THE UNIVERSITY OF
NEWCASTLE
AUSTRALIA

DISCIPLINE OF BIOLOGICAL SCIENCES

HONOURS AND UNDERGRADUATE RESEARCH PROJECTS

2026

Undergraduate Research in the Discipline of Biological Sciences

School of Science

There are three main research areas in the Discipline of Biological Sciences:

- Microbiology
- Reproductive Science
- Plant Science

We encourage undergraduates to get involved in research throughout their degree. By doing so you will learn and develop skills in searching, selecting and retrieving information from scientific sources, skills in project management, experimental research skills as well as skills in presenting scientific information in a clear and concise manner, both orally and in writing. These will provide you with a strong foundation for your future career, whether it be in the industrial, commercial or academic sector.

There are three main ways to get involved in research:

a) ***Summer research project:*** Short paid undergraduate research projects over summer. Scholarships are advertised each year

b) ***SCIE3500:*** A 10-unit undergraduate course consisting of a research project under the supervision of an academic staff member. Assessment is based on a progress report, a research notebook, a final project report and an oral presentation. The course is open to third year students who have successfully completed at least 140 units and have a cumulative GPA of at least 5.0 and is offered in both semesters. Course outline link here.

c) ***Honours research project:*** A full-year research project after completion of the Bachelor of Science or Bachelor of Biotechnology. A minimum GPA of 5.0 is required for entry into honours. Program handbook link here.

This booklet contains a list of undergraduate research projects currently available in the discipline. Academics are listed in alphabetical order. In all cases you should discuss potential projects with prospective supervisors before trying to enrol or apply.

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A/Prof Geoffry De Iuliis

Male infertility and Protein Structure

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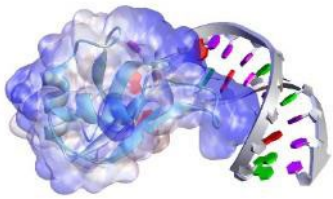
My research is aligned with investigating the underlying causes of male infertility, through understanding sperm cell biology and biochemistry. The potential impacts of environmental factors on these cells and in turn, human fertility, is a current focus. This research is more important than ever, especially as increasing numbers of Australians turn to assisted reproductive technologies like IVF for support. Another key focus of research is understanding the structure of proteins both in the reproduction and cancer fields. I also have a keen interest in promoting and fostering multidisciplinary science, myself having background in synthetic chemistry and a keen interest in quantum mechanics and cosmology.

Sperm RNA binding proteins and measuring RNA damage:

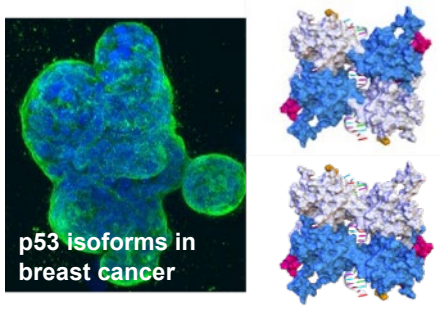
MicroRNA species are a key epigenetic factor that contributes not only to fertility but also to normal embryo development. While the importance of these epigenetic factors in reproduction is now established, how these microRNA species are packaged in the male reproductive tract and therefore their vulnerabilities to damage, particularly oxidative damage, is poorly characterised. This project will use a combination of a bioinformatics and protein/RNA isolation techniques to identify RNA binding protein candidates and to assess RNA oxidative damage.



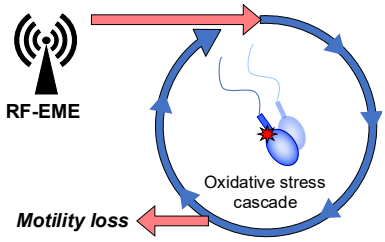
RNA Binding Protein

Developing Alphafold pipelines to assess the quaternary structures of key complexes in both fertility and cancer:

As an example, p53, known as the guardian of the genome, is a very high-profile target of investigation towards advancing cancer therapies. Surprisingly, the complete structure of this protein and its isoforms, as well as how they interact in complexes, is not fully understood. This project will predominately use molecular modelling, the newly available 'Alphafold' structures from Google Deepmind and other bioinformatics platforms towards developing our understanding how p53 variants may account for drug resistance in some breast cancer cell lines.

