop ligands that respond as ON/OFF fluorescent switches when complexed to different metal ions within cells.



Techniques you learn in our group may include: electrochemistry, synthesis, spectroscopy, structure determination.

Useful Majors: Chemistry / Biochemistry & Molecular Biology

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Theory and computation for new materials and fluids

My research group is interested in the study of matter using theoretical and computational methods that can ultimately be used to address a wide range of practical problems. Applications of interest include transport in nanopores, fluctuations in nanoscale systems, melting, solubility, separation of gases, lubrication, design of ionic liquids, design and assessment of materials for energy conversion and storage, carbon dioxide sequestration and catalysis. Our group has world leading expertise in various theoretical and computational methods ranging from quantum chemical calculations to the statistical mechanics of nonequilibrium systems, access to high performance computing facilities and an international team of collaborators. Possible projects include:

Transport in nanoporous systems

Nanoporous solids are used as adsorbents in pollution control, industrial separations, storage of fluids and catalysis. Simulations can be used to assist in the design of better materials, and to understand the fundamental nature of the adsorption and transport processes. One of the key factors determining flow of fluids through nanopores is their stick or slip behaviour near the walls. We have recently developed a new approach for studying this behaviour that should be more efficient for complex systems, and have projects where this approach can be applied.

Computational studies of ionic liquids

Ionic liquids have exceptional solvation properties and electrical conductivity, meaning they have a wide range of industrial applications. By combining different ions, ionic liquids can be designed to optimize their properties. However, the science of ionic liquids is new and therefore prediction of their properties is problematic. To address this, we are taking advantage of recent developments in nonequilibrium statistical mechanics to create efficient algorithms to determine key properties of ionic liquids.

Statistical mechanics of nonequilibrium fluids

Any system that is flowing, stirred, has a temperature gradient across it or is subject to an external field is in a nonequilibrium state. The properties of these systems are not well developed when the systems are far from equilibrium. In this project theory and computational methods will be used to expand our fundamental understanding of these systems.

Design of new materials for energy applications

New materials are required for solar energy applications, catalysis, adsorbents for pollutants, storage of fuels, new polymers, fuel cells etc. Quantum mechanics enables the properties of these materials to be predicted in an efficient and cost effective manner. Projects are available that will focus on the prediction of material properties using a range of computational quantum chemical methods.

Techniques you learn in our group may include: Molecular dynamics simulation, quantum chemical calculations, development of theories, modelling of experimental results.

Useful Majors/Minors: Bioinformatics / Biophysics / Chemistry / Computational Science / Computer Science / Mathematics / Physics / Chemical Engineering / Materials Engineering / Software Engineering

PROFESSOR JOANNE BLANCHFIELD

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Research Area

My research broadly concerns natural products isolation and elucidation, drug discovery, design and development. We search for potential new drugs in natural sources such as medicinal herbs and traditional remedies. We also examine the compounds' bioavailability using cell-based assay to explore the mechanisms of absorption across biological molecules. We are also involved in synthesising small molecule mimics of antigenic structures of pathogens that could be used in vaccine development.

Our goals are to:

- Explore the phytochemistry of traditional medicinal plants to elucidate the structure of new compounds and determine the active components of extracts.
- Determine the compounds in plant extracts that can cross the GI tract and thus are most likely to be the biologically active components.
- Build scaffolds that can present the components of antigens to the immune system to elicited protective antibodies without having to use whole organisms in vaccines.

Bioavailability of natural products from herbal extracts

Herbal remedies and traditional medicinal plants are a major source of medical treatment for much of the world's population. Unfortunately, little is known about the fate of the natural products in the extracts or which, if any, are biologically active. We offer projects that involve the isolation of natural products from Australian native plants and commercially significant herbal extracts. We also use a cellular model of the small intestine (Caco-2 cell monolayers) to investigate which natural products are likely to enter the blood stream after oral intake.

We also look closely at what changes the compounds undergo during digestion and absorption. This project involves working closely with collaborators from our industry partner, Integria Healthcare and colleagues at Menzies School of Health Research, Darwin and Indigenous communities in the Northern Territory.

Synthesis of antigen mimics for synthetic vaccines

In collaboration with Professor Paul Burn and Dr. Graham Leggatt (TRI) we are building fully synthetic constructs that display antigenic peptides or carbohydrates from HPV and HIV. We are building a molecule that resembles the outside surface of the infectious agents so that whole organisms do not have to be used in vaccines.

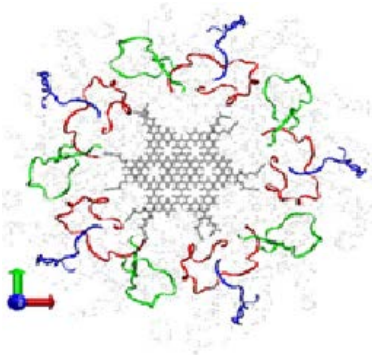

Figure: Energy minimised model of HPV discontinuous epitope displayed on a hexaphenylbenzene scaffold.

Techniques you learn in our group may include: Natural products isolation, organic synthesis, HPLC, NMR, MS, cell culture techniques, assay development and analytical chemistry.

Useful Majors: Chemistry / Biochemistry & Molecular Biology

ASSOCIATE PROFESSOR MIKAEL BODÉN

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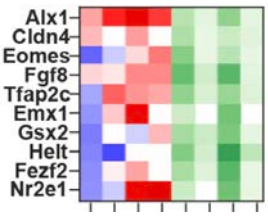
Bioinformatics

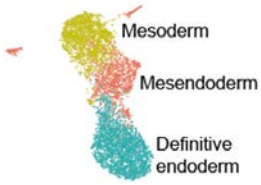
The scales of data produced by genome and proteome technologies allow us to distinguish biologically meaningful signals from mere noise or artefacts, e.g. to identify "drivers" of function and structure. On the flip side, the complexity of signals challenges our ability to process, integrate and interpret them. To this end, our research group uses probabilistic modelling, machine learning and data analytics. While we aim to resolve a range of ever-changing problems in genomics, systems and protein biology, our “bioinformatics” goals are to

1. effectively manage the computational complexity involved in analysing thousands of genomes, epigenomes and proteomes, each capturing thousands of biologically diverse molecules
2. enable the seamless integration of uncertain and incomplete data, typical of recent biotechnology and data collections, with strong attention to biological expertise to constrain resulting models
3. empower the interpretation of "whole system" data, aimed at understanding the genetic, epigenetic and evolutionary basis of phenotypes of scientific and applied significance

Modelling the dynamics in development and disease



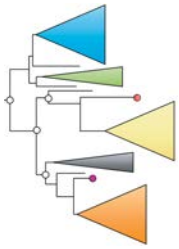
Increasingly genome technologies uncover spatial and temporal specificity of observations, but data need to be carefully and selectively pieced together. We work on integrating genomic, transcriptomic and epigenomic data, viewed together with information that can be predicted from sequence and other genomic markers, accounting for the uncertainty of their juxtaposition. With collaborators we have been using data integration to infer drivers in development (of the brain and other organs) as well as in cancer and disease.



Developing computational tools to harness sequencing data

New (sequencing) technologies bring new opportunities and challenges, including long- and short read technologies at single-cell or bulk resolution, and with spatial specificity. We develop tools for leveraging the scale of available data, including assessment of reproducibility, the discovery and extraction of biological footprints that emerge across time, in 3D and different cellular conditions, or that are available by complementarity between data types, including sequence motifs. We regularly publish prediction services and computational tools open to the scientific community.

Inferring evolutionary determinants to support synthetic biology



All biological components that are genetically encoded are subject to evolution—selective pressures in their ecological niche. With biochemists and protein engineers, we develop (phylogenetic) tools for detecting what specific changes explain the make-up of a gene or protein; this leads to a fundamental appreciation of genetic determinants of success, but can also be used to design novel variants or even re-run evolution artificially to generate gene products that perform in conditions for medical, industrial and agricultural applications in the emerging bioeconomy.

Skills you may develop include: machine learning, probabilistic modelling, advanced coding, statistical analysis in genomics, transcriptomics and epigenetics, phylogenetic analysis

Useful Majors/Minors: Bioinformatics / Biochemistry & Molecular Biology / Computational Science / Data Science / Genetics / Computer science

PROFESSOR PAUL BURN FAA FRSC

UQ Laureate Fellow

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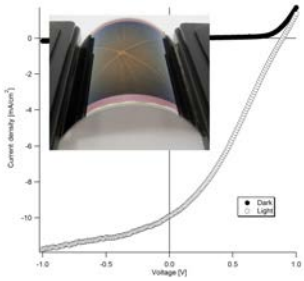
Chemistry of Materials and Nanotechnology

The research mission of the Centre for Organic Photonics and Electronics (COPE) is to take **nanotechnology** from the "bench to the market". COPE contains state-of-the-art synthesis laboratories, a Class 1000 clean room, device fabrication facilities, and a suite of instrument rooms for the characterization of materials and opto-electronic devices. COPE has Honours research projects in all branches of Chemistry (organic, inorganic, materials, physical, and computation) giving a fantastic opportunity for you to develop your own interests and skills at the cutting edge of a technological area, e.g., **solar cells, flat panel displays and lighting, plastic electronics, explosives sensors, cameras and imaging, and synthetic vaccines**. Below is a snapshot of some of the projects on offer and I would be happy to discuss them with you.

Thin film solar cells



A key component of slowing and ultimately halting climate change is converting a proportion of the 1 kJ of solar energy that falls on each square metre of the Earth's surface per second of every daylight hour into electricity. Would you like to use your synthetic chemistry skills to create new nanomaterials (organic and inorganic, e.g., perovskites) that can be used in efficient, flexible, and light-weight solar cells? Do your interests lie in studying structure using neutron scattering or would you like to apply computation to develop an understanding of why some materials work well and some do not, leading to new design criteria?

Flat panel displays and lighting

Lighting and displays based on organic light-emitting diodes (OLEDs) have the potential advantages of cheap manufacturing, better power consumption, better colours, and ultimately being flexible. Imagine a TV screen that could roll up into your mobile phone! Would you like to apply your interest in synthetic chemistry to develop new emissive materials that can be incorporated into real OLEDs at COPE or apply physical chemistry techniques to understand how they degrade?

Sensors for explosives

We are developing in partnership with industry a handheld technology based on fluorescence quenching for the detection of explosives to replace canines. Are you an organic or physical chemist who would like to work in an interdisciplinary team developing and testing dendritic sensing materials?

Techniques you learn in our group may include: Synthetic chemistry [organic and organometallic, small molecule, dendrimers, polymers, and poly(dendrimers)]; characterisation techniques [chemistry (NMR, mass spectroscopy, IR, UV-visible etc), materials (GPC, DSC, TGA, electrochemistry, neutron scattering etc)]; photophysical (PLQY, PL spectra, time resolved PL measurements); computation; device fabrication and testing.

Useful Majors/Minors: Chemistry / Computational Science

PROFESSOR BERNIE CARROLL

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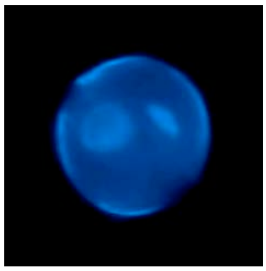
Research Area



We are using *Arabidopsis* as a eukaryotic model for studying the mechanisms of RNAi and epigenetic silencing. Gene silencing is a highly conserved process in plants and animals, and is of fundamental importance to developmental regulation of gene expression, defence against viruses, transposon silencing, adaptation to environments and genome evolution. Gene silencing is also of immense relevance to biotechnology.

Our goals are to:

- Understand components of gene silencing pathways in eukaryotes, including mechanisms of intercellular movement of gene silencing
- Define the importance of gene silencing pathways in eukaryotic development, reproductive biology, defense against pathogens, and adaptation to environmental change

Molecular basis of meiotic drive in pollen

Meiotic drive involves defective meiosis and results in preferential transmission of selfish chromosomes through to the next generation. We have recently identified the first example of meiotic drive in pollen of flowering plants (see above). This project aims to identify the gene responsible for the meiotic drive phenotype in pollen. Our data suggests that the meiotic drive phenotype may have an epigenetic basis. This project should shed new light on mechanisms of cell division (meiosis and mitosis) and sexual reproduction in both plants and animals.

Systemic RNAi and its relevance to defense & development

Remarkably, once RNAi is initiated, it spreads systemically throughout the plant to confer systemic resistance against homologous viruses. Using a GFP reporter (see left), we have identified *Arabidopsis* mutants that are defective in systemic RNAi, and many of these mutants also show epigenetic and/or developmental defects. This project will involve further characterization of these systemic RNAi mutants, including their interaction with plant viruses.

Techniques you learn in our group may include: Genetic analysis, genetic mapping and map-based gene cloning, plasmid construction and production of genetically modified plants (GM plants) including CRISPRs, micrografting of plants, plant pathogen assays, confocal microscopy, cell sorting, genetic diagnostics, genomics, bioinformatics.

Useful Majors/Minors: Genetics / Biochemistry & Molecular Biology / Bioinformatics / Microbiology

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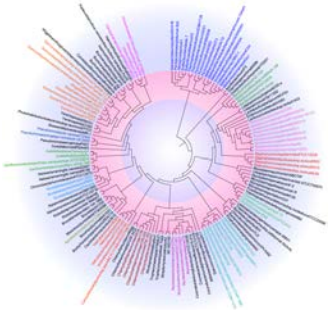
Genomics, Computational and Evolutionary Biology

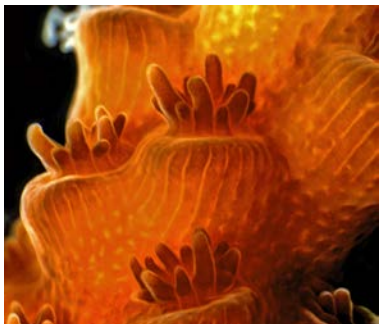
We use advanced computational approaches to investigate genome evolution. Our broad aims are:

- to understand evolution of diverse genomes in changing environments; and
- to develop highly scalable approaches for comparative genomics.

Genome evolution and innovation



We study the innovation of eukaryote genomes relative to the organismal adaptation to diverse ecological niches including extreme environments. Using comparative genomics, we aim to identify genome features, gene content, functions, and/or pathways that are specific to distinct ecological niches and conditions, including symbiosis, stress tolerance, and venom production. To address these questions, we routinely generate genome and other genome-scale data using various high-throughput sequencing technologies. Our research subjects range from bacteria, microbial eukaryotes, algae, plants, corals, to jellyfish; some of these genomes are highly complex with idiosyncratic features.

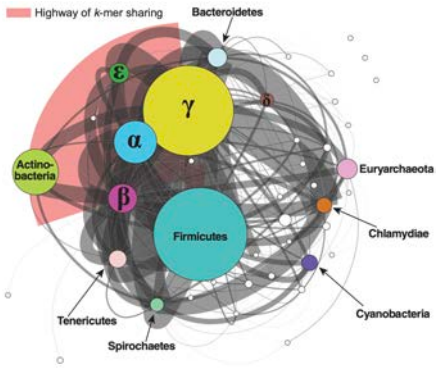


Hologenomics of symbiosis

We adopt metagenomic approaches to assess the genetic capacity of symbiotic partners in sustaining a functional ecological unit (i.e. a holobiont). Central to this research are corals that are critically sustained by symbiosis among the coral animal, the symbiotic dinoflagellate and other microbiome. Breakdown of this symbiosis leads to coral bleaching. We aim to understand genome evolution of the symbionts and its functional implications on coral reef health. We also study the role of microbiome in the accumulation of heavy metals in drought-resistant plants and in rehabilitating mined lands.

Scalable phylogenomics

Scalable comparative approaches are highly desirable when analysing genome-scale sequence data. The conventional approach based on multiple sequence alignment assumes (albeit unrealistically) that homologous sequences are contiguous in full length; it is also computationally intensive. We are developing and exploring alignment-free methods (e.g. based on *k*-mers) in large-scale inference of genome evolution as networks, beyond the conventional tree-like assumption of evolutionary history.



Techniques you learn in our group may include: *de novo* genomics, bioinformatics, scripting (Python/R), high-performance computing, comparative genomics, phylogenetics, phylogenomics, molecular evolution

Useful Majors/Minors: Bioinformatics / Biochemistry & Molecular Biology / Biomedical Science / Computational Science / Genetics / Microbiology

PROFESSOR JACK CLEGG

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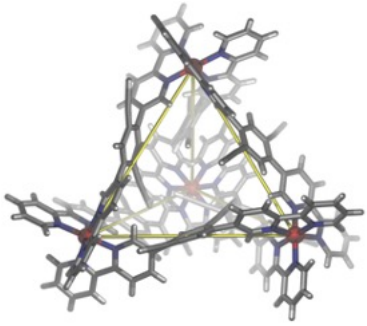
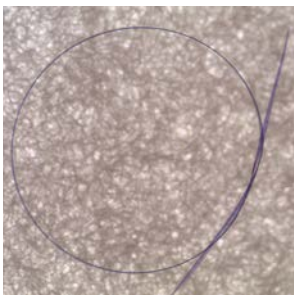
Research Area

My research is in the field of metallo-supramolecular chemistry and bridges the traditional fields of organic and inorganic chemistry. I use a self-assembly approach and by combing the inherent physical and chemical properties of metals with organic (ligand) components I can design and synthesis new materials with central cavities that are capable of selectively binding smaller molecules. The resulting nanoscale structures can be either discrete or polymeric (framework) in nature. The potential applications for these compounds are diverse including drug delivery, catalysis, sequestration, separation and gas storage. Many of my compounds are characterised by X-ray diffraction methods. Due to their large size, somewhere between average “small” molecules and biological macromolecules (and challenging diffraction properties), I often employ synchrotron radiation for analysis.

Metallo-supramolecular capsules and cages

Careful consideration of the geometrical properties of metals and organic components allows for the construction of a variety of discrete “supermolecules” formed from the spontaneous aggregation of numerous predesigned components. These structures, often with central cavities, take numerous forms from two-dimensional architectures such as triangular and square architectures to elaborate and beautiful three-dimensional species such as tetrahedra and cubes. Changing the size, shape, properties and charge of the architecture allows for the selective encapsulation of different materials inside them. Anions, cations, multiple solvent molecules, gases, drug molecules and pyrophoric substances have all been shown to be bound inside the larger self-assembled molecules.





Flexible Crystals

Single crystals are typically brittle, inelastic materials that crack, shatter or deform irreversibly when they are struck or bent. We have recently discovered a series of materials that possess the characteristics of both crystallinity and significant flexibility including single crystals of a metal-organic complex that exhibit sufficient elastic flexibility that they can be tied in a knot and are in the process of working out how and why this is the case.

Techniques used in our group include: Synthesis, PXRD, SCXRD, NMR, M/S, IR, Gas Sorption, DFT

Useful Majors/Minors: Chemistry / Computational Science / Engineering majors / Physics

PROFESSOR JAMES DE VOSS

Head of School

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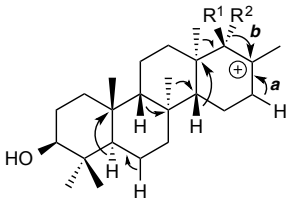
Biological and Synthetic Chemistry



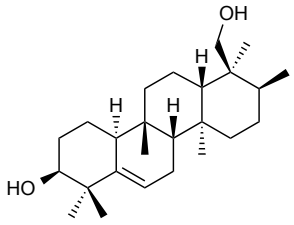
My group is concerned with *biological* and *synthetic* chemistry and in particular with the application of chemical principles to the understanding of biological processes. While some projects are purely synthetic in nature, most are a blend of the range of disciplines that make up modern bio-organic chemistry: molecular biology, protein purification and characterisation, synthesis and structure determination.

Our goals are to:

- Understand the mechanism of enzyme catalysed oxidations
- Discover the bioactive constituents of herbal medicines
- Synthesise herbal constituents and small molecule probes of enzyme mechanism

Cytochromes P450

The cytochromes P450 are a superfamily of oxidative haemoproteins that catalyse an amazing variety of oxidative transformations, ranging from simple alkene epoxidation all the way through to oxidative carbon carbon bond cleavage. P450s are of interest as they (i) are often unique enzymes in a biosyntheitc pathway and as such represent new targets for therapeutic agents or (ii) are extremely efficient biodegradative/biosynthetic catalysts that offer the potential of developing tailored oxidative catalysts for synthetic transformations. We are interested in understanding the mechanism of action of P450s that catalyse interesting and unusual biosynthetic and biodegradative reactions. This may eventually allow prediction of the types of reactions catalysed by P450s and their use in organic syntheses.



PhytochemicalCharacterisation of Constituents of Medicinally used Herbs

Whilst herbal medicines are widely used within the general community and have a long history of such use, their chemical constituents are often poorly characterised. This makes assessment of the true biological activity of many of these preparations extremely difficult. In collaboration with a local herbal medicine company (Integria) we have embarked upon a program of phytochemical characterisation of a number of therapeutically prescribed herbs with the aim of (i) determining the structure of their constituents and (ii) understanding the way in which these molecules are biosynthesised.

Techniques you learn in our group may include: Organic synthesis, enantiospecific synthesis, (enantioselective) chromatographic purification, structure determination (especially via nmr), site directed mutagenesis, protein expression and purification.

Useful Majors/Minors: Biochemistry & Molecular Biology / Biophysics / Chemistry

DR EVELYNE DEPLAZES

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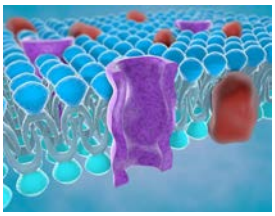
How do small molecules interact with cell membranes?