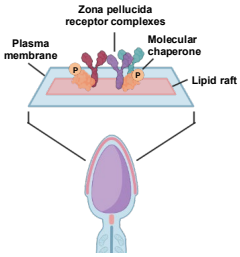


How do the electromagnetic fields used by mobile devices stop sperm motility?:

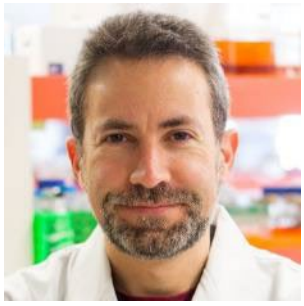


Electromagnetic energy in the radio and microwave spectrum (non-ionising radiation) are currently used for communications between mobile devices and access points (transmission towers and WiFi points). The ubiquitous nature of mobile device use in today's society has called into question the safety of such devices via the chronic exposure to low level, non-ionising radiation. We have found that experimental simulation of these fields are able to stop human sperm motility. This project will involve the exposure of spermatozoa to electromagnetic energy and the subsequent assessment of perturbed biochemical pathways that may lead to the observed motility loss. Understanding the origins of these effects in biology are critical for informing safety standards, while contributing to an area of science in the public spotlight.

Toward novel sperm selection materials for 'IVF':



We are developing our knowledge on what makes a good sperm. In concert with this we are also uncovering how both the male and female reproductive tracts complete their exceptional job of preparing and selecting the very best sperm for fertilisation. By using our new insights, this project will explore the new molecular targets found on the sperm surface and their utility to underpin a new sperm selection technology for 'IVF'.



A/Prof Ian Grainge

Molecular microbiology

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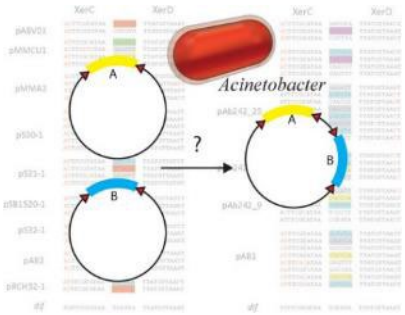
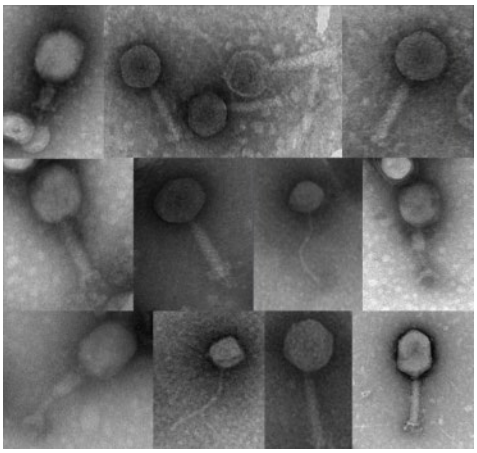
This year I will be offering projects in the following areas:
i) the spread of antibiotic resistance genes in human pathogens
ii) the use of bacteriophage as novel therapeutics against antibiotic resistant bacteria.
iii) cloning, overexpression and purification of enzymes from phage as antimicrobials

ii) A novel mechanism of antibiotic resistance gene spread in the pathogen *Acinetobacter baumannii*:



Carbapenem resistant *Acinetobacter baumannii* is ranked as the top priority pathogen for which novel treatments are required by the CDC and WHO. We have discovered a novel mobile genetic element, utilised by plasmids in this pathogen, that exchanges antibiotic resistance genes. This project will aim to uncover the molecular mechanism underlying this novel element. This will help understand the spread of antibiotic resistance genes and hopefully provide a method to combat this in the future.

ii) Discovery of novel bacteriophage:



Antibiotic resistant bacteria are predicted to become the leading cause of human death by the middle of the century unless novel treatments can be found. One alternative to using antibiotics is the use of bacteriophages - viruses that infect and kill bacteria. This project will isolate novel phages from waste-water treatment plant samples against a range of pathogens. The phage will be purified and amplified, then characterised by whole genome sequencing and electron microscopy. The purified phage can then be included in a BioBank being set up at Westmead hospital (Sydney) for use in patients.

iii) Cloning, overexpression and purification of enzymes from phage

Bacteriophage (phage) produce many several enzymes that have unique properties, from guiding their own DNA replication and RNA transcription, to enzymes to degrade the bacterial cell wall and punch holes in bacterial membranes. This project will aim to clone, overexpress and purify these useful enzymes and then characterise their functions.