Our lab studies the interaction of small molecules with biological membranes. This includes endogenous compounds essential to cellular function (e.g. hormones and compounds of interest to drug development). Have a look at this video or our recent outreach article for more details.

Our lab is unique in that it combines biophysical chemistry experiments and computer simulations in the same research group. Find out how computer simulations are used to understand chemical systems in this video.

Our goals are to:

- Understand how small molecules and peptides interact with cell membranes
- Characterise the structure of peptide-induced membrane pores
- Enable the development of new drugs and drug delivery systems

Antifungal peptides

Invasive fungal infections are difficult to treat, and many current drugs are toxic to human cells. This project studies the membrane-altering properties of peptides that increase the potency of existing anti-fungal drugs. Understanding the mechanism of actions of these peptides will help us to develop less toxic antifungal treatments. This industry-funded project is a collaboration with researchers from the University of Sydney and the University of Technology Sydney.

Membrane-active peptides isolated from the venom of spiders and ants

Animal venoms are rich source of bioactive peptides and many show antimicrobial, antiparasitic and cytotoxic acidity that is related to the peptide's ability to damage membranes. We have several potential projects to study the membrane interactions of peptides isolated from spiders or ants. This is a collaboration with researchers from Prof King's group at the UQ Institute of Molecular Bioscience.

Pore forming peptide, including viroporins and antimicrobial peptides

Peptides that self-assemble and induce pores in membranes are ubiquitous in nature. Examples include antimicrobial peptides found in our innate immune systems or viroporins that facilitate the release of virus particles from infected cells. This project aims to characterise the structure of these pores, understand how these pores are formed and provide structural models for drug development.

Steroid – membrane interactions

Steroids exert their biological or pharmacological activities via a range of different mechanism, including by altering the fluidity of cell membranes. We aim to understand how steroids interact with membranes and how this might be used to modulate the function of membrane proteins. This project is a collaboration with researchers from the University of Technology Sydney and the University of Sydney and funded by the Batten Disease Australia.

Techniques you learn in our group may include: Tethered lipid bilayer membranes (a unique technique to study small molecule – membrane interactions, see this video), fluorescence spectroscopy, molecular dynamics simulations, homology modelling.

Useful Majors/Minors: Biochemistry & Molecular Biology / Bioinformatics / Biomedical Science / Biophysics / Chemistry / Computational Science

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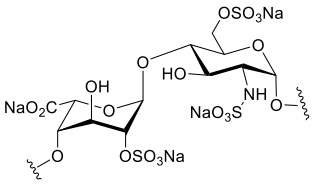
Carbohydrate and Medicinal Chemistry

We are focused on synthetic carbohydrate chemistry and medicinal chemistry. Of major interest is the synthesis of derivatives and mimetics of heparan sulfate (HS), a complex polysaccharide involved in numerous diseases.



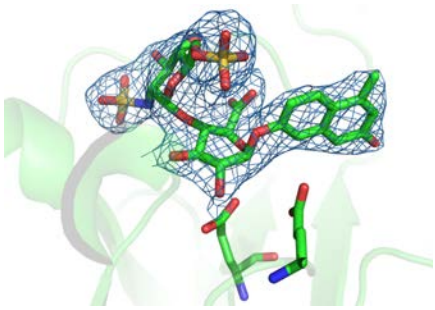
Heparan Sulfate

Our goals are to:

- Develop new methods to synthesise biologically relevant carbohydrates and their derivatives
- Design and synthesise compounds to probe and/or inhibit carbohydrate-protein interactions involved in disease processes

Pharmacological chaperones for MPS disorders

Mucopolysaccharidosis (or MPS) disorders, such as Sanfilippo syndrome, are rare genetic diseases caused by mutations in HS-degrading enzymes, resulting in accumulation of undegraded HS in cells and ultimately fatal brain damage. We aim to design and synthesize small molecules as “chaperones” to protect the defective enzyme from degradation and restore enzyme activity to sufficient levels to alleviate symptoms.



Heparan sulfate mimetics

Many viruses use HS as an entry receptor or co-receptor to initiate infection. We have recently shown that HS mimetics such as pixatimod (aka PG545) are potent inhibitors of SARS-CoV-2, the coronavirus that causes COVID-19. We aim to build on this work by designing and synthesizing novel HS mimetics that block infection and cell to cell spread of SARS-CoV-2 and other viruses. The enzyme heparanase mediates HS catabolism and is of considerable interest due to its prominent role in cancer, inflammation, and viral infections. Building on our structural insights into heparanase catalysis, we aim to synthesize novel probes and inhibitors to study heparanase biology and to develop new therapeutics. Additionally, we are developing new radical-based chemistry to efficiently synthesize rare L-sugars found in HS and on the surface of pathogenic bacteria.

Antibacterial glycoconjugates

We aim to design and synthesize novel glycoconjugates for various antibacterial applications. For example, multivalent structures to block the attachment of pathogenic bacteria to host cells to prevent infections; or adjuvants to stimulate the immune system, or to recruit pre-existing antibodies to kill bacteria; or glycoconjugates to more effectively target antibiotics to bacterial pathogens.

Techniques you learn in our group may include organic synthesis, NMR spectroscopy, mass spectrometry, flash chromatography, TLC, IR, molecular modelling

Useful Majors/Minors: Chemistry / Chemical & Nano Biotechnology / Medical Biotechnology / Nanotechnology

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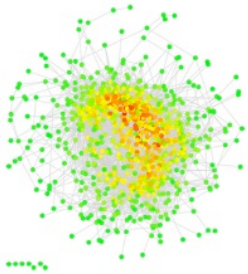
Genetics and genomics of mammalian reproduction



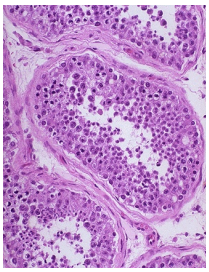
Understanding the physiology of mammalian reproduction has broad implications, from human fertility clinics to livestock productivity. In our group we use genetics and genomics as avenues to discover genes, gene networks and pathways associated with various aspects of mammalian reproduction, using livestock as a model.

Our goals are to:

- Identify mutations, genes and pathways associated with fertility
- Understand the genetic basis and inheritance of reproductive characteristics (aspects of sperm quality, for example)
- Create diagnostic assays (genotyping for fertility traits)

Genomics and gene expression underpinning fertility traits in Australian Brahman cattle

Brahman cattle are of particular importance for the beef industry in Queensland and northern Australia because of the breed's tropical adaptation. However, tropical adaptation comes with associated negative traits such as lower fertility and late puberty. This project has two aims: understanding the biological basis of late puberty in Brahman cattle and delivering a diagnostic tool, a DNA chip, specifically designed to assist selection for improvement in their fertility. Gene expression of key tissues will be measured in pre and post pubertal animals using next generation sequencing. This project is conducted in collaboration with the groups of Prof Stephen Moore (QAAFI), Dr Sigrid Lehnert (CSIRO) and Dr Toni Reverter (CSIRO).



RNA and ncRNA in testicular tissues

Normal sperm cell differentiation, termed spermatogenesis, requires re-organization of sperm DNA structure. The sperm head is much smaller than the nucleus of other cells and DNA must therefore adopt a highly condensed form in order to fit. This mechanism is hypothesized to be regulated by non-coding RNA (ncRNA). An essential role for ncRNA in regulation of spermatogenesis in mice has been demonstrated spermatogenesis (Yadav & Kotaja 2014). But, the impact of ncRNA on male fertility is poorly understood. This research will further investigate the role of ncRNA in spermatogenesis, profiling sperm ncRNA, RNA and protein content in testicular samples that represent three key stages of spermatogenesis.

Genetics of new sperm quality traits

Flow cytometric assays are replacing older methods used to define male fertility. Two emerging flow cytometric assays are the focus of this research: the sperm chromatin structure assay (SCSA) and the sperm protamine deficiency assay (SPDA, developed by our group). Sperm DNA damage measured by the SCSA is a known factor of male sub-fertility in mammals, including humans. We aim to investigate the relationship between protamine deficiency and sperm DNA damage, estimating for the first time the heritability of these sperm quality traits. This project is financed by Meat and Livestock Australia and is conduct in collaboration with Dr Gry Boe-Hansen and Dr Nana Satake (SVS).

Techniques you learn in our group may include: Quantitative Genetics, molecular genetics, bioinformatics, next generation sequencing, SNP genotyping, flow cytometry, analysis of sperm quality.

Useful Majors/Minors/Programs: Agricultural Biotechnology / Biochemistry & Molecular Biology / Bioinformatics / Biomedical Science / Computational Science / Genetics / Veterinary Science

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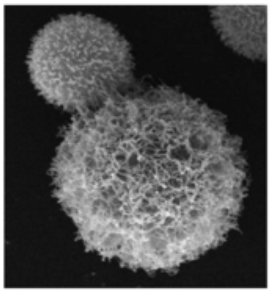
Fungal Pathogens of Humans



Cryptococcus neoformans, an encapsulated pathogenic yeast.

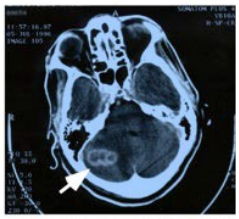
As immunosuppressed patient populations grow, the incidence of secondary infections from fungal pathogens has risen sharply to become a significant cause of death. Research in the Fungal Pathogenesis Laboratory focuses on species including *Cryptococcus neoformans*, the cause of one of the leading life-threatening infections in AIDS patients.

Our goals are to:

- Create new drugs for treating life-threatening fungal infections
- Identify how fungi evolve during infection to become more pathogenic
- Understand how primary metabolism and virulence are linked

Antifungal Development

Cryptococcosis is one of the top three killers of AIDS patients worldwide, in part due to the absence of an adequate array of antifungal drugs. We are addressing this need by pursuing the development of novel antimycotic agents active against *C. neoformans* and other fungal pathogens. Our current focus is on targets in the purine biosynthetic pathway, where we have been using mutagenesis, virulence models, crystallisation and high throughput screens to identify novel lead compounds upon which to base new therapeutic agents. This project is the focus of a collaboration with the groups of Prof. Bostjan Kobe and Assoc. Prof. Ulrike Kappler.



CT scan of brain lesions (indicated) caused by *C. neoformans* infection.

Microevolution of a Pathogen during Infection of Humans

Even if a patient survives an infection by *C. neoformans*, they often suffer relapse infections that are even more deadly. We have shown that while in the human host the strains causing these recurrent infections have accumulated mutations that are associated with virulence, facilitating relapse. Using next-generation sequencing of the genomes of series of isolates from individual patients, we are developing a deeper understanding of this process. By combining our bioinformatic studies with molecular genetic techniques, we are revealing weaknesses in the pathogen that we hope to exploit in our antifungal development program.

A New Era of Molecular Genetic Tools

The molecular genetic manipulation possible in an organism is limited by the toolkit of techniques available. In order to enable studies of ever-growing complexity investigating drug targets and mechanisms of virulence, we have developed a range of constructs and techniques that enable powerful genetic engineering of *Cryptococcus neoformans* that range from CRISPR and inhibitors of non-homologous end joining to facilitate targeted genetic manipulations, to a spectrum of fluorescent markers, a variety of tandem affinity purification tags and repurposed selectable markers. We continue to develop new technologies that empower our research, making more complex experimental design and greater discoveries possible.

Techniques you learn in our group may include: Cloning, gene deletion, genomics, protein purification, crystallisation, eukaryotic virulence models, next-generation sequencing, antifungal testing, karyotyping.

Useful Majors/Minors: Biochemistry & Molecular Biology / Bioinformatics / Biomedical Science / Biophysics / Chemistry / Computational Science / Genetics / Microbiology

PROFESSOR IAN GENTLE

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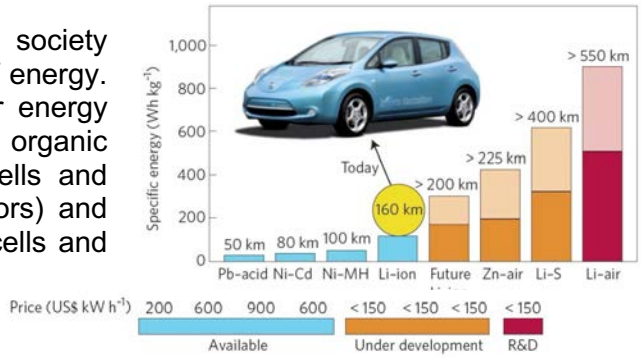
Energy Materials

Some of the biggest technological challenges facing society today are related to the generation, use and storage of energy. Advanced materials will play an important role in our energy future. In our group we are investigating materials for organic optoelectronic devices (light emitting diodes, solar cells and sensors), energy storage (batteries and supercapacitors) and catalysts for electrochemical energy conversion (fuel cells and batteries).

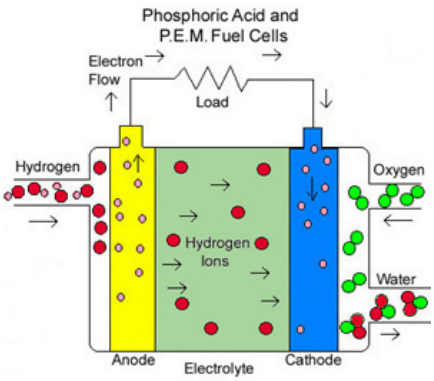


Our goals are to:

- Develop new materials for electronic devices
- Understand their behaviour using advanced characterization techniques
- Use this knowledge to design new materials and devices

Understanding interfaces in organic electronics

Over the past few years we have made good progress in the study of diffusion of organic materials in multilayer devices such as those found in organic light-emitting diodes and organic solar cells. It has now become clear that the interfaces between the organic materials and the inorganic electrodes can play a critical role in the performance and long-term stability of such devices. Using neutron reflectometry we have a unique method to study such interfaces, leading to insights that should allow us to engineer better devices with higher efficiencies and better durability.



Carbon materials for electrocatalysis

The reactions that occur in fuel cells and metal air batteries involve the reduction of oxygen to water. Because this reaction is sluggish a good catalyst is required and while noble metals such as platinum are good catalysts, they are expensive and scarce. Our goal is to design a carbon-based material to catalyse the oxygen reduction reaction in a similar way to platinum but at a much lower cost.

Carbon materials for energy storage

Electric vehicles are likely to play an important role in future transport solutions, particularly in cities. The major technological challenge facing widespread adoption of electric vehicles is the ability to store large amounts of energy in batteries that are light, durable, safe and low cost. We are researching carbon materials for use in lithium sulfur batteries, which offer the potential to store at least three times more energy than the current lithium ion technology and are cheap and easy to produce in large quantities.

Techniques you learn in our group may include: neutron reflectometry, film fabrication, electrochemical methods (CV, linear sweep voltammetry), battery fabrication and testing, electron microscopy, XPS.

Useful Majors/Minors: Chemistry / Computational Science

PROFESSOR ELIZABETH GILLAM

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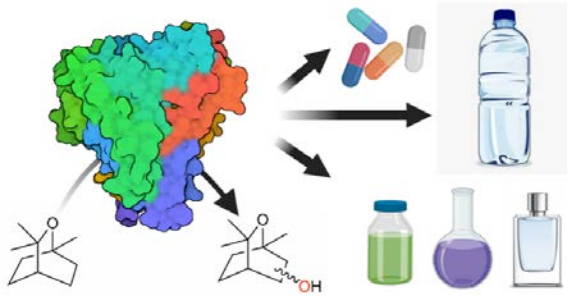
Synthetic Biology, Biocatalysis and Enzyme Evolution

Cytochrome P450 enzymes catalyse more than 60 different chemical transformations on a structurally diverse substrates, making them one of the most versatile groups of biocatalysts known. They are ancient enzymes distributed through all domains of life and carry out diverse roles such as in the synthesis of hormones, the utilisation of carbon sources, the production of defensive molecules such as antibiotics, and the clearance of drugs and toxins.



Our goals are to:

- Determine what factors drive P450 evolution
- Create novel enzymes and systems that use P450s in clever ways for useful purposes

P450s for green, solar-powered chemistry in drug development and bioremediation

We have developed extremely thermostable P450s that are very useful in industry since they can withstand long incubations at elevated temperatures. They can be used as 'off-the-shelf' reagents to catalyse useful chemistry, such as in drug discovery, fine chemical synthesis, and cleaning up the environment. Working with drug companies, we are exploring the structural features that make them efficient, robust and specialised, and how they can be best deployed in chemical processes. To make such processes cheaper and more sustainable, we are using synbio to immobilise P450s in protein cages and power P450 reactions for clean, green biocatalysis in algae.

Ancestral reconstruction of P450s, enzymes evolved to deal with the unknown in animal-plant-microbial chemical warfare

P450s metabolise ~ 95% of all drugs as well as innumerable environmental chemicals. This is an extraordinary range of substrates, many of which have not been present during evolution. We are studying how P450s have evolved to deal with such novel substrates by reconstructing ancestral precursors and evolutionary pathways. We are exploring such questions as how did the koala evolve to live on eucalyptus leaves, a toxic diet for most mammals.

Engineering P450s to improve food security and agricultural productivity

P450s are involved in the biosynthesis of strigolactones (SLs), plant hormones that control plant architecture, nutrient uptake and responses to parasitic weeds that cripple food production in the third world. Applying synthetic SLs to infested soils could clear arable land of parasitic weeds and enhance food production. We are engineering P450s to make novel, 'designer' SLs to counter parasitic weeds, improve nutrient uptake from poor soils and boost agricultural productivity.

Techniques you learn in our group may include: protein engineering, artificial evolution, synthetic biology approaches, enzymology, high throughput screening, bioinformatics, ancestral sequence reconstruction, fundamental methods of molecular cloning, protein purification and LC-MS analysis of small molecules.

Useful Majors/Minors: Biochemistry & Molecular Biology / Bioinformatics / Biophysics / Chemistry / Chemical Biology / Biotechnology / Genetics / Microbiology / Biomedical Science / Plant Science

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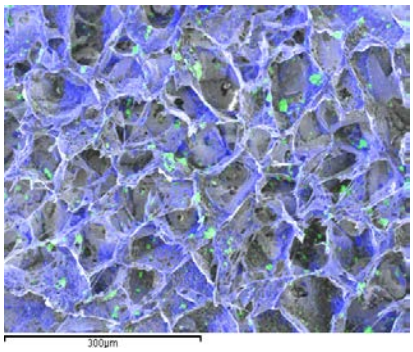
Research Area

The primary research area of the Grondahl Group is in materials design and evaluation. All projects builds on Physical and Materials Chemistry fundamentals.

Surface modification of polymeric materials

Polymeric materials including membranes are optimised with regards to their bulk properties but for many applications the surface properties are not ideal. Applications of surface-modified polymeric materials span from biomaterials science and tissue engineering to food science and water purification. This project will involve surface grafting of polymeric chains on polymeric substrates using free radical polymerisation. The modified materials will be evaluated with respect to surface chemistry, surface energy, surface roughness and viscoelastic properties were appropriate for the application. In addition, the modified materials will be tested for their performance in the intended application, eg. in vitro mineralisation, protein interactions, cell interactions.



Composite nano-materials for bone repair

Bone tissue engineering makes use of scaffolds for cell seeding. These scaffolds must have good mechanical integrity and bone-bonding ability. In order to achieve this, biocompatible polymers are combined with nano-sized filler particles. The function of the filler particles is two-fold: to enhance bone bonding ability and to enhance mechanical properties. However, to achieve this good dispersion as well as strong interfacial bonding with the polymer matrix is required. This project will use chemically modified hydroxyapatite nano-particels and study their dispersion both in solution and in polymer substrates. Evaluation of both in vitro mineralisation and mechanical properties will also form part of the project.

Protein delivery from polysaccharide systems

Delivery of protein drugs and nutraceuticals at an appropriate rate and with high bioactivity retained can be achieved by using a polysaccharide matrix material. Depending on the protein of interest and its intended application the polysaccharide matrix can be chemically modified to achieve a desired rate of release. Applications include delivery of growth factors to regenerate damaged tissue and incorporation of proteins with human benefit in food products. The project will involve the use of the polysaccharide alginate which will be modified with chemical moieties to modulate the intermolecular interactions with the protein thereby allowing for tailored rates of release. The chemically modified alginate will be evaluated using eg. NMR and FTIR while the intermolecular interactions between the protein and polysaccharide will be evaluated by eg. light scattering, and turbidity. Furthermore, the protein encapsulation efficiency and the release rate will be evaluated.

Techniques you learn in our group may include: XPS, FTIR, SEM, TEM, XRD, AFM.

Useful Majors/Minors: Chemistry / Chemical & Nano Biotechnology / Chemical Biology

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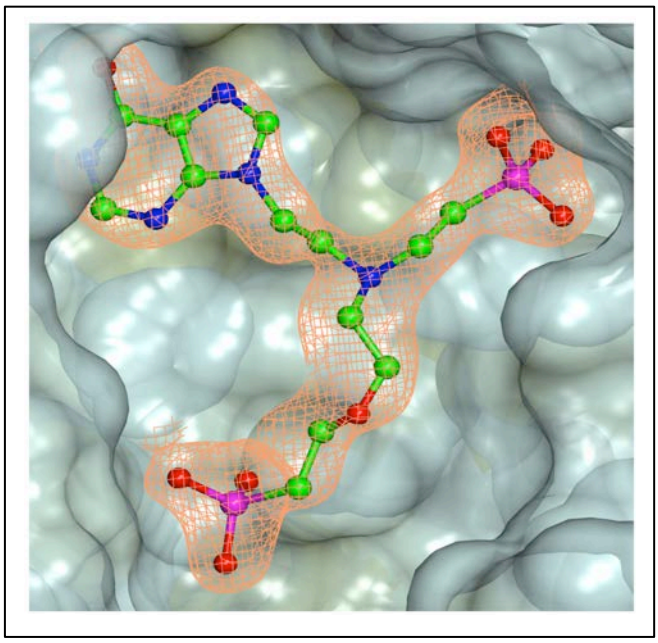
Research Focus: X-ray crystallography and Drug Design

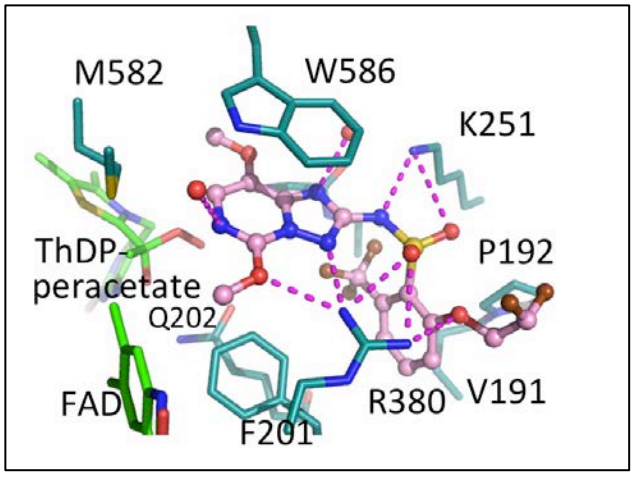


Our research is focused on understanding the structure, function and inhibition of enzymes that are essential to life. In particular, we are interested in studying enzymes involved in the synthesis of (i) RNA and DNA via the salvage pathway and (ii) the branched chain amino acids (BCAAs). These pathways are essential to the survival of many human pathogenic bacteria, parasites and fungi. For drug design this is a big advantage because humans and other animals either do not possess these pathways (*i.e.* BCAA pathway) or have alternative pathways (i.e. the *de novo* pathway for the biosynthesis of nucleoside monophosphates that are incorporated into RNA and DNA).

Our goals are to:

- Use X-ray crystallography to understand the structure and function of enzymes
- Use rational structure based drug design to develop potent enzyme inhibitors that can be tested as antimicrobial therapeutic drugs

Research Projects are available in a number of areas and can be tailored for honours, masters, masters by coursework and PhD students. Projects can range from protein expression, purification and characterization, to biological assays (e.g. testing for antimicrobial activity), to computer based drug design, chemical synthesis and X-ray crystallography. X-ray crystallography is the major technique used in this laboratory, but through collaborations with other research scientists (at UQ and overseas) we encourage multidisciplinary projects.



Useful Majors/Minors: Biochemistry & Molecular Biology / Bioinformatics / Biomedical Science / Biophysics / Chemistry / Computational Science / Genetics / Microbiology

PROFESSOR PHIL HUGENHOLTZ

UQ Laureate Fellow

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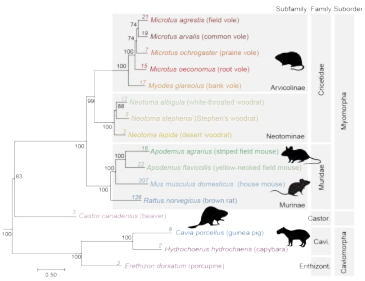
Ecogenomics

Most microorganisms have not been grown in the laboratory and, until fairly recently, we have been unaware of their existence. At the Australian Centre for Ecogenomics (ACE; https://ecogenomic.org), we explore and study this microbial dark matter in its ecological and evolutionary context using a culture-independent molecular toolbox, which includes metagenomics, single cell genomics, metatranscriptomics and imaging. Almost any microbial ecosystem can be characterised in this way and we have applied the molecular toolbox to a wide range of environmental and clinical habitats, some of which are described below. We also invest time and energy classifying microorganisms through phylogenetic analysis of their genomes (*https://gtdb.ecogenomic.org*) as this is a fundamental requirement for characterising microbial communities.

Marsupials and rodents



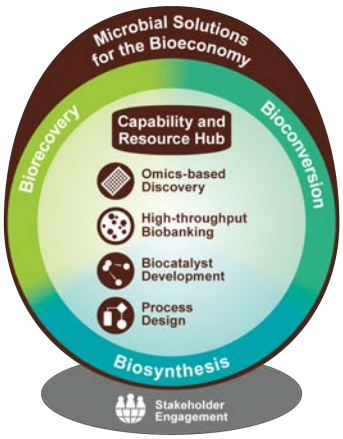
Australia is home to some of the most iconic animals on the planet, but surprisingly they have not been greatly investigated in terms of their microbiomes. We have a number of projects in this space including characterisation of the koala gut microbiome to assist in translocation of animals to new habitats with different types of eucalyptus leaves, characterisation of prominent uncultured taxa in the rodent gut microbiome and evolutionary surveys of diprotodont marsupials and rodent families.

Marine ecosystems

Marine microorganisms drive the ocean's major biogeochemical cycles and play vital roles in maintaining ecosystem health and resilience under environmental stress. Our aim is to combine molecular methods with experimental validation to unravel the marine microbial world. Projects in this space span a range of fields; from marine ecotoxicology and climate change impacts on ecosystem functioning, to symbiosis in marine invertebrates and harnessing microbial biofilms for coral reef restoration.

Microbial solutions for the Bioeconomy

The world is transitioning to renewables as part of a global push towards circular bioeconomies. Microorganisms and their enzymes are a vast untapped reservoir of biocatalysts which can help to establish the bioeconomy. We are probing this resource for industrially useful biocatalysts for a range of applications including recovery of rare earth elements from mining waste and biosynthesis of fine chemicals.



Techniques you learn in our group may include: metagenomics, metatranscriptomics, single cell genomics, comparative genomics, phylogenetics, fluorescence in situ hybridisation, bioinformatics, taxonomy

Useful Majors/Minors: Microbiology / Biochemistry & Molecular Biology / Bioinformatics / Biomedical Science / Computational Science / Genetics / Biophysics

DR MATHEW JONES

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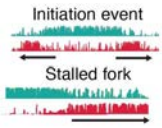
Research Video:
https://www.youtube.com/watch?v=KVxjxkJX-4Y&t=1s

Research Focus

Jones laboratory studies the cellular processes that control how healthy and cancerous cells grow and divide. We use a range of advanced microscopy techniques *(high content imaging & timelapse microscopy)*, DNA sequencing methods *(nanopore sequencing)* and genome engineering tools *(CRISPR/Cas9)* to study the human cell cycle and identify new druggable vulnerabilities that are selectively toxic to cancers.

Nanopore Sequencing



Our goal is to improve the specificity of cancer treatments by making fundamental discoveries about how cancer cells replicate their genome. These discoveries can be translated into chemotherapy treatments by

1. Targeting pathways that allow cancer cells to grow uncontrollably.
2. Exploiting genetic vulnerabilities that disrupt the ability of cancer cells to copy their genome or repair damaged DNA.

Improving cancer treatment by targeting DNA replication and repair
DNA replication is the fundamental mechanism of genetic inheritance and an essential process for all cellular life. In cancer cells, replication is corrupted and replication forks frequently stall and collapse causing DNA damage and copying errors that drive tumorigenesis. As a result, cancer cells are heavily dependent on the pathways that protect and repair stalled replication forks. Disrupting these mechanisms can be selectively toxic to cancer cells. A key player in the regulation of DNA replication and repair is DDK (Dbf4-dependent kinase also known as Cdc7). DDK is frequently overexpressed in cancer, but its role during DNA replication and the repair of stalled replication forks by homologous recombination has not been well characterised. Our research uses chemical genetic approaches to selectively target DDK and gain valuable insights into its requirements and molecular targets. We have two projects for students.

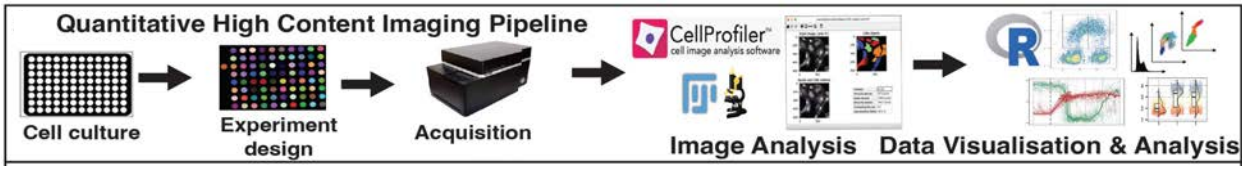
Project 1: aims to understand how DDK coordinates DNA replication and repair to help develop new therapeutic strategies to target these processes in breast cancer cells.

Project 2: aims to study how stalled replication forks are repair by homologous recombination in BRCA1/2 mutant breast cancer cells.

Techniques you learn in our group may include: Advanced confocal, widefield and super-resolution microscopy methods for imaging fixed and live human cell lines. Quantitative image analysis approaches that use machine learning software to segment and analyse images and tools for plotting extremely large datasets. Genome editing approaches to disrupt genes and nanopore ultra-long DNA sequencing methods to study DNA replication fork progression across the genome.

Useful Majors: Biochemistry & Molecular Biology / Bioinformatics / Biomedical Science / Computational Science / Genetics / Cell Biology

Useful Skills (not required): Experience in coding and programming languages including R, Python and Matlab. A genuine interest and enthusiasm for science, discovery and learning new methods.



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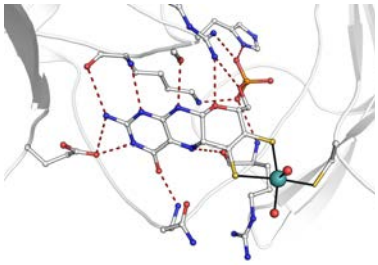
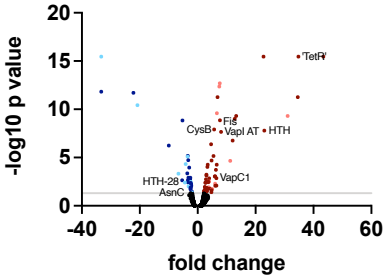
Research Area



I have always been fascinated by microbes and especially their ability to shape any environment they inhabit, including the human body. These interactions include the manipulation of host cells to reduce responses to infection, but also the development of specific processes that increase resistance to host produced antimicrobials, such as bleach and hydrogen peroxide. Using a wide range of techniques my group tries to understand

- How bacteria and host cells interact via the exchange of chemical signals
- Roles of bacterial (metallo-)enzymes in repairing and preventing fatal damage from antimicrobials
- The contribution of bacterial metabolism to survival in the host organism

How do bacteria manipulate host cells? - Interactions between *Haemophilus influenzae* and the human host *H. influenzae* (Hi) can cause respiratory tract infections of varying severity as well as invasive disease (septicaemia) but is unable to survive outside the human host. As a result, Hi is able to manipulate host metabolism and immune responses to enable it to 'stay alive' in its favourite niche. We are investigating how protein effectors, metabolites and specialized growth substrates contribute to Hi - host interactions in a range of clinical isolates by altering host cell metabolism and Hi host cell colonization.



Molecular determinants of resistance to natural antimicrobials This project aims to unravel how *Haemophilus influenzae* can resist a range of natural antimicrobials that are either produced by the human host (bleach, N-Chlorotaurine) or derived from plants such as allicin. Key questions are which enzymes and regulators are required to reverse cellular damage caused by these compounds and the mechanisms by which the antimicrobials affect the integrity of the bacterial cell.

Metalloenzymes and their roles in bacterial physiology Metalloenzymes are highly versatile and underpin essential reactions in all living cells, however, many of these enzymes are little studied, and even less is known about their role in the physiology of various bacteria. We have several current projects available looking to identify novel metalloenzymes & pathways involved in reactive sulfur compound detoxification in various species of bacteria, and we also study proteins involved in the regulation of these enzymes.

Techniques you learn in our group may include: molecular microbiology, bacterial genetics & physiology, RNA techniques, protein purification, enzyme kinetics, systems biology techniques, phylogenetic analyses

Useful Majors/Minors: Microbiology / Biochemistry & Molecular Biology / Bioinformatics / Biomedical Science / Chemistry / Genetics

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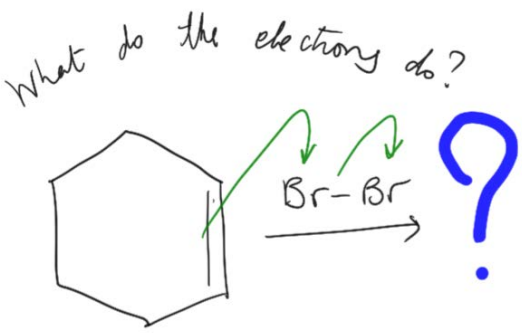
Chemistry Education Research

My interests and research focus mainly on how students learn new concepts in chemistry and how chemistry educators use this information to create learning tools to support their students. My research draws on constructivism, that is on the idea that students construct new knowledge by putting together pieces of their prior knowledge and the new material they are immersed in through their learning experiences. This makes learning an active process and students active agents in their learning journey.

Specific areas I am exploring currently include:

- How first year students learn in an introductory organic chemistry context
- How peer support and interactions help students develop a sense of community and belonging and how this affects their learning experiences and outcomes.



Understanding and representing organic reaction mechanisms

Students start learning about chemical reactions in high school. As they begin studying chemistry in their first year at UQ, they are introduced to organic reaction mechanisms. Reportedly, this is a topic a large number of students find hard. The aim of this project will be to investigate how our students think about reaction mechanisms, and what parts of this process they find hard.

Student peer support in learning

In the last two years, as a large portion of our learning activities has been moved online, many students feel disconnected from the university and student life. The objective of this project is to work with students to firstly try and define their emotion of disconnect as well as the effect it has in their learning and student experience overall. Lastly, the aim is to create a volunteer peer support and mentoring program in chemistry that will enable us to give our students a sense of belonging, while being part of a supporting learning community.

Techniques you learn in our group may include: Quantitative and qualitative research methods, including statistical analysis of psychometric data and interview skills. Information and communication technology skills and instructional design using new media and online tools.

Useful Majors/Minors/Programs: Chemistry / Biochemistry & Molecular Biology / Psychological Sciences / B Education + B Science Dual program

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Research Area

We study molecular mechanisms of virus replication, virus-host interactions, and viral pathogenesis of the mosquito-transmitted flaviviruses West Nile virus (WNV) and Zika virus (ZIKV) as well as Severe Acute Respiratory Syndrome coronavirus 2 (SARS-CoV-2). We use a combination of classical molecular biology and virology approaches as well as modern state-of the art molecular methodologies.

Our goals are to:

- Identify viral and host determinants of WNV, ZIKV and SARS-CoV-2 replication and virulence
- Understand mechanisms by which the identified virulence determinants influence outcome of infection
- Apply obtained knowledge to development of effective vaccines and antivirals

Viral and host proteins determining outcome of flavivirus infection

The projects aim to identify viral and host proteins responsible for determining outcomes of infection with WNV and ZIKV. The projects will employ cutting edge molecular methodologies based on the generation of large libraries of (i) flaviviruses with all amino acid mutants in each codon of viral proteins; and (ii) recombinant flaviviruses producing siRNAs targeting entire host genomes. High throughput screening of these viral libraries in vitro and in vivo followed by deep sequencing of enriched virus populations and sophisticated bioinformatics will allow identification of (i) residues in viral proteins essential for viral pathogenicity, and (ii) host proteins restricting virus replication

The role of viral noncoding RNAs in flavivirus-host interactions

Flaviviruses including WNV, ZIKV and insect-specific flaviviruses (ISFs) produce several non-coding RNAs from their 3' untranslated region, including subgenomic flavivirus RNA (sfRNA) that play vital roles in virus replication and virus-host interactions. The projects aim to determine the role and mechanisms of action for viral non-coding RNAs in flavivirus-host interactions and host restriction. The projects will employ RNAseq, bioinformatics, quantitative RT-PCR, RNA interference, small RNA detection, RNA-protein interactions, and proteomics to generate comprehensive networks of processes in infected cells regulated by viral non-coding RNAs.

Dissecting COVID-19 pathogenesis and development of vaccines and antivirals

We have generated a reverse genetic system for SARS-CoV-2 allowing rapid manipulation of the SARS-CoV-2 genome. The projects aim at using this system along with deep mutational scanning of viral proteins to identify viral determinants responsible for the evasion of innate immune response and antibody escape. The obtained knowledge will be applied to design new vaccines and antivirals.

Techniques you learn in our group include: Molecular cloning, DNA and RNA transfections, RNA isolations, quantitative RT-PCR, generation of viral infectious cDNA clones and large libraries of mutant and recombinant viruses, protein expression and detection, RNA interference, small RNA detection and functional analyses, CRISPR knock-out, recombinant lentivirus gene delivery, Next Gen sequencing, bioinformatics.

Useful Majors/Minors: Biochemistry & Molecular Biology / Bioinformatics / Biomedical Science / Biophysics / Chemistry / Computational Science / Genetics / Microbiology / Microbiolgy, Infection & Immunity

PROFESSOR BOSTJAN KOBE

ARC Laureate Fellow

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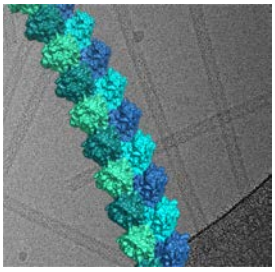
Structural biology of infection and immunity

The group's research theme involves protein structure and function, with an emphasis on understanding the structural basis of interactions formed by these macromolecules, and inferring function from structure. The biological focus is on proteins involved in infection and immunity. The main techniques are X-ray crystallography and cryo-electron microscopy, combined with molecular biology, biophysical and computational approaches.
Our goals are to:

- Use structural and molecular information to understand the molecular and cellular functions of proteins
- Validate proteins as therapeutic targets or biotechnological products
- Design new therapeutics and biotechnological applications

Molecular and structural basis of innate immunity

Innate immunity receptors detect pathogens and endogenous danger and initiate immune responses. In humans, innate immune pathways are associated with infectious, autoimmune, inflammatory, cardiovascular diseases and cancer. In plants, diseases account for a large portion of crop losses, and plant immune receptors represent an environmentally safe strategy to protect crops. Our aim is to use structural biology to understand the molecular basis of innate immune responses. In the animal system, we are focusing on the proteins involved in signalling by Toll-like and interleukin-1 receptors and associated proteins. In the plant system, we are focussing on the interaction between pathogen effector proteins and plant NLR (nucleotide binding/leucine-rich repeat) resistance proteins that initiate immune responses.



Molecular and structural basis of bacterial, viral and fungal pathogenesis

Infectious diseases continue to cause global morbidity and millions of deaths per year. Our aim is to use structural biology to understand the processes of pathogenesis by different pathogens. The work has implications for developing anti-infectives and vaccines against bacteria (e.g. Streptococcus pneumoniae), viruses (e.g. dengue), and fungal pathogens (e.g. Cryptococcus neoformans).

Techniques you learn in our group may include: Recombinant protein expression and purification, X-ray crystallography, cryo-electron microscopy and other structural biology methods, protein interaction analyses and biophysical characterization, molecular biology, bioinformatics and computational biology.

Useful Majors/Minors: Biochemistry & Molecular Biology / Bioinformatics / Biophysics / Chemistry / Computational Science / Microbiology

ASSOCIATE PROFESSOR ELIZABETH KRENSKE

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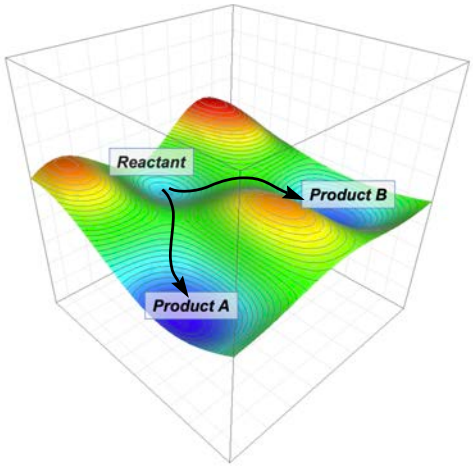
Computational Modelling, Chemical Reactivity, and Drug Design

Researchers in my laboratory uses sophisticated computer simulations to study the inner workings of chemical reactions. We focus on reaction pathways, using computer modelling to generate atomic-level insights about how molecules react. We apply these techniques to a variety of interesting problems, ranging from how a drug interacts with a specific therapeutic target inside the body, to how complex synthetic molecules can be made efficiently in the laboratory.

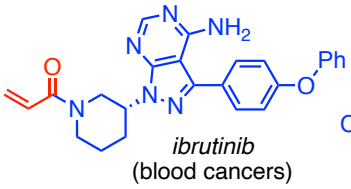
Our goals are to:

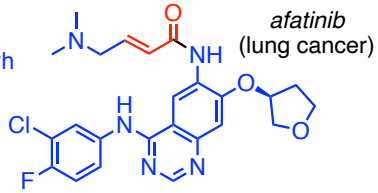
- Map out reaction pathways
- Understand reaction outcomes
- Design new drugs, reactions, and catalysts



Exploring Drug–Target Interactions

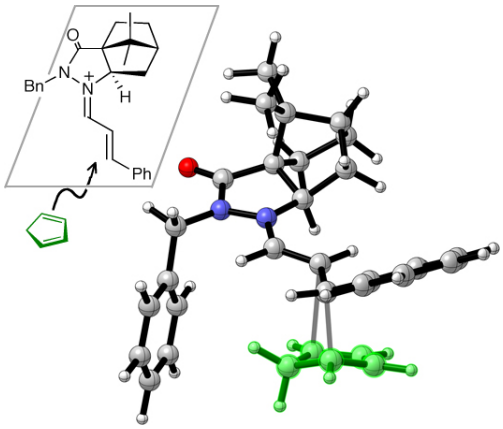
We are researching a new class of drugs called *covalent modifiers*. Through molecular modelling, we are studying how these drugs interact with biomolecules and what controls their behaviour. Our simulations are helping to uncover the ways in which covalent modifiers' structures influence their therapeutic activities and safety profiles as prospective drugs.