Dr Tessa Lord

Fertility and stem cell biology

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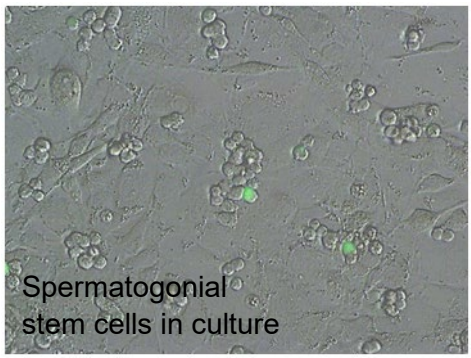
My research is primarily focused on understanding how the stem cells in the testis function to drive sperm production, and on harnessing this knowledge to support stem cell maintenance in an *in vitro* environment. Potential applications of such *in vitro* technologies include treatment of infertility in childhood cancer patients, and developing novel biobanking strategies for endangered wildlife.

Adapting culture conditions to expand spermatogonial stem cells in vitro:

Childhood cancer effects 700 Australian children each year, and while advancements in cancer research have ensured that survival rates are now over 80%, half of all male childhood cancer survivors are rendered infertile in adulthood. Because male paediatric cancer patients are not yet producing sperm, techniques for protecting their future fertility must instead utilise spermatogonial stem cells (SSCs) that are specified in the testes shortly after birth. My research looks at improving our capacity to expand and maintain these cells in *in vitro* culture, such that they could be collected prior to cancer treatments, then microinjected back into the testis in adulthood to restore fertility. Research projects on offer include studying the effects of supplementing novel growth factors into SSC cultures, and altering oxygen concentrations.



Spermatogonial stem cells in culture

Prof Brett Neilan

Microbial and Molecular Diversity

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My work is focused on the genetics, biochemistry and ecology of microbial natural products. These compounds, which include toxins and antibiotics, are often sourced from microbes residing in novel environments, such as hypersaline lakes, thermal springs, hot and polar deserts, or in symbiotic relationships with plants. While natural products provide producing microorganisms with an ecological advantage (e.g., through the deterrence or inhibition of other organisms), they also have a range of therapeutic and industrial uses (e.g., as drugs, insecticides and research tools).

Exploring cyanobacterial specialised metabolism using heterologous expression:

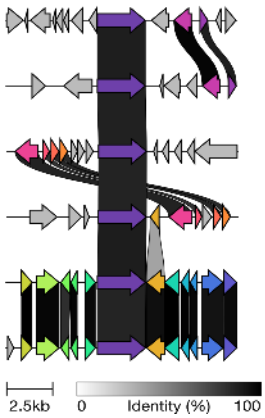
Microbial natural products have served as a major inspiration for the development of novel pharmaceuticals. The search for new natural products is a continuing endeavour, with new niches and microorganisms being probed to determine their ability to produce useful bioactive molecules. Cyanobacteria ('blue-green algae') are a largely untapped phyla that produce a multitude of natural products eliciting a range of pharmaceutically relevant activities, including antibiotic, anaesthetic, cytotoxic, and UV absorbing activities.

A large limitation for the exploitation of these molecules is the lack of accessibility in the natural host due to slow growth rates, relatively low production levels, and an inability to genetically manipulate the cyanobacteria. Therefore, this project will involve the isolation of cyanobacterial natural product biosynthesis genes, engineering them for heterologous expression in an industrial microorganism (*Escherichia coli*), and gene knockouts to characterise the enzymology of biosynthesis. The project has the potential to discover and sustainably produce novel compounds of ecological, industrial and biomedical significance.

Microbial endophytes as a source of novel medicines and pesticides:

Bacteria and fungi living within the tissues of plants offer their hosts a variety of ecological advantages. These so called 'endophytes' often produce specialised metabolites that deter pests and diseases, improve resilience to drought and salinity, or promote plant growth. Endophytes and their metabolites therefore have applications in agriculture and regenerative planting, as well as animal and human health. This project will explore endophytes from Australian plants for novel metabolites of ecological and industrial significance. Bacteria and fungi will be isolated from pant tissues, and their metabolites extracted and characterised (structurally and functionally). In parallel, endophyte genomes will be mined for specialised metabolite biosynthesis pathways, which will be expressed in an industrial microorganism (*Escherichia coli*). The project has the potential to discover novel medicines and natural alternatives to environmentally damaging agrochemicals.

Co-supervisor Dr Verlaine Timms - *The environmental antimicrobial resistome:*



Antimicrobial resistance (AMR) is predicted to cause a staggering 10 million deaths worldwide by 2050. This looming public health threat is thought to be a result of antibiotic over-use and the flux of antibiotic pollution from human activity. For example, 80% of antibiotics used in aquaculture end up in the environment. This is thought to maintain environmental AMR gene prevalence that is potentially passed to pathogens of concern.
The importance of the environmental resistome in maintaining and disseminating AMR genes is little understood. Horizontal gene transfer and pollution play critical roles in AMR dissemination. This project will employ laboratory models to study gene transfer dynamics under various pollutant stressors. The knowledge generated can be used to design novel solutions such as diagnostic tests or bioremediation tools to manage the burgeoning environmental AMR crisis.

Co-supervisor Dr Verlaine Timms - *Harnessing insect microbiomes to control mosquitoe-bourne disease:*

The saltmarsh mosquito, *Aedes vigilax,* is one of Australia's most prolific mosquito species and is the primary vector of Ross River virus; a disease affecting more than 4,000 Australians annually. By characterising the mosquito holobiome (host, bacterial, fungal, archaeal, and viral community), this project will provide unique insights into the symbiotic, commensal, and transiting microbiota and their capacity to influence mosquito health and development, as well as the transmission of disease. The data generated will be used to design novel solutions for mosquito management in the Hunter region and beyond.
Note: This project is offered only during the mosquito season (December–March).

A/Prof Karl Hassan

Microbial genomics and biochemistry

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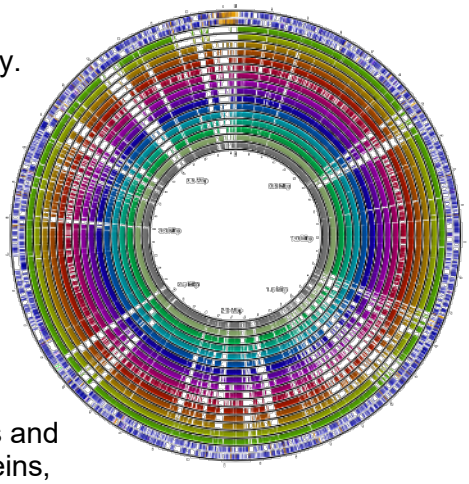
Microorganisms impact our lives in countless ways. Some can make us sick, but many others have positive impacts on human and environmental health. Microorganisms will also play a leading role in clean energy and manufacturing futures. My lab applies comparative and functional genomics, biochemistry and synthetic biology to investigate microbial processes that have positive and negative impacts on our lives and to harness microbial activities in small molecule detection and production. Projects are available in the following research areas.

Antimicrobial drug resistance in hospital acquired bacteria

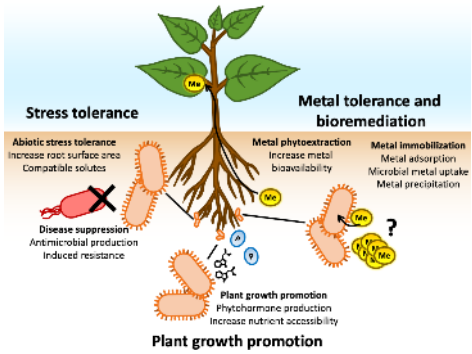


Hospital-acquired infections caused by pathogenic bacteria cost billions of dollars each year and increase patient pain and morbidity. These infections are becoming increasingly difficult to treat due to rising levels of drug resistance in the pathogens. Projects in my lab are focused on understanding the mechanisms of antimicrobial resistance and virulence in human bacterial pathogens, understand how these pathogens and their resistance genes are spreading and investigate novel approaches to controlling their growth.
We are working with colleagues in hospitals to identify reservoirs of drug resistant bacteria and examine their evolution to inform infection control strategies. We have developed new technologies to identify and functionally characterise bacterial resistance factors and used these technologies to describe new bacterial resistance proteins, including a completely new class of multidrug resistance determinants.