Designing New Catalysts

We also study *designer catalysts* that enable new kinds of chemical reactions to be carried out. Our modelling provides detailed pictures of the transition states of catalyzed reactions, uncovering hidden features responsible for controlling reaction outcomes. These insights help guide the discovery of more efficient catalysts.



We frequently collaborate with other researchers, including experimentalists, both from within SCMB and around the world.

Techniques you learn in our group may include: Molecular modelling including density functional theory (DFT) calculations, *ab initio* calculations, molecular mechanics and dynamics simulations. Analysis of reaction mechanisms and transition states. High-performance computing.

Useful Majors/Minors: Chemistry / Computational Science

ASSOCIATE PROFESSOR MICHAEL LANDSBERG

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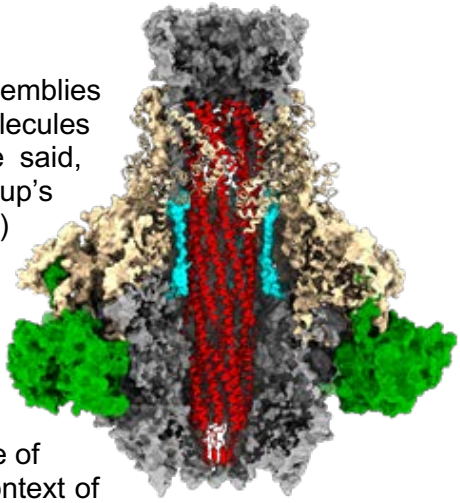
Structure and function of molecular machines



Our group studies molecular machines; large, biomolecular assemblies that are formed when proteins and other biological macromolecules interact. The well-known theoretician Richard Feynman once said, "*What I cannot create, I do not understand*" and our group's philosophy is that it is difficult to create (and thus understand) something without first knowing what it looks like. To this end, we use structural biology techniques, primarily electron cryo-microscopy to investigate the structure (and ultimately understand the function) of molecular machines.

Our goals are to:

- Determine novel structures of protein complexes that are of fundamental biological importance, particularly in the context of microbial pathogenesis and disease
- Elucidate biological mechanisms and establish new insights into function
- Develop novel, protein-based therapeutics and biotechnologies based on these discoveries

Structure and function of pore-forming bacterial toxins

Pore-forming toxins (PFTs) are molecular machines that compromise the impermeability of cellular membranes by quite literally punching holes in them. Our lab has played a key role in the discovery of a new family of bacterial PFTs, known as ABC toxins. These toxins function by specifically recognising receptors on the surface of targeted cells, and deliver a highly potent, cytotoxic enzyme through the membrane pore. We are particularly interested in learning more about how ABC toxins recognise cell surfaces, as well as understanding in more detail the mechanism of toxin translocation and the role ABC toxins play in bacterial pathogenesis.

Multienzymes and multifunctional protein complexes

We are also interested in using structural biology techniques to uncover the complex and often unexpected mechanisms that result when Nature combines multiple enzymatic activities into a single, large protein or protein complex. Such "functional aggregation" usually confers an efficiency dividend for the cell or organism, driven by evolution in response to a high cellular demand. It thus follows that mutations in human multienzymes are often closely associated with severe diseases including cancer, while inhibitors of multienzymes in pathogenic microrganisms are often effective antimicrobials.

Our expertise in cryo-EM also sees us contribute towards a variety of projects involving the structural characterisation of virus particles, viral proteins, and candidate viral vaccine antigens.

Techniques you learn in our group may include: Protein expression, purification and characterization, electron cryo-microscopy, single particle image processing, 3D structure interpretation and modelling, novel molecular imaging methodologies, bioinformatics.

Useful Majors/Minors: Biochemistry & Molecular Biology / Biophysics / Bioinformatics / Chemistry / Computational Science / Microbiology

PROFESSOR GWEN LAWRIE

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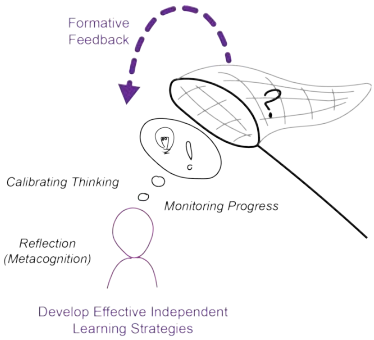
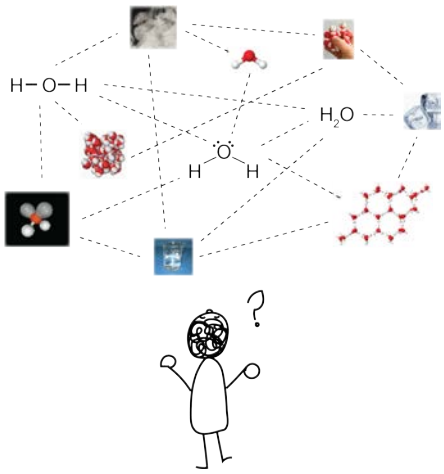
Science & Chemistry Education Research

Science education research enables us to develop richer and more responsive environments to support student learning. Instructional design informed by research involves evidence of how students construct their understanding of chemistry concepts as well as the factors that motivate and engage them in learning. Our current research explores:

- how multimodal external representations of concepts can be effectively integrated to construct student understanding of concepts in digital learning environments.
- the effectiveness of online assessment approaches that aim to authentically capture student thinking, informing the provision of formative feedback.





Development and evaluation of multimodal resources

Learning chemistry (and science) requires that students develop accurate internal mental models of concepts; hence instructors often use multiple external representations (MERs) in their teaching. MERs are typically adopted to provide complementary information; more strategic approaches involve integration of MERs to promote students' construction of deeper understanding. Our research explores how the translation, combination and sequencing of external representations across multiple modes can improve student learning. Our work has investigated several aspects of student learning including their visuospatial skills and the cognitive load introduced through multimedia representations. Current research aims to gain deeper insights into effective pedagogies and practices in teaching chemistry involving the combination and creation of virtual and tactile (including 3D printing) resources.

New approaches to assessment in digital learning environments.

This research investigates the format and timing of formative feedback on student learning in hybrid learning environments. Instructional strategies, informed by research and evaluation findings, have been designed that make students' thinking explicit, as well as capturing their actions in response to formative feedback. The role of instructional scaffolding to support students' development of critical reasoning and metacognitive skills is under exploration applying discourse analysis as a methodological framework. The aim of this project is to design authentic online assessment tasks requiring the design of stimulus resources that involve complex real-world chemical systems.

Techniques you learn in our group may include: Quantitative and qualitative research methodologies including statistical analysis of psychometric data and interview skills. Information and communication technology skills and instructional design involving multimodal and digital resources/tools.

Useful Majors/Programs: Chemistry / Biochemistry & Molecular Biology / Psychological Sciences / B Education + B Science Dual program

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Immunotherapy for non-melanoma skin cancer (NMSC)

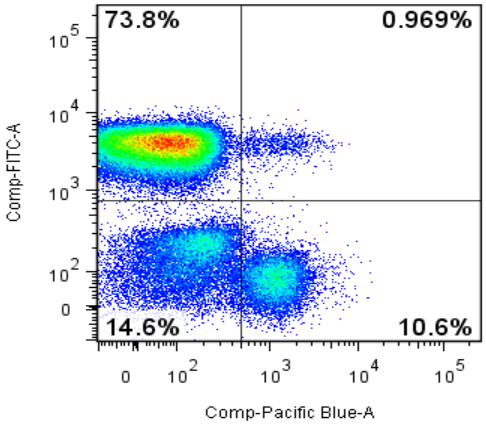
In Australia, approximately 2% of the population is diagnosed with a non-melanoma skin cancer each year. In Queensland, we are particularly susceptible given that sunlight is the causative agent for skin cancers and we lead an outdoor lifestyle. Our current research is focused on understanding the immune response against non-melanoma skin cancers and developing immunotherapies for treatment of these tumours. Currently, the most common treatment for NMSC is surgical removal which can be disfiguring to the patient. A subset of these cancers are also aggressive and move from the skin to form cancers at other sites in the body. It appears that the cancers develop the ability to avoid or inhibit our natural immune response and understanding this process is the central focus of my lab. We are also interested in the types of immune cells required to attack the cancer and how best to activate and maintain their activity over time.

Our goals are to:

- Promote CD8 T cell function in NMSC by reducing tumour-induced immunosuppression
- Study the development of CD8 T cell memory within precancerous and cancerous skin tissue

Immunotherapy of NMSC and their precursor lesions during lymphopenia

We have previously shown that precancerous skin lesions invoke an immunosuppressive local tumour environment through the actions of natural killer T cells (NKT). This project is focused on eliminating these suppressor cells through lymphodepleting drugs or irradiation followed by reconstitution of anti-tumour immunity. The project looks at different combinations of lymphodepleting regimes and the timing of immune cell transfer.



Memory CD8 T cell subsets in NMSC

Long-lived, memory T cells are a key goal of any vaccination strategy for cancer. This project studies the development of different memory CD8 T cell subsets within skin precancers and tumours including the recently described tissue-resident memory T cells. Both the function and longevity of these T cells are analysed to determine how we can enhance their anti-tumour efficacy.

Techniques you learn in our group may include: flow cytometry, ELISPOT, ELISA, tissue culture, T cell proliferation assays. immunofluorescence microscopy.

Useful Majors/Minors: Biochemistry & Molecular Biology / Biomedical Science / Microbiology

ASSOCIATE PROFESSOR SHIH-CHUN (LAWRENCE) LO

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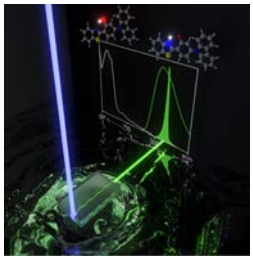
Research Area



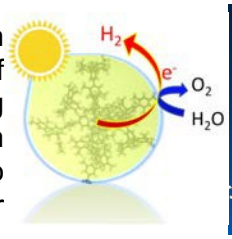
Functional organic/organometallic materials have been playing a key role in advancing organic photonic and electronic applications, as well as biotechnology. In my research group, we focus on new materials design and synthesis and characterisation. Our goals are to:

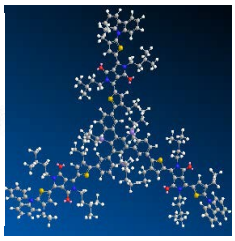
- gain understanding of chemical structure-property relationships;
- create new classes of highly efficient organic materials

Luminescent materials for displays, lasers & augmented realities

Highly efficient luminescent organic/organometallic chromophores have been used as the active materials for high-end/high-quality displays (*e.g.*, mobile phones and TVs). The key aim of the programs is to create new highly efficient light-emitting materials for transparent light-emitting displays, transistors, bio-sensors, lasers and augmented realities, utilising low-cost solution processing or printing methods.
*images from https://www.wheels.ca/news/augmented-reality-inroads-auto-industry/ & au.pcmag.com/pokemon-go-foriphone/46578/feature/is-augmented-reality-ready-for-mainstream-business

New materials for clean energy generation





Search for renewable clean energy is of urgent need to meet with the increasing global energy demands. Effective conversion of solar energy into electricity (or chemical energy) is a promising approach. The programs involve design of new light absorption dyes via molecular engineering to get new insights into photophysical properties for improved performance in solar electricity production and/or clean hydrogen fuel generation.

Bio-nanomaterials for imaging and cancer treatment

Photodynamic therapy (PDT) offers non-invasive (*cf.* conventional surgery) and less side effects (*cf.* chemotherapy) for cancer treatment. PDT can be accurately targeted, and repeatedly administered without total-dose limitations related with radiotherapy, resulting in little or no scarring after healing. We are developing high-resolution 3D imaging agents and PDT agents for deep tissue treatment.

Techniques you learn in our group may include: state-of-the-art material design principle, synthesis, advanced purification and characterisation; understanding fundamental photophysical/electrochemical/thermal properties; device characteristics for applications like clean energy creation, organic light-emitting diodes, transparent light-emitting field-effect transistors, bio-sensing, photodynamic therapy, 3D imaging, organic lasers, and augmented realities.

Useful Majors/Minors/Programs: Chemistry / Chemical & Nano Biotechnology / Sustainable Energy / Biotechnology

PROFESSOR MICHAEL MONTEIRO

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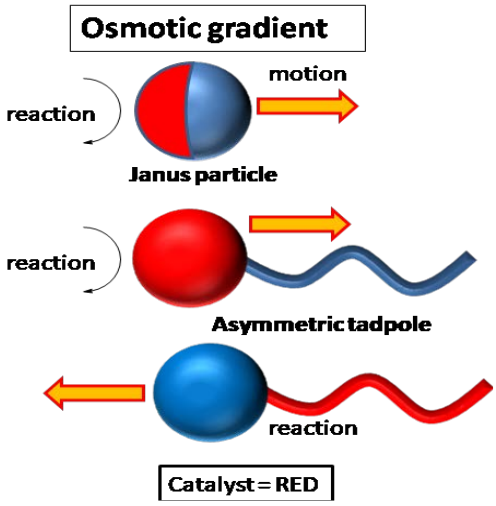
Research Area

Professor Monteiro has established an international reputation in the field of 'living' radical polymerization to create complex polymer architectures, including dendrimers, cyclic polymers and polymer nanostructures. His work focuses on building designer polymers for various biomedical applications, including vaccines, drug delivery and stem cells.

Our goals are to create new polymers with 'smart' and responsive behaviour for applications in biomedicine.



Designer Polymer Nanomotors

The aim of the project is to understand and then mimic the function of specialised, efficient and powerful biological molecular motors; this represents a grand challenge in the field of nanotechnology. Nature has recognised that controlling movement using molecular machines allows completion of complex tasks, such as active cargo transport, response and adaptation to environmental cues, regulation and transcription of RNA and DNA, cell fate and many more. Fuels (e.g. ATP) that drive biological motors and keep the system out-of-equilibrium are a key requirement for motion or motility. Directed motion for active transport has the distinct advantage that it overcomes the limitation of Brownian diffusion, providing nanoscale motors with faster and thus greater target-receptor selectivity, sampling of significantly larger volumes and decision options (i.e. logic functions).

My group devised an innovative method that utilises thermoresponsive polymers and *in situ* polymerization to make block copolymers. We were the first to create stable nanostructures directly in water at high weight fractions of polymer with multifunctional and orthogonal chemical groups on the surface through a one-step process. Thus formed block copolymers have a very low PDIs (<1.1), allowing reproducibility in forming the nanostructure. **Producing such nanostructures directly in water with surface chemical functionality will provide a facile method to covalently attach catalysts for fuel driven reactions. Further, producing these nanostructures at high weight fractions will allow scale-up for future applications.**

Techniques you learn in our group may include: Organic and Polymer Chemistry, Kinetics, Thermodynamics, Cell transfection in tumour sphere models.

Useful Majors/Minors: Chemistry / Computational Science / Biochemistry & Molecular Biology / Biomedical Science / Biophysics

ASSOCIATE PROFESSOR EVAN MOORE

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Lanthanide Chemistry

Our research is focused on exploiting the unique luminescent properties of the Lanthanide series of metal ions, which are increasing utilised in high-end technological applications. Their unusual properties can be traced to their electronic structures, which are characterised by the progressive filling of 4f atomic orbitals. Our current research projects relate to the development of organic lanthanide complexes for applications in several different areas, as summarised below.

Luminescent Imaging

Lanthanides have well known luminescence properties. Their Laporte forbidden emission bands are sharp and atom-like, due to the core nature of the 4f orbitals involved, and their emission is much longer lived (μsec to msec) compared to organic molecules (nsec). We are interested in developing complexes of Yb(III) and Nd(III), which show emission in the Near Infra-Red (NIR) region. These wavelengths allow for improved penetration into tissue, and emissive complexes can be used in NIR imaging and optical tomography.

Photodynamic Therapy

Due to their high atomic mass, lanthanides exert a strong influence on the efficiency of intersystem crossing (eg. excited singlet to triplet state conversion) by enhancing spin-orbit coupling. The long-lived triplet state of organic molecules can act as a photosensitiser leading to the formation of excited (1Δg) singlet oxygen, which is a highly reactive molecule, and can damage cellular structures, forming the basis of photodynamic therapy (PDT). We are exploring the use of Ln(III) complexes to influence existing photosensitisers used for PDT, and developing new Ln(III) based compounds with enhanced efficacy.

Lanthanide Frameworks

Coordination Polymers (CP's) (or Metal Organic Frameworks – MOF's) are crystalline materials built from infinitely repeating units of (typically) rigid organic ligands interconnected by metal cations to form 1-, 2-, or 3 dimensional structures. Our research in this area involves the construction of CP/MOF's utilising Ln(III) metal cations (as opposed to more commonly used transition metals), in combination with organic ligands such as aromatic N-oxides. We are interested in the structural, magnetic, and luminescent properties of these materials, together with their applications in important industrial processes such as gas sorption, separation and storage.

Techniques you learn in our group may include: Organic and inorganic synthesis, coordination chemistry, spectroscopy (NMR, UVVis, Luminescence).

Useful Major: Chemistry

DR DAVID MULLER

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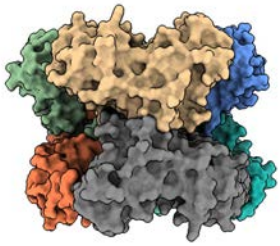
Vaccine development, delivery and molecular virology

HD-MAP & applicator

The major focus of our research is to understand virus-host interactions with a particular focus on 3 viruses; dengue virus - a serious mosquito-borne disease in many tropical countries, poliovirus - a disabling and life-threatening disease on the verge of eradication, and more recently SARS-CoV-2 – the virus responsible for the current pandemic. This research extends from virus-host interactions at the cellular level through to understanding virus immune system interplay and how to exploit this for novel vaccine and therapeutic design. To maximise the immunological impact of vaccine candidates our team uses a High-density Microarray patch skin delivery platform. This platform delivers vaccine to the layers of the skin rich in antigen presenting cells. This targeted delivery produces enhanced immune responses with a fraction of a dose when compared to traditional needle-based vaccine delivery systems.

Ongoing projects involve:

- Needle-free, microarray patch delivery to the skin of a range of both established (influenza, measles and Rubella) and novel (dengue, polio, SARS-CoV-2, breast cancer vaccines) with enhanced potency.
- Needle-free delivery of nucleic acid encoded antibodies to protect against viral infection
- Investigating the molecular signatures immune response to HD-MAP vaccination using spatial transcriptomics.
- Understand the role the NS1 protein plays in dengue virus replication.



Dengue virus NS1 protein

High-Density Microarray Patch delivery of vaccines and therapeutic antibodies.

Our current work focuses on developing subunit and mRNA vaccine approaches for many serious human pathogens including SARS-CoV-2 and dengue virus. We are also investigating the potential of HD-MAP delivered mRNA encoded antibodies as therapeutic agents to fight infectious diseases.

Understanding the role of the dengue virus NS1 protein in virus replication.

This project aims to identify the structural and mechanistic role played by NS1 in the flavivirus replication complex formation. This project will use virological, reverse genetics, cellular, biochemical and advanced imaging approaches to identify (1) how the NS1 protein engages with membranes (including various lipid components) and (2) how these membrane contacts influence NS1's role in viral replication complex formation.

Techniques you learn in our group may include: Virus growth and cell culture, protein biochemistry, recombinant protein expression and purification, immunological techniques, immunofluorescence, confocal microscopy, animal handling techniques and vaccines studies.

Useful Majors: Microbiology / Biomedical Science / Cell Biology /Biochemistry and Molecular Biology / Immunology

ASSOCIATE PROFESSOR MARLOES NITERT DEKKER

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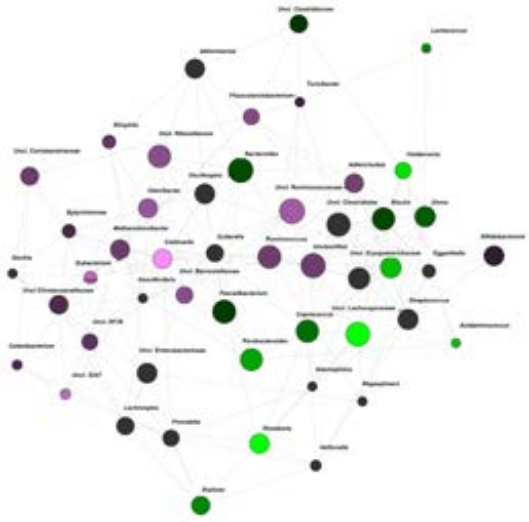
Metabolism, microbiome and pregnancy complications

Pregnancy is a time of many, large physiological changes to allow for the growth and development of an infant. Maternal metabolism is first geared toward storing energy and then moves to using stored energy to ensure sufficient nutrient supply to the infant. In addition, pregnancy is associated with significant shifts to the gut microbiome and these have been linked to the metabolic changes observed in healthy pregnancy. We investigate the links between the maternal microbiome and metabolism to understand how these are related to complications of pregnancy.

Our goals are to:

- Identify the links between changes in maternal metabolism and microbiome composition and function and the risk of pregnancy complications.
- Use our knowledge of these links to design and test interventions to prevent pregnancy complications from occurring.