Synthetic Biology

The ability to design and synthetically produce biological parts has almost unimaginable potential to solve the world's challenges. One application of this technology is in the engineering of microbes to catalyse the production of industrially useful chemicals using renewable feedstocks. These chemicals could be used as alternatives to oil as fuels or in the manufacture of polymers. Our research team is investigating approaches to streamline microbial engineering to develop next-generation biocatalysts.

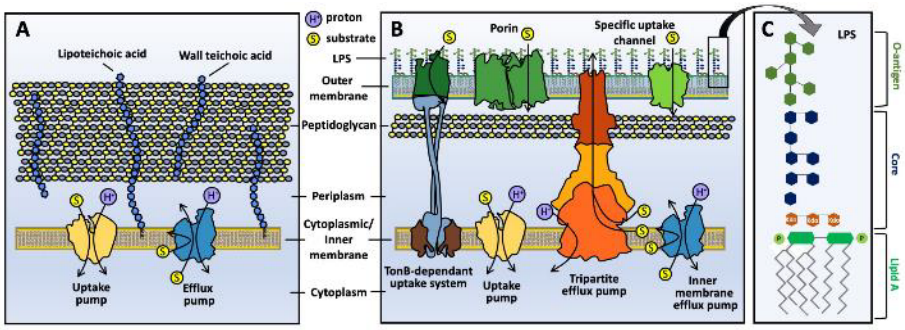
Soil bacteria in plant biocontrol and bioremediation



Soil microbes are hugely diverse and central to terrestrial ecosystems. We are investigating plant-colonising bacteria that could be used to protect crops from disease. These bacteria could alleviate the need for harmful agrochemicals. We have identified several novel gene clusters that encode plant protection factors, such as secreted specialised metabolites, and determined environmental conditions that promote their expression. We are investigating various species of soil bacteria, both plant associated and free living, that are able to degrade harmful chemical pollutants or help to prevent their spread. We have identified gene clusters that are likely to facilitate these activities.

Membrane transport systems and bacterial cell envelopes

Biological membranes are fundamental to cellular life. These thin layers of lipids provide permeability barriers that help to prevent the entry of toxins and the exit of nutrients from cells and sub-cellular compartments. Membrane transport systems are comprised of proteins that sit in biological membranes and facilitate the movement of ions or molecules from one side to another. Our research has focused on these proteins for over a decade. We have discovered new families of transport proteins involved in antimicrobial resistance and identified novel substrates for uptake and efflux pumps that are relevant to drug resistance and biotechnology. Using protein engineering, we are working to develop new to nature pumps designed to recognise compounds of interest.



Dr Ben Long

Photosynthesis research

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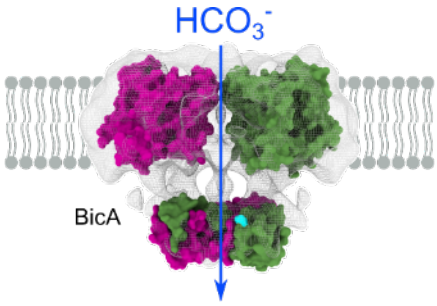
My research is focused on the understanding and application of CO_2 concentrating mechanisms, found in cyanobacteria (blue-green algae), for the improvement of photosynthetic CO_2 capture by plants and synthetic biological systems. This biotechnological approach to both improve crop yield and carbon sequestration is of critical importance as CO_2 emissions, climate change, and food security become more pressing global issues.