Gut and oral microbiota composition and risk for preeclampsia

Preeclampsia, the presence of high blood pressure and kidney dysfunction, affects 5-8% of all pregnancies and is associated with serious adverse outcomes for mother and infant. The gut microbiota is altered already prior to the occurrence of symptoms with increased levels of gut permeability and lower levels of circulating bacterial metabolites. The oral microbiota also shows changes in preeclampsia that are associated increased levels of known cardiovascular risk factors. We want to investigate if increasing the levels of the metabolites lowers the risk of the development of preeclampsia.

Glucose and lipid metabolism and gut microbiota composition in pregnancy

We are also engaged in a number of research projects focused on understanding how glucose and lipid metabolism are altered in pregnant women who have pre-existing diabetes or are at high risk of developing gestational diabetes. We specifically investigate the changes in the gut microbiota and how these are related to microbial metabolites and to dietary intake. We also study if bariatric surgery alters these relationships. We work mostly with human samples and in close collaboration with physicians and dietitians.

Techniques you learn in our group may include: Molecular biology, microbial genetics, bioinformatics, proteomic analysis.

Useful Majors/Minors: Biochemistry & Molecular Biology / Bioinformatics / Biomedical Science / Microbiology

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Research Area

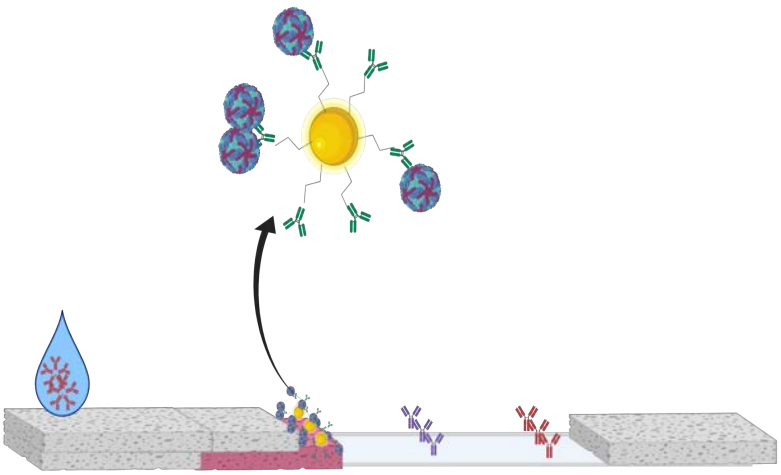
Insect-specific viruses are present in mosquito populations worldwide. Despite being genetically related to human and animal pathogens, these insect-specific viruses cannot grow in vertebrate cells. My research focuses on the discovery of new mosquito-borne viruses, understanding the host restriction of these viruses and exploiting the safe properties of insect-specific viruses to develop innovative chimeric diagnostic and vaccine platforms. The work also encompasses the development of new methods for recombinant protein bioprocessing.

My research is translation-driven, with many collaborations with commercial companies and institutes. However, fundamental research is also occurring in my lab to understand evolutionary characteristics of insect-specific viruses and how they relate to known and emerging pathogens.

Possible Hons, MSc, intro to research projects

Possible projects will focus on:

- the application of chimeric, insect-specific virus-based antigens to diagnostic assays, such as rapid, point-of-care lateral flow assays and other laboratory-based assays.
- Modulation of chimeric antigens to increase diagnostic accuracy.
- The development of new reverse genetics systems to expand the insect-specific virus-based antigen pipeline
- Develop and characterise novel monoclonal antibodies as tools to study insect-specific viruses and for the use in diagnostic assays against emergent pathogens.
- insect-specific virus host-restriction studies.
- Development of new vaccine platforms.



Techniques you learn in our group may include: Virus and cell culture, immunological techniques (IFA, ELISA, Western blot, hybridoma technology), molecular techniques (viral RNA manipulation, PCR, construction of infectious viral clones, cloning and expression of recombinant proteins), next generation sequencing.

Useful Majors: Biochemistry & Molecular Biology / Microbiology (virology)/Biotechnology

DR JUSTIN RIDGE

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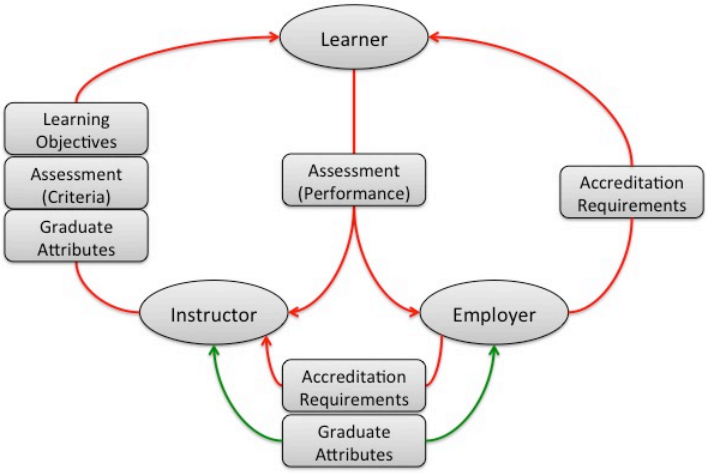
Science Education

My research focuses on the expectations of the key stakeholders (learners, instructors and employers) in the education of work-ready graduates. The basics of the relationships between the three stakeholder groups, and the means of communicating expectations, are shown below. There are three significant issues around these relationships: we do not fully understand the expectations of each group; we do not know if the expectations are being communicated effectively; and much of the communication is unidirectional (red arrows).

Our goals are to determine:

- What these expectations are for each of the stakeholders;
- How these expectations are communicated between stakeholders; and
- How we can seek to improve communication and manage expectations.



What skills should we teach (and how do we teach them)?

Students are often perceived to be poorly prepared to enter the research laboratory. To address this requires a multi-faceted approach to answer key questions: What skills do laboratory heads desire? Do students value the same skills? Are those skills being taught and assessed adequately? We hope to go on to: revise and improve learning objectives; and develop a research-skills portfolio for students. This project involves interviewing and surveying stakeholders to establish the rationale for change and the subsequent evaluation of changes we implement.

Engaging students in the learning design process

Academic staff go to considerable effort to create learning objectives that are aligned with graduate attributes, learning activities and assessment. However, students often fail to engage with, or understand learning objectives. This has negative impacts on student expectation and learning gains. This project will develop a series of workshop that will: improve student understanding of learning objectives and provide a mechanism for iterative and collaborative improvement of these objectives.

Techniques you learn in our group may include: Mixed-methods research including: design and implementation of surveys; quantitative and qualitative data analysis; ethnography; and grounded theory.

Useful Majors/Minors/Programs: All Science and Biomedical Science Majors and Minors / Education

PROFESSOR AVRIL ROBERTSON

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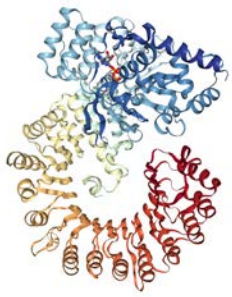
Research Area

The major focus of my research group is discovery and development of novel therapeutics for areas of unmet medical need. We are particularly interested in small molecule modulators of innate immune pathways to prevent or enhance inflammation. Other focus areas include cancer and infection, linking strongly to our interest in immune response. These multidisciplinary projects often include collaboration at local, national and/or international level.

Inflammasome inhibitors



NLRC4 protein
(PDB:4KXF)

Inflammasomes are multimeric protein complexes which form as part of the innate immune response. They act as platforms to process pro-inflammatory cytokines interleukin (IL) -1β and IL-18 to their active form and also trigger a pro-inflammatory cell death called pyroptosis.

Inflammasome dysregulation underlies an astounding array of disease states including Parkinson's Disease, asthma, cardiovascular diseases, autoimmune diseases (CAPS, Muckle Wells, NOMID) amongst many others. Therapeutic potential of inflammasome modulation has led to keen commercial and academic interest. NLRP3 inflammasome is the most well understood and a few inhibitory molecules are now entering clinical phase. Other inflammasomes, such as AIM2 and NLRC4, remain underexplored with no potent, selective inhibitors. We have multiple projects in this area.

Antifungal drug discovery

The pathogenic fungi Cryptococcus neoformans is a leading cause of death in HIV/AIDS patients. Infection usually occurs in immunocompromised patients after airborne basidiospores or desiccated yeast cells are inhaled resulting in pneumonia or, more frequently, dissemination to the central nervous system to manifest as meningoencephalitis. Without treatment, this disease is uniformly fatal. There are very few drugs available to treat pathogenic fungal infections. Current treatment is focussed on three available drugs: amphotericin B, flucytosine and fluconazole. Alarmingly, resistance to all three drugs has been observed and novel antifungal agents are urgently needed. We are working in collaboration with Assoc Prof Fraser and Prof Kobe to design and develop new antifungal drugs.

Techniques you learn in our group may include: medicinal chemistry, isotopic labelling, tests for drug-likeness, organic synthesis, chromatographic purification, structure determination.

Useful Majors/Minors: Chemical & Nano Biotechnology / Medical Biotechnology / Biochemistry & Molecular Biology / Bioinformatics / Biomedical Science / Chemistry / Computational Science

DR ANNE SAWYER

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Research Area

I am developing RNA vaccines to protect Australian crops and native plants from aggressive fungal pathogens. Unlike conventional fungicides that suffer from issues of resistance, run-off, lack of specificity, residues and toxicity to humans and the environment, RNA vaccines are a sustainable, environmentally-friendly, cost-effective plant protection platform. They involve pathogen-specific dsRNA being exogenously applied to host plants to trigger RNA interference (RNAi) and silence targeted genes. To date, most work on RNAi-based crop protection relies on genetic modification (GM). RNA vaccines are a new, non-transgenic strategy that has the potential to revolutionise crop protection. The platform allows a more rapid response to new plant diseases and is free from the stringent regulation and costs GM crops are subject to, creating massive value. It offers a clean green safe control for invasive plant diseases, safeguarding Australian agriculture and providing long-term benefits for conservation and biodiversity.

Our goals are to:

- Understand the mechanism of RNAi-mediated plant protection
- Improve the efficiency of the RNA vaccines
- Provide systemic protection to plants in the field

Control of myrtle rust

Myrtle rust is a highly-invasive fungal disease threatening about 400 native Australian Myrtaceae species (paperbarks, tea-trees, eucalypts, and lillipillies). The causal pathogen, *Austropuccinia psidii,* arrived in Australia in 2010 and has pushed species to the brink of extinction. Critically endangered species are at risk, as are species of significance to indigenous culture and industry (native forestry, cut flower, essential oils, honey, native foods). We have developed dsRNA that is effective against myrtle rust and are now trying to achieve systemic plant protection.

Control of Phytophthora root rot

Phytophthora is the most dreaded pineapple pathogen in Queensland and worldwide, infecting plants throughout production, impacting productivity and profitability. It is also one of the main factors limiting avocado yields in Queensland, with Phytophthora-affected trees producing small, poor-quality fruit. We have designed dsRNA molecules targeting *Phytophthora cinnamomi* and are currently testing them on avocadoes, pineapples and lupins.

Techniques you learn in our group may include: PCR, qPCR, *in vitro* dsRNA synthesis, northern blotting, aseptic techniques, fluorescent microscopy, plant pathology assays.

Useful Majors: Biochemistry & Molecular Biology / Bioinformatics / Genetics / Microbiology

PROFESSOR MARK SCHEMBRI

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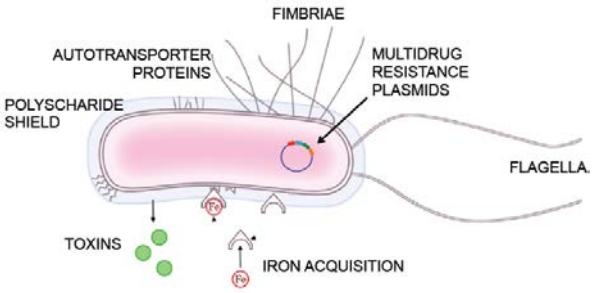
Molecular characterisation of multidrug resistant uropathogenic *E. coli*

Urinary tract infections (UTIs) are one of the most common infectious diseases of humans and a major cause of morbidity. Uropathogenic *E. coli* (UPEC) cause the majority (>80%) of UTIs and are a major contributor to global antibiotic resistance. UPEC are also a major cause of sepsis. Research in my lab aims to understand the virulence of multidrug resistant (MDR) UPEC, and to develop new approaches to treat and prevent UTI. The outcomes will address the enormous challenge of combating antibiotic resistance.

Our goals are to:

- Understand the virulence of MDR UPEC.
- Develop new methods to treat and prevent UTI.
- Characterize molecular mechanisms of adhesion, aggregation and biofilm formation utilized by MDR UPEC.



UPEC virulence factors

Molecular characterisation of UPEC clones

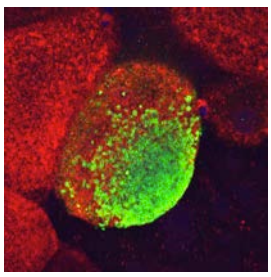
MDR UPEC strains from predominant clonal groups, including the globally disseminated MDR *E. coli* ST131 clone, exhibit important differences in virulence gene content and expression compared to other well-characterised non-resistant UPEC strains. We aim to understand the molecular mechanisms of MDR UPEC virulence using genomic, epigenetic and high throughput gene function analyses. We will study *E. coli* ST131 and other common MDR *E. coli* sequence types, including carbapenem-resistant strains and MDR strains of animal origin.

Development of new methods to treat and prevent UTI

New approaches are urgently needed to treat and prevent UTI caused by MDR UPEC. We aim to (i) identify and characterise novel UPEC vaccine targets, (ii) test novel anti-adhesive molecules for their ability to prevent UPEC adhesion and bladder colonisation, and (iii) develop the asymptomatic bacteriuria *E. coli* strain 83972 as a novel therapeutic agent for the prevention of UTI.

Molecular characterisation UPEC adhesins and biofilms

Aggregation and biofilm formation are critical mechanisms for bacterial resistance to host immune factors and antibiotics. Fimbriae and autotransporter proteins represent adhesins that contribute significantly to these phenotypes. Most UPEC strains produce multiple adhesins. We aim to study the regulation, function and structure of UPEC adhesins, and to determine their role in aggregation, biofilm formation, interaction with epithelial and immune cells, and colonization of the urinary tract.



UPEC intracellular biofilm

Techniques you learn in our group may include: PCR, cloning, SDS-PAGE, Western blotting, advanced genetic and proteomic techniques, TraDIS, RNAseq, cell culture, biofilm model systems, animal models.

Useful Majors/Minors: Microbiology / Microbiology, Infection & Immunity / Biochemistry & Molecular Biology / Bioinformatics / Genetics

PROFESSOR GERHARD (GARY) SCHENK

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Biocatalysts for the Bioeconomy

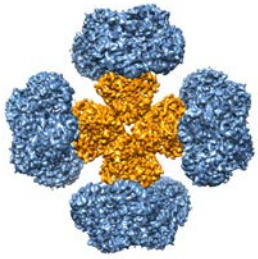
The main research focus of my group is the discovery, characterisation and optimisation of enzymes (*i.e*. biocatalysts) for processes that are relevant for applications in the bioeconomy. Specifically, we are interested in establishing enzyme-based reactions that enable the conversion of renewable feedstocks or waste streams into valuable products. In parallel, we are also interested in developing specific inhibitors for enzymes that contribute to major health problems, including the resistance to antibiotics, infections and bone-related disorders

Our goals are to:

- Use omics methods to discover novel enzymes, and characterise their properties.
- Use rational (*i.e.* structure), combinatorial and bioinformatics-based approaches to optimise catalytic properties of enzymes for applications relevant to the bioeconomy.
- Discover novel inhibitors for enzymes to develop new chemotherapeutics.

Enzyme-based biomanufacturing processes

Synthetic biology has emerged as a powerful methodology to engineer bio-based processes for the manufacture of valuable chemicals (including pharma- and nutraceuticals, biofuels and bioplastics). In my group we focus on the optimisation of cell-free enzyme cascades that enable the conversion of renewable feedstocks (*e.g.* sugar) into platform chemicals (such as isobutanol). In collaboration with colleagues from the AIBN we also optimise the corresponding metabolic pathways in some microorganisms to facilitate the conversion of waste streams into such platform chemicals.



Enzyme-catalysed bioremediation

Enzymes are not only useful to make valuable chemicals from renewable feedstocks or waste streams. They can also be employed to degrade pollutants from the environment. My group has a strong interest in optimising enzymes and building application platforms for the detoxification of pesticide- and antibiotics-contaminated habitats (such as water ways, agricultural and industrial environments).

Enzyme inhibition to combat antibiotic resistance and infectious diseases

Enzyme-catalysed reactions provide the foundation of all living organisms. However, many of these enzymes also play a role in a plethora of human ailments. My group focuses on enzymes that contribute to antibiotic resistance, infectious diseases (e.g. tuberculosis) and bone-related disorders. We aim to develop specific inhibitors for these enzymes as a strategy for novel chemotherapeutics.

Techniques you learn in our group may include: Molecular biology, protein expression and purification, structural biology and modelling, enzyme kinetics and engineering, bioinformatics.

Useful Majors/Minors: Biochemistry & Molecular Biology / Bioinformatics / Biomedical Science / Biophysics / Chemistry / Computational Science / Microbiology

PROFESSOR BENJAMIN SCHULZ

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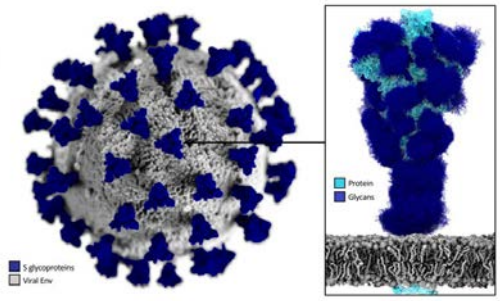
Molecular Systems Biology

The research in my group focuses on the mechanisms, biological roles and applications in biotechnology of glycosylation, the most abundant and complex post-translational modification of proteins. Glycosylation is important in biological processes such as viral infection, cancer, and development. This is because glycosylation is essential in biological activities as diverse as protein folding, fine-tuning protein enzymatic activity and determining protein-protein interactions. Half of all proteins are glycosylated, and a single protein can be modified by hundreds of different sugar moieties.

The diversity of glycoproteins therefore requires that we take a systems biology approach in our research. All our projects use a core set of methods in molecular biology, genetic manipulation, protein biochemistry, protein analysis and mass spectrometry. We aim to understand the mechanisms controlling glycosylation in these various systems to develop diagnostics, therapies, vaccines and applications in biotechnology.

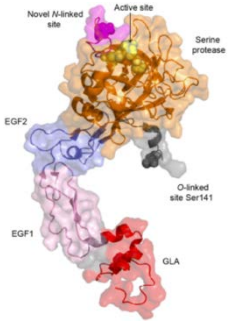


Viral glycobiology

Glycosylation shields viruses from the immune response and is critical for many of the functions of viral proteins. This is especially important for the respiratory pathogens Influenza virus and SARS-CoV-2. We aim to understand the mechanisms controlling these processes using cell-based infection systems, protein structural and biochemical analyses, mass spectrometry glycoproteomics, and bioinformatics to determine their impact on viral biology and vaccine design.

Engineering glycoprotein biopharmaceuticals

Many important biopharmaceuticals are glycoproteins, such as monoclonal antibodies and vaccines. The glycosylation and other post-translational modifications of these proteins are critical for their function, but recombinant proteins produced from mammalian cell culture are often different to the native proteins. We use mass spectrometry for detailed structural analysis of biopharmaceuticals, and cell-line and protein engineering to improve their quality.



Beer, wine, and yeast

Beer brewing and wine making are perhaps the most ancient biotechnologies. We use modern analytical techniques to investigate and improve these complex and important processes, and to investigate the metabolic diversity of wild yeasts.

Techniques you learn in our group may include: Mass spectrometry, proteomics, glycoproteomics, molecular biology, protein expression and purification, bioinformatics, fermentation.

Useful Majors/Minors: Biochemistry & Molecular Biology / Bioinformatics / Biomedical Science / Biophysics / Chemical Biology / Chemistry / Food Science & Nutrition / Food Technology / Genetics / Microbiology

DR PHILIP SHARPE

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Research Area

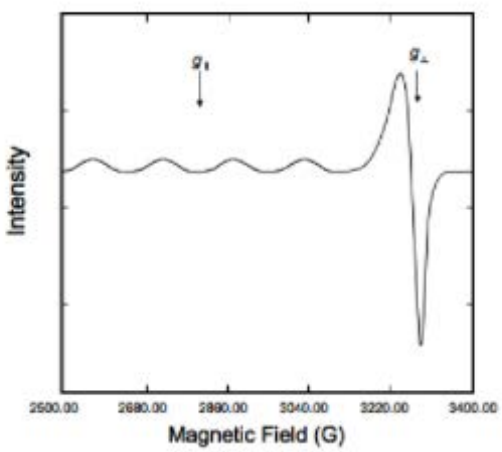
My research concentrates on how students learn in the Chemistry laboratory. Other interests include the development of ethically aware Chemistry students and incorporation of green chemistry principles into undergraduate courses.

Our goals are to:

- Acquire a deeper understanding of how students learn in the Chemistry laboratory, in order to assist their learning.
- Improve the environmental friendliness of undergraduate Chemistry experiments, while maintaining or enhancing the educational benefits.

"Greening" undergraduate laboratory experiments

Creation of interesting, robust, "greener" experiments for the Chemistry teaching laboratories and testing their educational effectiveness against traditional experiments. This is suited to undergraduate project students.



A concept inventory for EPR Spectroscopy

Electron Magnetic Resonance (EMR) Spectroscopy is a useful spectroscopic technique for chemists. The way that students learn EMR spectroscopy and common misconceptions has not been investigated in the Chemistry education literature. This project would involve surveying academics to investigate how EMR spectroscopy is taught and constructing a consensus expert concept map of the subject area and then develop a student concept inventory. This will aid in defining the best teaching approach. For example, does prior knowledge of NMR spectroscopy hinder or help students? This project is suited to an Honours or Ph.D. level student.

Chemistry ethics – a longitudinal study

Many undergraduate chemistry curricula include a mandatory ethics component. There are few studies that have investigated how students view their studies in ethics over the long term. A longitudinal study using structured interviews will investigate student views on the usefulness and appropriateness of explicit teaching in ethics as part of an undergraduate chemistry curriculum and how this has shaped the thinking and approaches of post-graduate researchers.

Techniques you learn in our group may include: Mixed methods research design, including conducting guided interviews, survey design, use of coding software, quantitative and qualitative data analysis.

Useful Major: Chemistry

ASSOCIATE PROFESSOR KIRSTY SHORT

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Chronic medical conditions & severe influenza virus infections

Influenza A virus typically causes an acute and self-limiting infection characterised by symptoms such as muscle ache, fever and a dry cough. However, in patients with one or more underlying medical conditions, influenza A virus can cause severe, and even fatal, disease. This interaction between chronic medical conditions and severe influenza was particularly evident after the 2009 H1N1 influenza pandemic. Specifically, this pandemic highlighted that people with diabetes, asthma and obesity suffered from more severe influenza than people with no underlying medical condition. Our research seeks to identify the role of host impairments in the anti-viral response (asthma), chronic inflammation (obesity) and hyperglycaemia/glycaemic variability (diabetes) plays in the pathogenesis of influenza virus.

Ongoing projects involve:

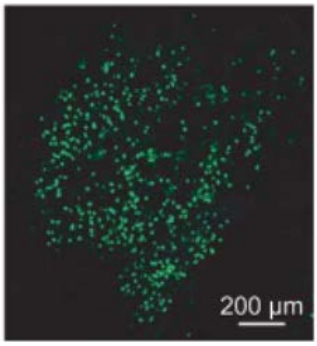
- Defining the role of obesity and asthma in the emergence of influenza virus variants
- Investigating the ability of asthma to facilitate influenza virus reassortment
- Identifying the role of obesity in driving the extra-respiratory complications (cardiac and neurological) complications of influenza
- Assessing the ability of influenza vaccination to prevent the microvascular complications of diabetes
- Determining the role of diabetic glycaemic variability in severe influenza virus infections

The role of endothelial cells in avian influenza

Birds are the natural reservoirs of influenza virus. However, amongst different avian species there are marked differences in influenza virus pathogenesis. In particular, whilst highly pathogenic influenza viruses target the endothelial cells that line the blood vessels in chickens, the endothelial cells of wild bird species are rarely infected. This project involves the culture of primary avian endothelial cells and next-generation sequencing to identify the species-dependent differences in the pathogenesis of avian influenza.

Fluorescent imaging of influenza virus

Fluorescent influenza A viruses offer new opportunities to study influenza virus replication, tropism and pathogenesis. To date, several influenza A reporter viruses have been described, each with their own pros and cons. This project involves optimising a novel strategy for creating virulent, replication competent fluorescent influenza viruses that can be ultimately used to study *in vivo* viral transmission.



Fluorescent influenza virus in the lungs of infected mice

Techniques you may learn in our group include: Virus growth and cell culture, primary cell culture (human, mouse and avian), murine infections, FACS, immunofluorescence, confocal microscopy, *in vivo* imaging, influenza virus deep sequencing, RNA Seq, Sanger sequencing, high-resolution melt analysis, qPCR, *in vivo* imaging (Carestream), *in vitro* co-culture models, PCR mutagenesis, cloning, immunohistochemistry and high-resolution imaging.

Useful Majors/Minors: Microbiology / Biochemistry & Molecular Biology / Bioinformatics / Biomedical Science / Computational Science / Genetics

DR ANDRII SLONCHAK

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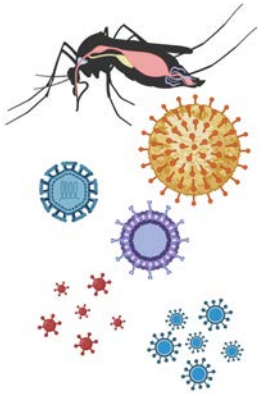
Systems Biology of Viral Infection

In our research group we are employing the power of systems biology to understand viral pathogenesis, transmission, and antiviral response. Systems biology uses combination of traditional molecular biology, transcriptomics, proteomics, bioinformatics and structural biology to obtain a holistic view of the processes of interest and interrogate complex biological systems as whole. We work with flaviviruses such as West Nile, Zika and Yellow fever viruses, insect-specific flaviviruses, and SARS-CoV-2. Our research group investigates viral infection in vertebrate and mosquito hosts and uses a of state-of-the-art methodologies (single cell sequencing, spatial transcriptomics, RNAi library screens) as well as a wide range of traditional virology and molecular biology techniques. Our students often published in highly ranked international journals such Science Advances, Nature Communications, Nature Microbiology, etc as an outcome of their projects.

Why certain insect viruses prevent mosquitoes from transmitting diseases?



Mosquitoes transmit dangerous human flaviviruses such as Dengue, West Nile, Yellow fever and Zika virus. However, there is another group of flaviviruses, that only infect mosquitoes and cannot be transmitted to humans. They are called insect-specific flaviviruses and some of them have a curious ability to make mosquitoes resistant to infection with pathogenic flaviviruses and incapable of virus transmission. In this project we will use advanced transcriptomics and artificial miRNA screening to identify the mechanisms of this phenomenon, which is known as superinfection exclusion.

What is hiding inside defective infectious particles?

Cells infected with flaviviruses produce a lot of infectious virions. However, they also produce substantial amount of viral particles that contain incomplete viral genomes inside the capsid. These particles are replication deficient and their function in viral infection is unknown. In this project we will use long read sequencing, bioinformatics analyses, and RNA structure probing to analyse the content of these particles and identify their functions.

What is the function of the noncoding RNA of flaviviruses in mosquitoes?

Flaviviruses have a unique ability to produce viral noncoding RNAs (sfRNAs) by sacrificing a part of their genome. In vertebrate host these RNAs inhibit interferon response acting together with viral protein NS5. Curiously, these RNAs are also produced by insect-specific flaviviruses that only replicate in mosquitoes. However, mosquitoes don't have an interferon response. Then what is the function of these RNAs in mosquitoes and why is their production so evolutionary conserved? In this project we will use virus engineering, proteomics and transcriptomics as well as a range of molecular virology techniques to answer this long-standing question.

Techniques you learn in our group may include: work with viruses, virus reverse genetics, virus titration, western blotting, northern blotting, immunofluorescence, next generation sequencing, mass-spectrometry, bioinformatics, generation of recombinant plasmids, protein expression, quantitative RT-PCR, affinity pull-down, RNA structure probing by SHAPE, cell culture and transfection

Useful Majors: Virology / Microbiology / Biochemistry & Molecular Biology / Bioinformatics

PROFESSOR KATE STACEY

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Pathogen recognition by innate immune cells

How does the immune system actually tell that things are foreign? This is one of the most fundamental questions in immunology. The last 20 years have seen an explosion of information on the recognition of “pathogen-associated molecular patterns” (PAMPs). These are characteristic conserved microbial molecules that activate innate immune cells through receptors such as toll-like receptors (TLR) or inflammasome initiators. This innate immune cell activation is essential for generation of subsequent T and B cell responses. PAMP recognition is thus a key to discrimination between self and foreign, and has enormous importance in initiating the response to infection. Innate immunity can also be initiated by some self-molecules that indicate danger or damage to cells. These are called "damage associated molecular patterns" (DAMPs) and they activate some of the same receptors that respond to PAMPs. Our lab works on PAMP/DAMP recognition, particularly by TLR4 that is the receptor for bacterial lipopolysaccharide (LPS).

Our goal is to characterise PAMP and DAMP signalling pathways. This will promote development of therapies to prevent the inflammatory damage that underlies a great variety of disease states.

Cytosolic DNA as a danger signal

DNA, if it is well-behaved, stays in the nucleus and mitochondria. DNA in the cytosol indicates danger to the cell - infection or damage to the genome. Cell death is an appropriate response. Our ongoing work seeks to characterise and unknown pathway of DNA-induced cell death that involves membrane pore formation within 2 minutes of introduction of DNA.

Stress molecules activating TLR4

We find that under certain stresses cells can release molecules that activate TLR4 to give a potent inflammatory response, similar to bacterial LPS. We propose this is a key to the involvement of TLR4 in a wide range of non-infectious pathologies such as atherosclerosis, diabetes, Alzheimer's disease and stroke-related damage. We are working to identify the molecules responsible.

TLR4 signalling mechanism

We are characterising in detail the molecular interactions involved in TLR4 signalling. We test the function of mutated signalling molecules in cellular responses to validate structural assumptions.

Dengue virus and gut pathology

The mosquito-borne dengue virus is an increasing problem in tropical and subtropical areas, and can cause life-threatening haemorrhagic disease and shock. We are characterising the development of gut inflammation in dengue infection, that may be important in triggering severe manifestations of dengue disease.

Inflammasome structure and function

Inflammasomes are large complexes that function to activate the protease caspase-1. Caspase-1 is involved in processing and release of inflammatory cytokines as well as rapid lytic cell death. Inflammasomes are activated in a similar wide variety of pathologies to TLR4 discussed above. We are characterising the molecular interactions required for caspase-1 activation.

Techniques you learn in our group may include: Flow cytometry, live cell fluorescence microscopy, ELISA, cell culture, molecular biology, real time PCR, protein purification, mass spectrometry, mouse models

Useful Majors/Minors: Biochemistry & Molecular Biology / Microbiology / Chemistry / Biomedical Science

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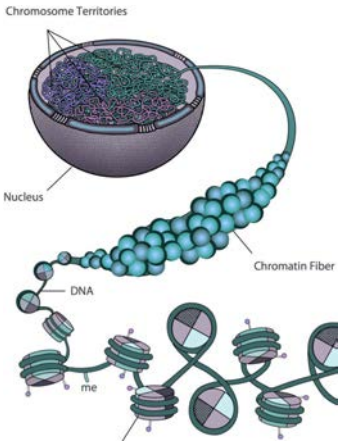
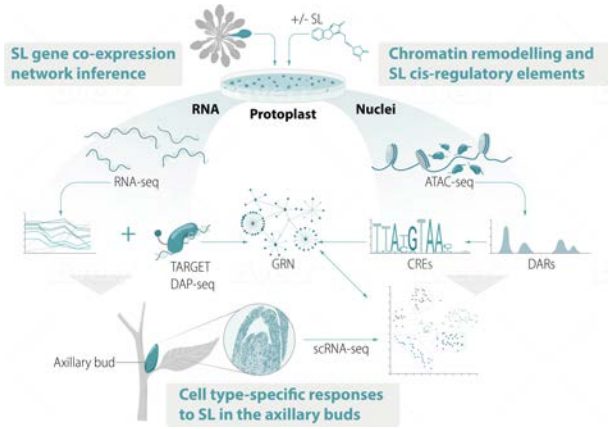
Molecular genetics and genomics of plant developmental plasticity

The research effort in my group is focused on harnessing transformative genomics technology to understand the genetics of plant development, and to discover regulatory mechanisms coordinating plant growth and development. We utilize a variety of plant species in our research, from the model plant organism Arabidopsis to grain and horticultural crops like wheat, mango, avocado and macadamia. We employ a range of techniques based on high throughout DNA sequencing to explore gene expression, chromatin accessibility and modifications from single cell to whole plant levels, bioinformatics and computational biology tools to infer genetic components of gene regulatory networks, as well as gene editing technology to evaluate phenotypic consequences of perturbations in gene regulatory networks.



The role of chromatin regulation in plant development

We are interested in how chromatin accessibility and changes to histone modifications control gene expression and, subsequently, development of an organism. Several projects using high throughput sequencing coupled with a variety of analytics methods to profile histone modifications and chromatin accessibility to discover cis-regulatory genetic elements and their trans-acting counterparts are available.



Single cell analyses of plant dormancy

Our research into the molecular and genetic basis of plant dormancy has taken us into the realm of single cell analyses applied to plant developmental biology. Several projects are available into gene expression and chromatin accessibility changes between active and dormant axillary buds (plant vegetative organ primordia and stem cells) geared towards understanding cell-type specific responses to dormancy signals.

Functional genomics of fruit trees

We continuously work on translating our basic research findings and genome profiling technologies to improve and intensify crop production in collaborative research with government and industry partners. Currently, research projects of various length and research focus are available on the functional genomics of tree architecture in mangos, avocados, macadamia and citrus.

Techniques you learn in our group may include: Molecular genetics, functional genomics, bioinformatics, gene cloning, transgenics, CRISPR.

Useful Majors: Genetics / Bioinformatics / Biochemistry & Molecular Biology / Computational Science

PROFESSOR ISTVAN TOTH

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Vaccine design and delivery platforms for peptides

Vaccine against infectious diseases: Conventional vaccines composed of live/attenuated or killed microorganism have been efficacious against many diseases such as influenza, small-pox, chicken-pox etc. However, pathogen-based vaccines may also be associated with risks of autoimmunity and allergic responses, for example, occurrence of such responses during clinical trials blocked development of a vaccine against Group A streptococcus (GAS). In recent years, new generation of subunit vaccines have gained increasing attention in vaccinology field because of their safety profile and cost-effective production. Peptide-based vaccines utilize a small defined peptide fragment responsible for induction of immune responses, which make them safer than other types of vaccines, but it also reduces their immunogenicity because of lack of pathogen associated patterns.

Anticancer vaccine: Classical vaccines incorporating live or attenuated microorganisms possess several disadvantages and cannot be applied against cancer and some pathogens. Modern vaccines utilizing immunogenic subunits derived from a particular pathogen are able to overcome these obstacles but need a specific delivery system for their efficacy. Nanotechnology has opened a new window into these delivery methodologies. Particles-based subunit vaccine formulations have been proven to be very effective in inducing cellular and humoral immune responses. Additionally, many peptides are promising drug leads their poor bioavailability and stability limit their clinical use. This project aims to develop a novel carrier system, the Lipidic Amino Acid (LAA) system, for the oral delivery of vaccines by exploiting the particulate-forming properties of LAA to form micro- particulate oral antigens. It is anticipated that vesicle size, stability, drug loading, permeability, lipophilicity, antigenicity, *in vivo* behavior, etc. will depend on the LAA composition of the liposomes.

Our goals are to:

- Develop a practical delivery system for peptide drugs and antigens.
- Design and develop vaccine candidates combining the adjuvant, carrier and antigen in a single molecule.

Non-viral carriers for gene delivery

Gene therapy has the potential to cure a variety of diseases including cancer and muscular dystrophy. One of the plasma membrane biggest challenges preventing its use in the clinic is poor delivery into target cells. We aim to build novel peptide-based oligonucleotide carriers for gene therapy.

Our goal is to: Design and synthesise libraries of peptide-based molecules for gene delivery.

Useful Majors/Minors: Chemistry / Biochemistry & Molecular Biology / Biomedical Science

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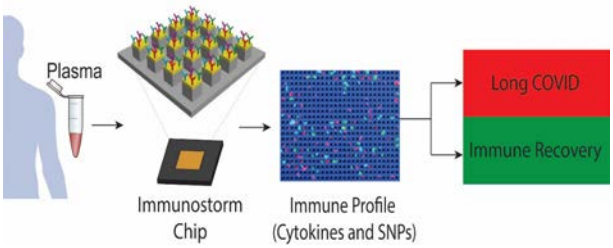
Research Area

Understanding nanostructured assembly and manipulation of matter in order to produce novel materials and devices, with a specific focus on innovative liquid biopsy technology and precision medicine. Our goals are to:

- Make advances on important practical problems such as the application of biomarkers and nanotechnology to the early detection of preventable diseases
- Find effective paths to translate the technology toward clinical and / or commercial sectors.

Counting single molecules to unravel long COVID



An increasing number of COVID-19 patients continue to have a deteriorated health post-infection, which are now referred to as long COVID patients. Long COVID is not well understood but is believed that low level chronic inflammation is a driver of the disease. The detection of an inflammation signature is extremely challenging due to the low abundance of biomarkers in blood and patient specific variations in these markers. This project develops an ultra-sensitive nanotechnology, the Immunostorm Chip, to investigate the role of low-level inflammatory markers in long COVID patients. The aim is to develop a blood-based screening test for patients at risk to develop long COVID.

Investigating tumour immune evasion in lung cancer by nanotechnology-enabled deciphering of exosomal cargo.

Significant improvements in the overall survival of lung cancer have been achieved since the introduction of immune checkpoint inhibition (ICI). However, continuous treatment response to ICI is only observed in a small group of patients, while a considerable number of patients show negligible prolonged responses to ICI. Although not yet fully understood, evasion of the tumour from the ICI-activated immune system by secretion of immune-suppressive cargo and display of specific antigens on tumour cells are thought to be the main drivers of the immune-manipulative process. This project uses an in-house developed nanotechnology to investigate the role of extracellular vesicles carrying immune-manipulative molecules in-vitro and in-vivo.

Catching Lung Tumour Relapse before it happens.

A high proportion of lung cancer patients suffer from tumour relapse after surgical resection. This process is mediated by minimal residual disease, whereby cancer cells that remain in the patient after treatment build metastatic niches for future disease progression. Due to the extremely low abundance of cancer cell secreted markers for minimal residual disease and the need for highly sensitive technology, the clinical implementation of patient screening methods after curative surgery remains vastly underexplored. This project will develop a sensitive and multiplex nanotechnology suitable for detecting minimal residual disease in lung cancer patients after tumour resection.

Techniques you learn in our group may include: PCR, DNA/RNA extraction, qPCR, cell culture, protein analysis, Western blotting, Genomics applications and next generation sequencing technologies.

Useful Majors/Minors: Biochemistry & Molecular Biology / Bioinformatics / Biomedical Science / Chemistry / Nanotechnology / Biotechnology

ASSOCIATE PROFESSOR JACK WANG

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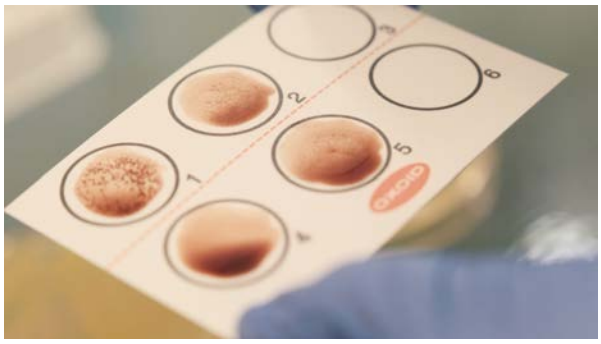
Science Education

I am a Teaching-focused academic in Microbiology, and my research revolves around innovative strategies and technologies in Science Education. This research relies upon interacting with large networks of people – namely the students, academics, and administrators in Higher Education – to extract trends and develop new technology in teaching and learning. These projects may be useful if you are interested in careers in secondary or tertiary teaching and learning design:

Innovations in blended and online learning in Science Education



The rapid expansion of online learning has highlighted the need to transform the technology requirements and learning strategies for teachers and students alike. This project will create screencasts, videos, animations, and podcasts to enrich the learning experience at UQ and evaluate their effectiveness for internal and external delivery. This includes surveying and interviewing students and instructors and triangulating the findings with in-depth learning analytics from online platforms.

Online Laboratory Training in the Molecular Biosciences

STEM employers value flexibility, independence, and organisation in graduate recruits and in the molecular biosciences the demand for these skillsets is most evident in the laboratory. For external students studying remotely, laboratory training needs to be completely online, and there is a paucity of standardised online resources in science education. This project focuses on the production of a specific set of online resources in bioscience education – laboratory skills training videos and interactive animations that can be flexibly used across online learning environments in different contexts.

Techniques you learn in our group may include: Survey design and analysis, focus group interviews, generating and analysing video and multimedia content, coding and thematic analyses of qualitative and quantitative data, communicating with a variety of audiences.

Useful Majors/Minors: Biochemistry & Molecular Biology / Biomedical Science / Genetics / Microbiology

ASSOCIATE PROFESSOR DANIEL WATTERSON

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From virus structure to vaccines

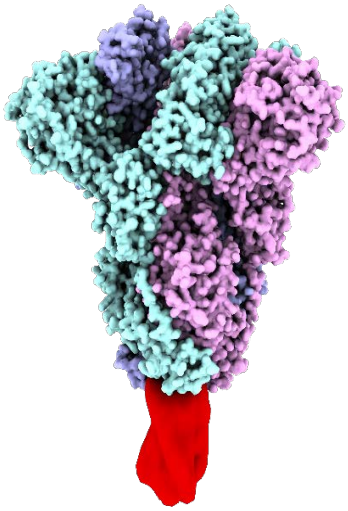
Our lab focuses on understanding the 3D structure of viruses to help guide new vaccines and therapies for important human pathogens, such as dengue virus, Nipah virus and SARS-CoV-2.

In order to study these often highly pathogenic viruses we utilize powerful but safe viral antigen platforms.

The molecular clamp is a rapid response vaccine platform that stabilizes the “Spike” protein of a wide range of viruses including SARS-CoV-2, Ebola, Nipah and a potential “Disease X”.

A chimeric flavivirus that repurposes a benign Australian mosquito-restricted flavivirus allows us to grow and study viruses normally restricted to the highest level containment facilities.