Directed evolution of bicarbonate transporters for crop improvement:

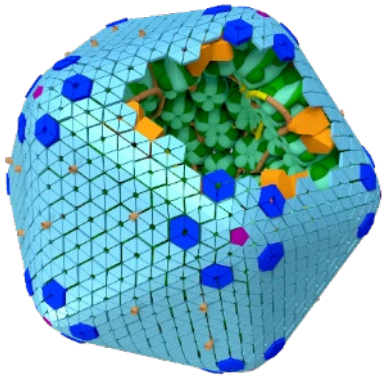
A synthetic biology aim in plant biology is the reconstruction of cyanobacterial CO_2 concentrating mechanisms (CCMs) in plants to improve carbon fixation and crop yield. Membrane bicarbonate transporters pump inorganic carbon across membranes to feed substrate to the world's most abundant enzyme, Rubisco. Engineering strategies to synthetically reconstruct CCMs in plants have been slowed by challenges to deliver functional bicarbonate transporters to plant chloroplast membranes. This project aims to evolve novel bicarbonate transporters that could be used in plant-based CCMs. Using synthetic biology approaches, a library of potential membrane transporters will be screened using a directed evolution system to create new genetic parts. Sequencing of modified transporters will enable additional rational design to further modify transporter function. The project will require Loop DNA assembly to generate complex expression cassettes, protein expression analysis and DNA sequence design.



The cyanobacterial bicarbonate pump, BicA

Building carboxysomes (turbo-charged CO_2 fixation engines) in E. coli:

The central component of the cyanobacterial CO_2 concentrating mechanism (CCM) are large proteinaceous, subcellular compartments called carboxysomes. Carboxysomes are nano-metre sized protein capsules containing hundreds of copies of the CO_2 fixing enzyme Rubisco, the enzyme carbonic anhydrase. Inside carboxysomes, bicarbonate is converted into CO_2 to fuel turbo-charged carbon capture. This characteristic of cyanobacterial CCMs makes them an important target for reconstruction in crop plants to enhance carbon fixation and yield. In this project a series of component carboxysome genes will be used to test the step-by-step construction of carboxysomes in *E. coli*. Using Goldengate DNA assembly techniques and a library of genetic parts, a complex set of carboxysome genes sets will be tested. Assessment of protein expression and the purification and analysis of carboxysomes will be used to test how well different expression units perform. Successful combinations of genes will form the basis of plant transformation to generate carboxysomes in plant chloroplasts.



Carboxysomes are nanometre-sized proteinaceous 'organelles' that capture CO_2 in cyanobacteria

Professor Brett Nixon

Male infertility, Andrology, Sperm-Egg Recognition

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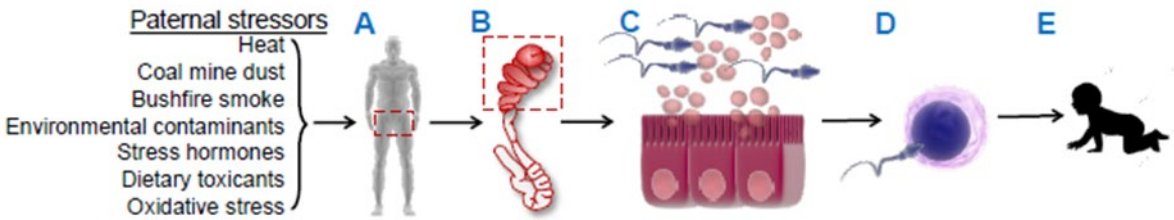
I have career goal of understanding the molecular basis of sperm development. In the last 20 years, I have developed a leading international profile for cell biology, proteomic, and sncRNA studies that have helped to resolve the mechanistic detail of how sperm acquire the functional competence to engage in the process of fertilisation and how this process is dysregulated in response to environmental stressors. My research includes studies that have defined the significant role of extracellular vesicles in coordinating sperm cell maturation, and the investigation of that maturation during sperm's transit of the epididymis. Currently we are working on the implementation of a number of innovations, such as the development of epididymal organoid cultures and a robust co-culture system for studying epididymosome-sperm interactions.

Project Title: Defining the impact of environmental stresses on male reproduction

Description: Environmental stressors impact male gamete quality with consequences extending to sperm dysfunction, dysregulated embryo development and phenotypic changes in the offspring. The overarching goal of this project is to identify how the male reproductive tract (epididymis) responds to environmental stressors to promote the transmission of epigenetic information to maturing sperm cells. We hypothesise that such changes are driven by a novel chain of cause and effect involving activation of the glucocorticoid receptor (NR3C1) within epididymal cells leading to the generation of epigenetic 'stress' signatures (i.e. small regulatory RNAs; sncRNAs), and their delivery to sperm via packaging and release of extracellular vesicles. Accordingly, in this project we will use multi-omic analytical tools to determine the biochemical changes in epithelial cells lining the epididymis that arise from paternal exposure to a range of clinically/occupationally relevant environmental stressors (heat, coal mine dust, direct stress hormone) and investigate the contribution of extracellular vesicles in relaying the 'stressed sncRNA' signals from the epithelial cells to the maturing sperm cells held within the lumen of the tract.



Dr Vanessa Melino

Listen now

Plant biology: salt tolerance and domestication

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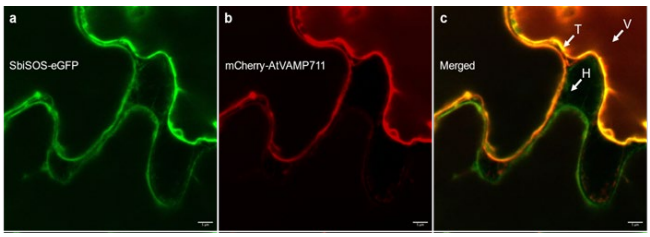
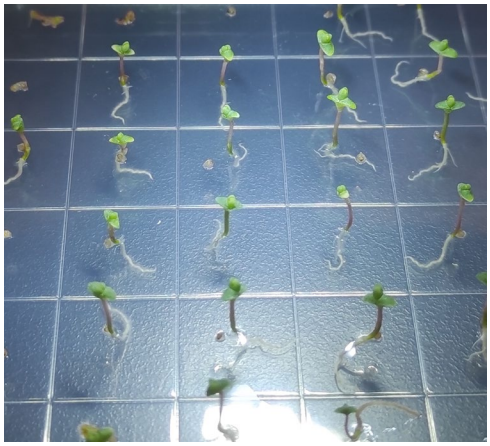
Salinity affects an estimated 30% of agricultural lands globally. In certain regions, salinization is now at levels that prevent economically feasible growth of even the most salt tolerant crops available to farmers. Halophytic plants have a remarkable ability to grow in saline water and the potential to provide food, fodder and fuels. Our group has led efforts to develop several chromosome scale reference genomes for Salicornia for comparative genomic studies. We have developed genetic germplasm for domestication and tools to study salt tolerance at the molecular level.

Bioengineering salt tolerant proteins



Edible halophytes in the genus Salicornia, also known as samphire or sea asparagus, thrive in seawater, accumulating up to 750 mM sodium (Na^+). It is remarkable that these plants can maintain growth and reproduction despite accumulating concentrations of Na^+ that is toxic to metabolic processes, and to cell development and growth of most other plant species. This so-called “tissue tolerance” must be enabled by at least three processes: vacuolar sequestration of Na^+, stabilization of protein translation and accumulation of osmolytes. Using a proteomic approach, we identified an intrinsically disordered protein, SALTY, predicted to provide mRNA-specific translational control in response to environmental change. We will use yeast, model plant species and *in vitro* assays to characterise these proteins and compare them to homologous proteins in salt sensitive species. By exploring unique protein domains and motifs from halophytes, we aim to introduce similar functionality into salt-sensitive species.

Domesticating halophytes for salt-water agriculture



Conventional breeding efforts have led to only modest improvements in salinity tolerance in a few crops. We propose an accelerated modern breeding program to domesticate wild Salicornia into a viable crop for distribution to water-scarce and saline environments. Genome editing can allow for rapid domestication of plants; however, a transformation and regeneration system is required. We have established a method to induce, proliferate and transfect callus from *Salicornia europaea* and we now need to induce organogenesis, which is technically the most challenging component.

Dr John Schjenken

Seminal Plasma and Extracellular Vesicle Biology

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Our research aims to advance knowledge of the male contribution at conception with emphasis on investigation the composition of seminal plasma and the function of signalling molecules present in this fluid. To achieve this, our group uses multiomic approaches, combining transcriptomics, proteomics and bioinformatics. Ultimately our research aims to expand our understanding of male factors contributing to infertility and the development of disorders of pregnancy in humans.