Whole dengue virion solved by cryoEM to unprecedented resolution reveals new targets for vaccines.



Platform technologies including the molecular clamp help us make new vaccines and study emerging virus structure rapidly and safely.

Visualizing viruses and antibodies that recognize them

Enveloped viruses such as SARS-CoV-2, Influenza and dengue enter cells by first engaging with cellular receptors and then deliver their genomes via membrane fusion. These processes are driven by specific sites on the viral proteins and require large-scale structural rearrangement. Our group studies the architecture of these viral proteins and how our antibodies block these functions to protect us.

Structure based vaccine design

Once virus structure and function is understood at the molecular level it is possible to generate “designer” vaccines that can exploit critical viral components that make vaccine escape more difficult and increase the breadth of protection. Our lab is assessing several structure based strategies in preclinical models with the aim of developing better vaccines.

New antibody treatments

Understanding viral structure also reveal sites of vulnerability on the virus that can be targeted by antibodies. Our lab is using this approach to develop new antibody-based therapies for important human pathogens including flaviviruses dengue & Japanese encephalitis virus and coronaviruses like SARS-CoV-2.

Techniques you learn in our group may include: Virology, Molecular biology, protein expression and purification, cryo-EM, single particle image processing, structural modelling, animal models of disease.

Useful Majors/Minors: Biochemistry & Molecular Biology / Microbiology / Biophysics / Computational Science

ASSOCIATE PROFESSOR NICK WEST

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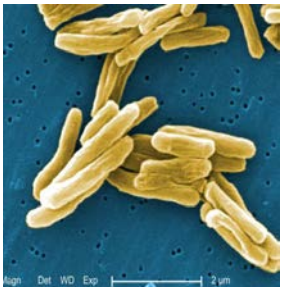
Tuberculosis (TB)



TB continues to kill more people in the world each year than any other bacterial pathogen and is also a major cause of HIV-related death. In the West Lab we study the pathogenesis of *Mycobacterium tuberculosis (Mtb)*, the bacterium responsible for TB. Our lab is fully equipped for the study of *Mtb*, from its microbiology, interaction with host cells, through to pre-clinical drug and vaccine trials; making us the only lab in Qld with such capabilities.

Our goals are to:

- Identify disease causing bacterial genes and gene products
- Develop new, potent anti-TB drugs
- Create novel efficacious vaccines
- Produce effective point-of-care diagnostics

The following are examples of the projects offered to students:

Characterisation of proteins essential for survival in the host.

We have identified a series of bacterial factors which are dispensable for growth in laboratory media but which are in-dispensable in the host. This project will define the role of three of these essential virulence determinants by modern molecular and proteomic approaches to characterise *when* and *where* they are expressed and to what end.

Essential gene regulation in *M. tuberculosis*.

Our genetic screening identified a series of transcriptional regulators essential to the bacterium *in vivo*. In this project you will clone, express and purify two novel regulators. To define the role of these regulators the influence of these mutations will be assessed by mammalian cellular infection studies and transcriptomic/ DNA binding analysis.

Next Generation Anti-TB Vaccine

We have identified proteins of *Mtb* which are only expressed during the latent phase of TB. These proteins would therefore not be expressed in the current vaccine, i.e., BCG. These proteins therefore represent attractive targets for inclusion as subunit vaccine antigens. You will assess these antigens as purified protein vaccines and also as inclusion in live recombinant vaccine strains.

Techniques you will learn in our group may include: Microbiological techniques. Gene cloning, protein and/or DNA vaccinations, immunological assays, macrophage cell culture and mycobacterial infection, PCR and molecular analysis. DNA binding assays and small molecule inhibition.

Useful Majors/Minors: Microbiology / Microbiology, Infection & Immunity / Biochemistry & Molecular Biology / Bioinformatics / Computational Science / Genetics

PROFESSOR CRAIG WILLIAMS

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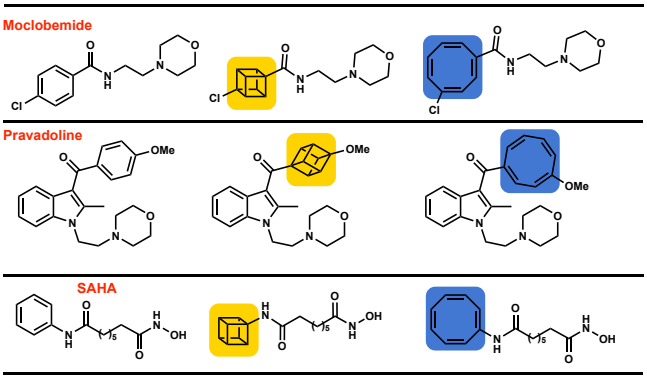
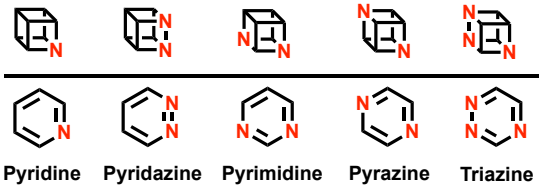
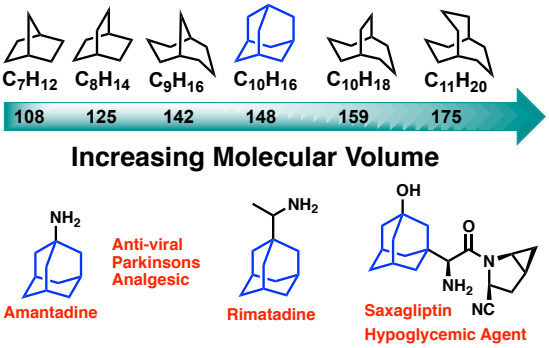
Research Programs: The Williams research group enjoys the exploration of scholarly and hardcore organic chemistry (concepts, theory, philosophy and synthesis).



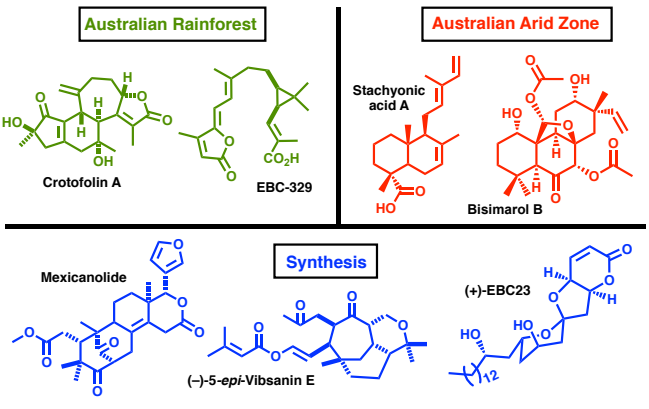
1) Fundamental molecules for pharmaceutical, agrichemical and materials development: Projects in this area build on our fundamental and highly publicised cubane (yellow) and cyclooctatetraene (blue) for phenyl (black) bioisosterism work. We are currently taking this program to the next level by attempting to make nitrogen derivatives of cubane i.e., the so-called aza-cubanes. These are reported to be stable by theoreticians, but have never previously been synthesised. These molecules have direct application to bioisosteres of a range of heterocycles that commonly appear in pharmaceuticals and agrichemicals. The translation of these fundamental molecules will have immediate impact on food security (e.g., herbicides and pesticides), and will rejuvenate tired drug templates for pipeline bolstering.





The above project fits within the general area of fundamental cage hydrocarbon development, where we are exploring the molecular size constraints of novel cage hydrocarbons i.e., developing fundamental building blocks to advance discovery chemistry. This work is currently focused on microelectronics polymer design, and drug development (e.g., antiviral agents).

2) Natural product isolation and synthesis: Research in this area investigates the isolation and elucidation of novel natural products from the Australian desert and the Australian rainforest; the latter in collaboration with industry. Synthesis of complex natural products is also an area of expertise, which covers diterpenes, alkaloids, opioids, and polyketides. Traditional synthetic methodology development, medicinal, theoretical, and computational chemistry is closely aligned with these ventures.



Techniques acquired: All projects instil high-level theoretical and laboratory organic chemistry competency and training.

Useful Majors/Minors: Chemistry / Computational Science / Biochemistry & Molecular Biology

DR SIMON WORRALL

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Mechanisms of Drug-Induced Tissue Injury

Liver, muscle, heart and brain injury have long been associated with the abuse and clinical use of drugs. My predominant research interest focuses on ethanol, the most commonly abused drug in Western societies. Ethanol is widely tolerated but induces a wide variety of tissue injury in a small number of individuals. Thus, my main research focus is the investigation of immunological and genetic phenomena associated with alcohol-induced tissue injury.

The metabolism of ethanol, a relatively benign substance, produces a series of highly reactive, more toxic, compounds that interact with cellular molecules to produce chemical modifications known as adducts. Such modifications generated by high levels of blood glucose in diabetics are now used as a measure of the blood glucose concentration over extended periods. Our aim is to discover analogous adducts which will allow clinicians to estimate blood alcohol concentrations over periods of weeks and months.

Protein Modification in the Alcoholic Brain

One of the major targets of alcohol toxicity is the brain, leading to a variety of forms of injury. We are concentrating on one form called alcoholic cerebellar degeneration to see whether adducts of alcohol metabolites can be used as a marker of the severity of injury.

Protein Modification in the Alcohol-exposed Foetus

Alcohol consumed by pregnant women can harm their unborn babies. Foetal alcohol spectrum disorder (FASD) refers to a group of conditions that can occur in a person whose mother drank alcohol during pregnancy. Problems that may occur in babies exposed to alcohol before birth include low birth weight, distinctive facial features, heart defects, behavioural problems and intellectual disability. We are looking for biomarkers that will indicate how much alcohol the foetus was exposed to in the uterus, and will also determine whether such modifications play a role in the pathological process occurring in these individuals.

Techniques you learn in our group may include: Protein purification, raising mono- and polyclonal antibodies, immunological techniques such as western blotting and ELISA, mass spectrometry; UV-visible and fluorescence spectroscopy.

Useful Majors/Minors: Biochemistry & Molecular Biology / Biomedical Science / Chemistry

ASSOCIATE PROFESSOR ROWAN YOUNG

ARC Future Fellow

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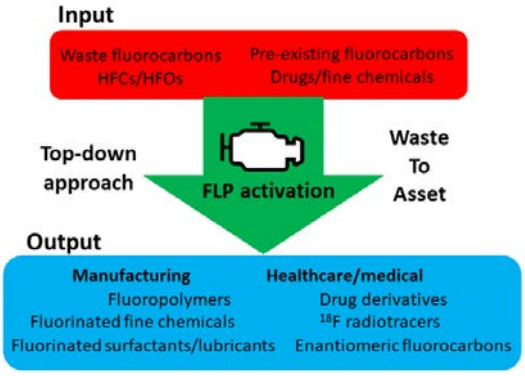
Research Area

My group is focused on developing new methods for converting cheap and unreactive starting materials into valuable complex molecules. To do this, we use a combination of main group frustrated Lewis pairs, transition metal pincer complexes and acidic metal hydrides.

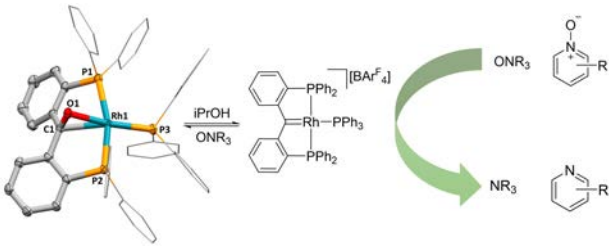
Our goals are to:

- Develop new catalytic systems
- Discover new reactions/reactivity that allows us to do unique chemistry
- Understand how it all works



Main group frustrated Lewis pairs for C-F bond activation

The development of main group frustrated Lewis pair (FLP) chemistry over the last 15 years has focused on mimicking existing transition chemistry. However, we have found that we can utilise such catalytic systems to activate fluorocarbons in a unique and controlled manner. This has allowed us to utilise waste fluorocarbons as feedstocks to generate more valuable fluorinated products. The applications of this chemistry are far reaching (from radiopharmaceutical development to materials manufacturing) and something that we are continuing to explore.



Transition metal $PC_{carbene}P$ complexes

Most metal catalysed chemical transformations are heavily reliant upon a small group of rare and expensive noble metals (e.g. Pt, Pd, Ir, Rh). In contrast, cheap and abundant base metals (e.g. Fe, Co, Ni) are much less reactive for difficult bond activations. We have developed methods to access a class of pincer ligands that enhances the reactivity of base metal complexes through metal-ligand cooperativity. The basis of this enhanced reactivity revolves around the presence of a metal-carbon double bond anchoring the pincer ligand to the metal. We have explored the coordination chemistry of a range of these ligands with Fe, Co, Rh and Ir complexes and are beginning to explore their application in catalytic processes.

Umpolung reactivity of acid metal hydrides

Metal hydrides are generally thought of as basic complexes, where the hydride acts as a base. However, metal hydrides can be engineered such that the hydride is very acidic in nature. We have been exploring the chemistry of such metal hydrides to determine if we can access new (umpolung) reaction pathways that allow divergent reactivity (as compared to basic metal hydrides). We have also utilised the conjugate bases of such metal hydrides in frustrated Lewis pair chemistry, allowing enhanced reactivity of otherwise inert base metal complexes.

Techniques you learn in our group may include: Organometallic and organic synthetic techniques, detailed chemical analysis (NMR and IR spectroscopy, X-ray diffractometry, mass spectrometry), inert chemistry skills

Useful Majors: Chemical Sciences, Chemistry

DR LUCÍA ZACCHI

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Research Area

Our research group is interested in understanding basic molecular mechanisms in biology and to use this knowledge for biotechnological applications.

Microevolution and fungal pathogenesis

We are interested in understanding how cells acquire new traits within a short period of time, a process called microevolution, and how microevolution impacts pathogenesis. The fungal pathogen *Candida albicans* is one of the leading causes of death due to bloodstream infections. *C. albicans* is a normal part of our flora, but it can become pathogenic, with devastating consequences. We are using *C. albicans* mutants with increased microevolution frequency to dissect the molecular mechanisms that allow this pathogen to become fatally infectious.

The secretory pathway and its biotechnological applications

We aim to better understand the cellular processes involved in the production and secretion of proteins from the cells. We use the model yeast *Saccharomyces cerevisiae* (Baker's yeast) and mammalian cells to study mechanisms of protein glycosylation, protein quality control, and protein degradation in the cell, under physiological conditions or during disease.

Antibody discovery and development

Definitely our most applied line of research. We are interested in identifying antibodies that can bind a range of proteins with therapeutical and/or diagnostic potential. We also develop improved tools for antibody discovery. We collaborate with the National Biologics Facility and with Assoc Prof Keith Chappell, as well as the Australian Red Cross, and other industry partners.

Techniques you learn in our group may include: Molecular biology / Cellular biology / Microbiology/ Biochemistry / Glycobiology / Mass Spectrometry Proteomics / Antibody Discovery / Flow cytometry / Protein production, purification, and characterisation / Communication skills.

Useful Majors/Minors: Microbiology / Microbiology, Infection & Immunity / Biochemistry & Molecular Biology / Bioinformatics / Biomedical Science / Computational Science / Genetics

RESEARCH FELLOWS

DR SEWERYN BIALASIEWICZ

Senior Research Fellow

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Research Area

Our research investigates the microbial ecosystem, it's key players, and how to manipulate or exploit those connections to achieve particular outcomes, with a major focus on the microbial ecosystem of the human. Part of this focus is to use a combination of existing and emerging technologies and techniques to explore the hidden diversity of microorganisms which may not have been well characterised in particular body sites or have been missed due to limitations of traditional techniques.

The primary scope of our work is in chronic bacterial infections, particularly those which are difficult to treat, and how the microbiome relates to health and disease. Within this area, we are currently working on:

- Characterisation of bacteriophages in chronic Pseudomonas infections in Cystic Fibrosis patients and their role in modulating disease severity.
- Discovery and characterisation of bacteriophages as therapy candidates to combat chronic otitis media (ear infection) in Aboriginal and Torres Strait Islander children.
- Characterisation and manipulation of the microbiome in chronic rhinosinusitis (CRS) with the goal of developing additional therapeutic or preventative options for people with CRS.

Useful Majors/Minors: Biochemistry & Molecular Biology / Bioinformatics / Biomedical Science / Computational Science / Microbiology

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ARC Future Fellow

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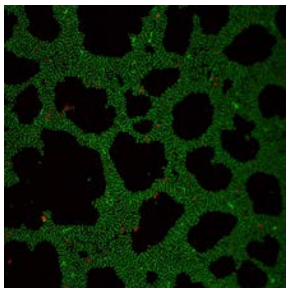
Microbial Methane Metabolism

Methane is an important compound in the global carbon cycle and is mostly mediated by microorganisms that produce or consume this common substrate. Many of these methane-metabolising bacteria and archaea are found in strictly anaerobic and/or high temperature environments. However, they remain poorly characterised due to our inability to culture these recalcitrant organisms. The recent development and use of high throughput DNA sequencing technologies allows us to now study the metabolism of these mircoorganisms in greater detail. My team uses a combination of DNA sequencing and cultivation based techniques to understand how these organisms cycle methane and other compounds.



Possible research projects

- Understand the metabolism of methanogens from Australian hot springs.
- Characterise the microbial community of herbivorous Australian marsupials.
- Infer the metabolism of novel archaeal lineages from engineered systems.

Useful Majors/Minors: Biochemistry & Molecular Biology / Bioinformatics / Biomedical Science / Computational Science / Genetics / Microbiology

DR NAPHAK MODHIRAN

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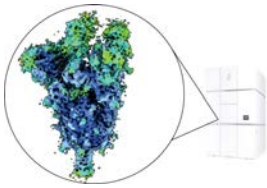
Virus-Host immunity interaction and structural-based vaccine design

Our research focuses on understanding how the immune system responds to infection with a special emphasis on emerging and re-emerging enveloped viruses. This includes flaviviruses (Dengue, Japanese Encephalitis virus), alphaviruses (Chikungunya virus), Coronaviruses (SARS-CoV-2), Henipaviruses (Nipah virus). This work directly informs vaccine development programs. Our lab uses various methods to answer questions ranging from structural analysis (cryogenenic Electron Microscopy, cryo-EM), fluorescent-activating cell sorting, protein design and expression to mouse models of virus infection.



Visualising SARS-CoV-2 spike using cryo-EM

Research Project

Projects are available in a number of areas and can be tailored for honours, masters, masters by coursework and PhD students. Projects can range from vaccine design, protein expression, purification and characterization, to biological assays (e.g. testing for antiviral activity), to structural analysis, to study virus pathogenesis using molecular and *in vivo* model of virus infection. We encourage multidisciplinary projects.

Useful Majors: Biochemistry & Molecular Biology / Bioinformatics / Biomedical Science / Biophysics / Chemical Sciences / Chemistry / Computational Science / Genetics / Microbiology

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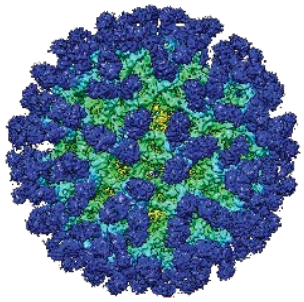
Flaviviruses

My research is focused on studying the structure and molecular makeup of highly pathogenic tick- and mosquito-borne flaviviruses, such as dengue virus, with implications for viral evolution, rational vaccine design and therapeutic antibody development. In collaboration with Assoc Prof Daniel Watterson, I utilise cutting-edge structural biology in combination with a chimeric flavivirus platform which allows us to safely explore viral emergence and evolution at the molecular level. My aim is translate these findings into new vaccines and strategies to overcome current epidemics and counter emerging flaviviral threats.



Possible Research Projects

Possible projects will combine molecular and structural virology techniques to understand pathogenesis, structure and antigenic profile of urban, sylvatic and ancestral flaviviruses. Techniques will include PCR, *in vitro* antibody analysis, virus purification and protein analysis.

Useful Majors: Biochemistry & Molecular Biology / Biomedical Science / Microbiology

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DR MARIUSZ SKWARCZYNSKI

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Nanotechnology in vaccine delivery

Our major interest is development of delivery systems for peptide-based vaccines. We are developing vaccines against *Streptococcus pyogenes*, hookworm, cervical cancer, *Schistosoma mansoni*, liver fluke, COVID-19, malaria, tuberculosis, to control fertility of wild animals, etc.

Our ultimate goal is to:

- Develop synthetic nanovaccines against emerging diseases.

Self-adjuvanting peptide nanovaccines

Immune stimulants (adjuvants) are crucial vaccine components. Many adjuvants are toxic, not biodegradable; they invariably invoke adverse reactions. We demonstrated that a peptide antigen can be coupled to poly(hydrophobic amino acid) or other polymers and then self-assembled into nanoparticles. Following immunization in mice, these nanoparticles induced production of opsonic antibodies without the need of an adjuvant. This project aims to further explore the natural polymers composition, conformation, size and morphology on the efficacy of vaccines against variety of diseases.

Techniques you learn in our group may include: Chemistry: SPPS, macromolecules conjugation, HPLC, ESI-MS, naon self-assembly, DLS, CD. Biotechnology/immunology: immunization techniques, in vivo, ELISA.

Useful Majors/Minors: Biomedical Science / Chemistry / Biotechnology / Immunology

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DR ROCHELLE SOO

ARC DECRA Fellow

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Research Area

The ability to extract draft genomes of individual microbial populations from metagenomic datasets has provided us with a new and exciting opportunity to examine the metabolic potential of as-yet uncultured organisms. My main research area is focused on the diversity, evolution and ecology of uncultured non-photosynthetic cyanobacterial lineages. Another area of interest is exploring and characterising the phylogeny and physiological ecology of methane-producing Archaea found in marsupial microbiomes.

Possible research projects

Possible projects include using bioinformatic tools to analyse the non-photosynthetic cyanobacterial lineages and their viruses, isolation and characterisation from environmental samples and visualisation using electron microscopy. Other projects include analysing archaeal lineages from Australian herbivores for comparison to those from ruminants and humans.

Useful Majors/Minors: Biochemistry & Molecular Biology / Bioinformatics / Computational Science / Genetics / Microbiology

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DR RACHEL STEPHENSON

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Nano-technology in vaccine delivery

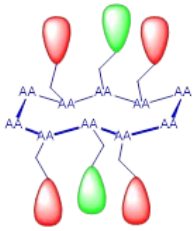
Vaccination is one of the most effective public health strategies undertaken. Our next generation vaccines use pathogen-derived peptides which allow advanced tailoring of the vaccine. Our major interest is in the development of vaccine adjuvant delivery systems for peptide-based vaccines against infectouis diseases (e.g., group A *Streptococcus*) and illicit drugs (e.g., cocaine).

Our goals are to:

- Develop synthetic nano-vaccines and assess their biological activity.
- Use structure-immune activity studies to elucidate the importance of adjuvant delivery ststem and antigen on vaccine design, establishing new insights into function-activity relationships for the development of new vaccine platforms.

These projects are part of the Toth Medicinal Chemistry group

Cyclic peptides as vaccine delivery platforms



Cyclic peptides represent useful scaffolds for the multivalent presentation of peptide epitopes to the immune system. With this in mind, the project would involve a structure-activity investigation into the role of antigens attached to the cyclic ring. It would be expected that an immune response would change with different antigen attachment positions, making it an exciting project.

Techniques you learn may include: Peptide synthesis, HPLC, mass spectrometry, analytical chemistry, NMR, cell culture techniques, etc

Useful Majors/Minors: Biochemistry & Molecular Biology / Chemistry

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DR ANITHA SUDHEED KUMAR

UQ Amplify Fellow
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As a member of Professor Lisbeth Grondahl's laboratory, my research interests are lying on the development of nanoparticles systems developed from biopolymers and synthetic polymers for drug delivery applications. The key therapeutic entities which are used in the nanoencapsulation include therapeutic proteins, chemotherapeutic agents as well as anticancer phytochemicals. Currently, I am working on the development of a targeted drug encapsulated nanoparticle systems (based on PLGA polymer and sulfated alginates) for the treatment of skeletal metastasised breast cancers.

Polymer based therapeurtic delivery systems for protein/anticancer drug delivery for bone metastasised cancers. PLGA, chitosan and alginate based polymers

Useful Majors/Minors: Biochemistry & Molecular Biology / Chemistry

SCMB AFFILIATE STAFF

ASSOCIATE PROFESSOR MARK BLASKOVICH

INSTITUTE FOR MOLECULAR BIOSCIENCE (IMB)

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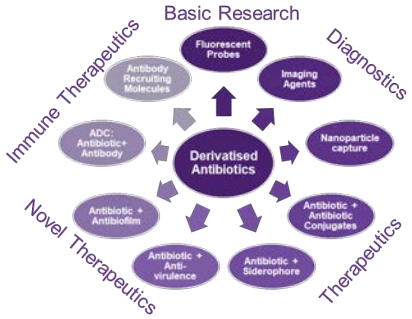
Superdrugs vs Superbugs!

Antimicrobial resistance is increasingly recognised as one of the greatest global threats to human health. Our group takes a multidisciplinary approach to find new therapies to treat drug-resistant infections and develop new diagnostics to detect them. Anchored by core expertise in organic and medicinal chemistry, our research methodology extends into microbiology, chemoinformatics, microbial genetics and pharmacology through many national and international collaborators.



Possible research projects

We have developed a core research platform based on derivatising existing antibiotics and adding additional functionality, with a wide range of potential applications.

- Design of new antibiotic derivatives and antibiotic conjugates with dual-modes of action
- Development of fluorescent and PET probes to image bacterial cells and infections in mice
- Development of diagnostics that selectively capture bacteria with magnetic nanoparticles

Useful Majors/Minors: Chemistry / Biochemistry & Molecular Biology / Biomedical Science / Computational Science / Genetics / Microbiology

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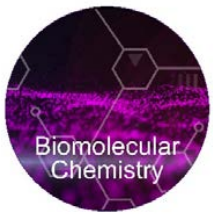
PROFESSOR ROBERT CAPON



INSTITUTE FOR MOLECULAR BIOSCIENCE (IMB)

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Biodiscovery: learning from nature

My research group focuses on the discovery and use of novel bioactive natural products from Australian marine and terrestrial biodiversity. These metabolites span all known biosynthetic classes and include many molecules that are new to science. Our research makes use of a range of sophisticated chemical technologies, and extends into the fields of microbiology, cell biology, pharmacology and biochemistry, supported by an extensive network of collaborators. Natural products uncovered during our investigations represent valuable new leads in the search for drugs in the fields of human and animal health and crop protection. They also have potential application as molecular probes to better interrogate, understand and manage living systems.

Possible research projects

- Marine biodiscovery
- Microbial biodiscovery
- Drug discovery: infectious diseases, cancer and pain
- Synthetic and medicinal chemistry
- Cane toad chemical ecology

Useful Majors/Minors: Biochemistry & Molecular Biology / Biomedical Science / Chemistry

PROFESSOR DAVID FARILIE

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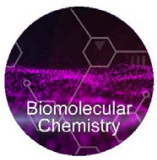
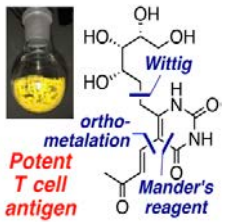
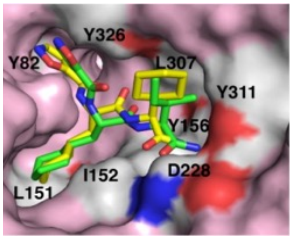


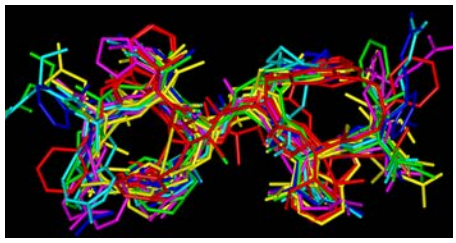
Organic Chemistry, Drug Design, Cell Biology, Immunology & Pharmacology

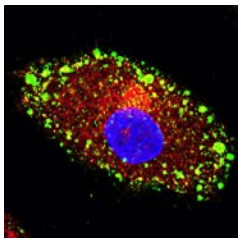
Our *chemists* design (computer modelling), synthesise (solution/solid phase reactions), and solve structures (NMR) for chemicals, drugs & proteins.Our *biologists* study drugs, proteins, enzymes, cells and mouse models of disease to identify new drug targets and interrogate mechanisms of action. We invent new drugs, chemicals and chemical reactions, solve new chemical and protein structures, and discover new mechanisms in inflammatory, metabolic and neurodegenerative diseases, viral infections and cancers.

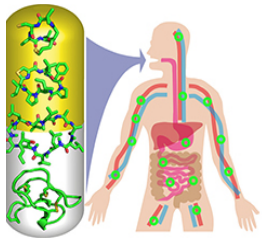


●Chemistry ●Synthesis ●Structure ●Enzymology ●Cells ●Signalling ●Immunology ●Pharmacology









PROFESSOR MARY FLETCHER

QUEENSLAND ALLIANCE FOR
AGRICULTURE & FOOD INNOVATIONS (QAAFI)

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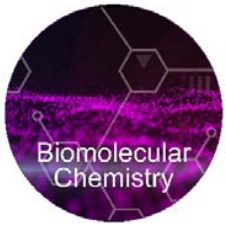

Natural toxins and bioactives

Our group focuses on the identification and analysis of natural toxins and other bioactives in a range of plants, fungi and agricultural products. Bioactives of interest include toxins from pasture plants such as pyrrolizidine alkaloids and indospicine and simplexin that can impact on animal health and also have the potential to form residues in agricultural products that pose a risk to consumers. Current projects also focus on bioactive sugars in stingless bee honey and compounds for mitigating methane production in cattle.

Possible Research Projects

Native Pimelea plants contain an unusual daphnane orthoester poisonous to grazing cattle. SPE and LC-MS/MS will assess the ability of biopolymers to adsorb the toxin simplexin in fermentations resembling cattle rumen conditions and determine whether there is a bound form of simplexin in the Pimelea plants. Biopolymers are also being explored for controlled release of bioactives for methane mitigation in cattle.

Useful Majors/Minors: Chemistry / Biochemistry & Molecular Biology

DR EMMA GORDON

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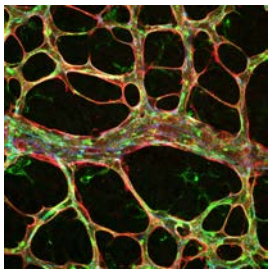
There is a gap in our knowledge about how the environment surrounding vessels mediates mechanisms within the cells of the vessel wall to guide vessel behaviour. Our lab aims to identify the signals connecting the extracellular and intracellular environments, and how these go wrong to induce pathological vascular growth and leakage. We hope that our work will identify new pathways and novel targets to prevent vascular dysfunction in disease.



The aim of our lab is to further knowledge about how vessels grow and function in development and disease. We utilise novel biological models, biochemical assays and imaging techniques to better understand how the cells within vessels behave to control function. Specific projects include: How does intracellular trafficking guide cell movement and vessel growth? What are the mechanisms leading to pathological vascular growth and leakage in eye disease? How is blood vessel integrity controlled across specific vessel types? How does the novel coronavirus SARS-CoV-2 cause vascular dysfunction? How does the mechanical environment surrounding vessels influence disease progression?

Useful Majors/Minors: Biochemistry & Molecular Biology / Biomedical Science / Biophysics / Genetics / Microbiology

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PROFESSOR GLENN KING

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Research Area

More than 20% of all animal species on the planet are venomous. Our lab harnesses the extraordinary chemical and pharmacological diversity of venoms to develop eco-friendly insecticides, human therapeutics, and intraoperative imaging agents. Our research is highly translational and has led to two spinout companies (Vestaron Corporation and Infensa Biotech). Current areas of therapeutic interest include chronic pain, epilepsy, heart attack, and stroke. We maintain the largest collection of venoms in the world, comprising venom from more than 500 species of ants, caterpillars, centipedes, scorpions, spiders, wasps and other invertebrates, and we replenish and augment this collection through regular field trips.

Projects are available across a wide range of topics ranging from fundamental studies of animal venoms to commercial development of bioinsecticides, therapeutics, and imaging agents. We use a wide range of advanced techniques including cryoelectron microscopy, electrophysiology, genomics, proteotranscriptomics, and multidimensional heteronuclear NMR spectroscopy. We are passionate about communicating the results of our research to a broad audience, and consequently there are always opportunities for engagement with the media (print, radio, television, etc.) and general public.

Useful Majors/Minors: Biochemistry & Molecular Biology / Bioinformatics / Biomedical Science / Biophysics / Chemistry / Computational Science /

PROFESSOR MEHDI MOBLI

CENTRE FOR ADVANCED IMAGING (CAI)

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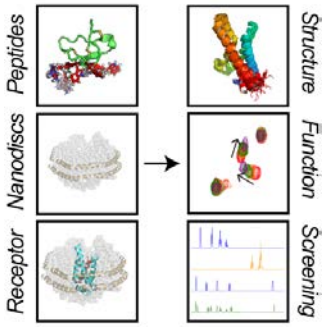
Structural Biology and Drug Discovery

The research in our group involves the study of bioactive disulfide-rich peptides. These molecules are ubiquitous in nature and have varied roles from being critical signalling molecules (e.g. hormones) to acting as lethal weapons (e.g. venom toxins).

Modulation of Neuronal Signalling

Our research focuses specifically on ligands that modulate neuronal signalling. This may be through the study of the **structure and dynamics of neuronal ion channels in development of novel analgesics** or **characterisation of novel neuronal enzyme modulators involved in the reward pathway.**



We are also actively using in silico methods to mine disulfide rich peptides with novel neuromodulatory functions, with projects underway looking specifically at how ***avidity is gained through domain duplication.***

We routinely use a range of biophysical techniques including NMR, MS, EM and ITC to characterise proteins that we produce through recombinant gene expression.

Useful Majors/Minors: Biochemistry & Molecular Biology / Biophysics / Chemistry / Computational Science

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PROFESSOR MARK MORRISON

FRAZER INSTITUTE

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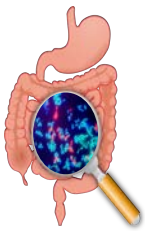
Research Area



Our research focuses on “how what we eat becomes what we are” by examining the roles microbes play in health and gastrointestinal diseases like IBD, diabetes and cancer. We collaborate with clinicians, biomedical scientists, and other microbiologists to use microbiology and metagenomics to: i) characterise structural and/or functional changes in gut microbial communities; ii) isolate “new” bacteria from the human gut and; iii) use techniques in bacterial genetics, to better understand host-microbe interactions affecting health and disease.

Possible projects

- Food additives as modulators of host-microbe interactions and gut homeostasis
- Functional studies of the Crohn’s disease mucosa-associated microbiota
- Microbes of the small intestine – the forgotten microbiome in digestive diseases and disorders
- Unchartered territory: Archaea x host interactions in health and disease

Useful Majors/Minors: Biochemistry & Molecular Biology / Bioinformatics / Biomedical Science / Biophysics / Chemical Sciences / Chemistry / Computational Science / Genetics / Microbiology

PROFESSOR MEGAN O'MARA

AUSTRALIAN INSTITUTE FOR BIOENGINEERING AND NANOTECHNOLOGY(AIBN)

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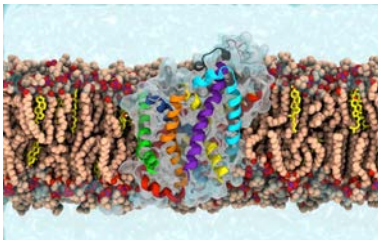
Multiscale simulation approaches for targeted therapeutics

While our knowledge of structural biology, systems biology and omics data has expanded rapidly in the last few years, significant gaps remain in our understanding of how proteins, lipids and other biomolecules come together to bring about the molecular regulation of living cells. My group uses multiscale simulations to understand how the chemical environment of the cell influences function, and how biochemical changes resulting from inflammatory or disease processes change the cell's biophysical properties. My group is particularly interested in how these changes can lead to differences in the efficacy of pharmaceuticals and the design of biocompatible molecules that will improve targeted drug delivery

Possible research projects



Research projects focus on understanding how the biochemical environment influences biophysical properties and function. Possible projects include: the impact of lipid modifications on cell membrane function; computational strategies for targeted lipid nanotechnologies; allosteric modulation of synaptic proteins by neurosteroids and oxysterols; or membrane mediated antimicrobial resistance. All projects use molecular dynamics simulation techniques, however no prior computational experience is necessary.

Useful Majors: Biochemistry & Molecular Biology / Bioinformatics / Biomedical Science / Biophysics / Chemical Sciences / Chemistry / Computational Science / Genetics / Microbiology

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PROFESSOR KATE SCHRODER

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Research Area

During injury or infection, our body's immune system protects us by launching inflammation. But uncontrolled inflammation drives diseases such as gout, diabetes, neurodegenerative disease and cancer. The Inflammasome Lab is defining the molecular and cellular processes of inflammation. We seek to unravel the secrets of inflammasomes – protein complexes at the heart of inflammation and disease – to allow for new therapies to fight human diseases.

Broad Title for Individual Research Project Areas

We integrate molecular and cell biology approaches with *in vivo* studies to gain a holistic understanding of: • Mechanisms of inflammasome signalling • Inflammasomes in host defence against infection • Inflammasomes in disease (auto-inflammatory, Alzheimer's & chronic liver diseases) • Blocking the inflammasome with small molecule drugs.

Useful Majors/Minors: Biochemistry & Molecular Biology / Biomedical Science / Chemistry / Microbiology

PROFESSOR MATT SWEET

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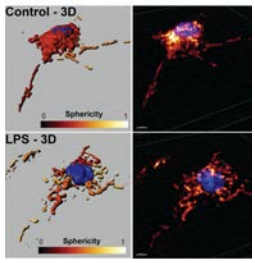
Web: http://www.imb.uq.edu.au/matt-sweet

Research Area

We study innate immunity, infection and inflammation, particularly with respect to the Toll-like Receptor (TLR) family of pattern recognition receptors. We characterize TLR-inducible antimicrobial pathways in macrophages and how bacterial pathogens such as Salmonella and uropathogenic *E. coli* subvert these responses. We also focus on TLR signalling and how this signalling contributes to dysregulated inflammatory responses in the context of acute and chronic inflammation-driven diseases. Our goals are to develop strategies to manipulate innate immune pathways to combat both infectious and inflammatory diseases.

(1) Targeting histone deacetylases as an anti-infective strategy; (2) Targeting TLR-inducible macrophage metabolism as an anti-inflammatory strategy; (3) Defining roles of mitochondria and lipid droplets in macrophage functions; and (4) Characterizing toll-like receptor-inducible zinc poisoning as an innate immune antimicrobial weapon. Approaches used span molecular and cellular biology, immunology and *in vivo* models of inflammation and infection.



Useful Majors/Minors: Biochemistry & Molecular Biology / Biomedical Science / Genetics / Microbiology

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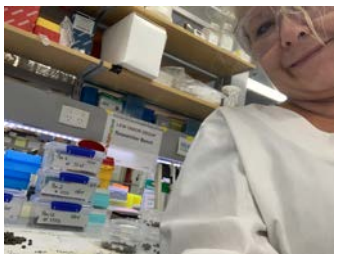

PROFESSOR ALA TABOR

QUEENSLAND ALLIANCE FOR AGRICULTURE & FOOD INNOVATIONS (QAAFI)

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Research Area

Our group focusses on developing translational solutions for animal health associated with bovine venereal diseases, ecto-parasites and vector borne diseases. Bovine venereal diseases affect cattle in northern Australia causing decreased calf output and thus a reduction in breeding efficiencies. Our laboratory is developing novel diagnostic methods to differentiate pathogens and we are also examining the pathobiome of infected cattle to determine if this influences the development of bovine VD. Ticks and tick borne diseases affect humans, livestock and pets. The Tabor group has on-going research activities associated with vaccines (patents), molecular assays and biomarkers. We are interested in identifying host biomarkers for bovine fly and tick resistance (costing Australia ~$290m p.a.). Currently we are exploring novel genomes and transcriptomes of neglected ecto-parasites and nematodes towards improved control strategies.

Opportunities exist for novel genome sequencing (MinION technologies in house), comparative genomics, bovine host metagenomics, molecular diagnostic assay development, tick host biomarker including proteomics, miRNAomes, RNA-Seq and bioinformatics. The angle of the project can be negotiated to suit the candidate.

Useful Majors/Minors: Biochemistry & Molecular Biology / Bioinformatics / Microbiology

PROFESSOR ANDREW WHITTAKER

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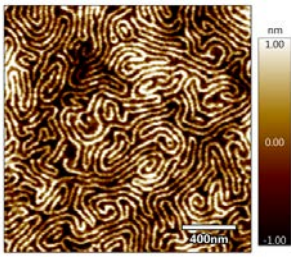
Research Area

Our goal is to translate fundamental research findings and knowledge into products and health-care protocols. We use knowledge in the field of physical and synthetic chemistry to design and synthesize novel materials for important applications. These are currently materials for photolithography and for medicine. The Whittaker Group consists of ~25 scientists working in a range of projects spanning fundamental physical chemistry to applied polymer chemistry. Our projects aim to impart detailed knowledge of important chemical systems, and provide training in modern scientific techniques.

Novel Biologically-Responsive MRI Agents: Polymers for imaging of diseased tissue; *Novel Polymers for Lithographic Applications*: Materials for advanced manufacture of computer chips; more at https://polymer-chemistry.group.uq.edu.au/students/available-student-projects



Useful Majors/Minors: Biochemistry & Molecular Biology / Chemistry / Computational Science

AFFILIATED INSTITUTIONS

Projects may also be available in the following UQ Centres and Institutes that have strong links with the School of Chemistry & Molecular Biosciences:

AUSTRALIAN INSTITUTE FOR BIOENGINEERING AND NANOTECHNOLOGY

Website: https://aibn.uq.edu.au/
Contact: reception@aibn.uq.edu.au

AUSTRALIAN CENTRE FOR WATER AND ENVIRONMENTAL BIOTECHNOLOGY

Website: http://www.acweb.uq.edu.au/
Contact: acweb@uq.edu.au

CENTRE FOR ADVANCED IMAGING

Website: https://cai.centre.uq.edu.au/
Contact: cai@enquire.uq.edu.au

CENTRE FOR CLINICAL RESEARCH

Website: https://clinical-research.centre.uq.edu.au/
Contact: information@uqccr.uq.edu.au

FRAZER INSTITUTE

Website: https://frazer.uq.edu.au/
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INSTITUTE FOR MOLECULAR BIOSCIENCE

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QUEENSLAND ALLIANCE FOR AGRICULTURE AND FOOD INNOVATION

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QUEENSLAND BRAIN INSTITUTE

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EXTERNAL INSTITUTIONS

QIMR BERGHOFER MEDICAL RESEARCH INSTITUTE

HOSPITALS COMPLEX, HERSTON

Website: http://www.qimrberghofer.edu.au
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MATER RESEARCH

HOSPITALS COMPLEX, SOUTH BRISBANE

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