Novel determinants of male fertility carried by seminal fluid extracellular vesicles

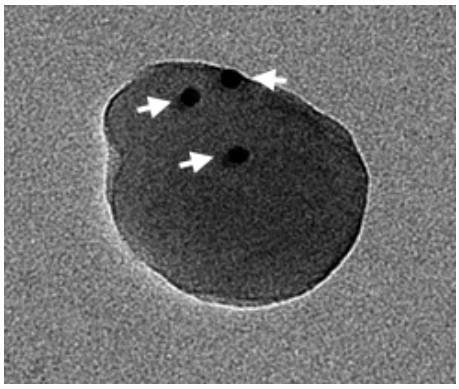


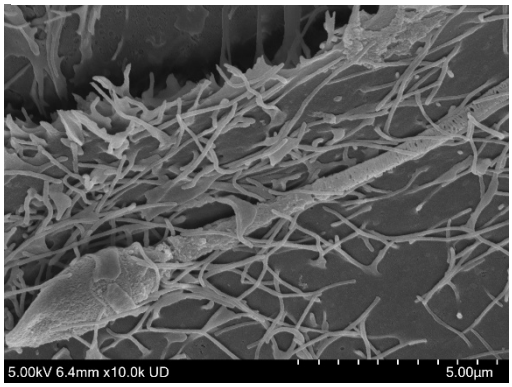
Fig 1. Transmission electron microscopy image of human seminal extracellular vesicle labelled with extracellular vesicle marker, Flotillin-1.

Infertility is a global public health issue, affecting 1 in 6 Australian couples. The reasons behind the increasing incidence of human infertility are complex, however male infertility is implicated in approximately 50% of infertile couples. Current understanding of the causes of male infertility and subfertility is limited and as such very few therapeutic treatments or tools that are available. While defective sperm is undeniably a major cause of infertility, emerging evidence suggests that other bioactive agents carried by seminal fluid play an important and underappreciated role in fertility, and likely contribute to infertility and subfertility in men. Amongst the components seminal fluid that exert effects at conception, extracellular vesicles (Fig. 1) are emerging as a poorly understood vehicle which can modify the constitution and function of sperm and seminal fluid. In this proposal, we will use established human models and leverage large clinical biobanks to characterise the biological actions of seminal fluid extracellular vesicles and define the relationship between extracellular vesicle composition, bioactivity, and fertility status in men. This project addresses a critical knowledge gap in the urgent need to define key mechanisms that underpin male infertility, which in turn will fundamentally change our understanding of the male contribution to the biological events of conception. Ultimately, the work proposed in this study will lay the foundation for the development of novel preventative and therapeutic interventions to improve fertility, mitigate pregnancy disorders, and benefit the overall health of future generations.

Sperm - a novel role in human reproduction beyond fertilisation

Understanding of the fundamental biology underpinning events at the time of conception, and the mechanisms by which male and female components interact, is limited and our capacity to understand the key determinants of fertility remains poor. We have shown that appropriate conditioning of the female immune system occurs by exposure to the conceiving male's seminal fluid at coitus prior to and at the time of conception. This 'priming' is in part mediated by soluble immune-regulatory agents and male transplantation antigens contained in seminal plasma. Whether or not sperm also contribute to modifying the female immune response is not known.

Fig 2. Scanning electron microscopy image of human spermatozoa interacting with female reproductive tract cells.



Recently, we have made the surprising discovery in mice that sperm also directly influence female tissues (Fig. 2) to attenuate reproductive success. This study will investigate whether similar sperm-mediated immune modulation occurs in women and investigate the underlying molecular mechanisms. We will utilise a well-accepted in vitro model of male seminal fluid signalling to investigate the signalling potential of sperm in men and will identify key sperm-associated signalling agents as well as define biochemical differences between sperm from fertile men, and men with unexplained infertility, that account for variance in immune-regulatory capacity. We will determine whether differential abundance of key signalling molecules on sperm contributes to fertility status and associates with clinical parameters. If a direct effect of sperm signalling on the events that facilitate female reproductive function can be proven, this will revolutionise our commonly held view of the role of sperm in the reproductive process and substantially advance our understanding of the paternal contribution to conception and fertility. The results of this project will inform development of new diagnostic tests to extend current semen analyses that will better define fertility status in men, and provide new insight and targets for improving male reproductive health.