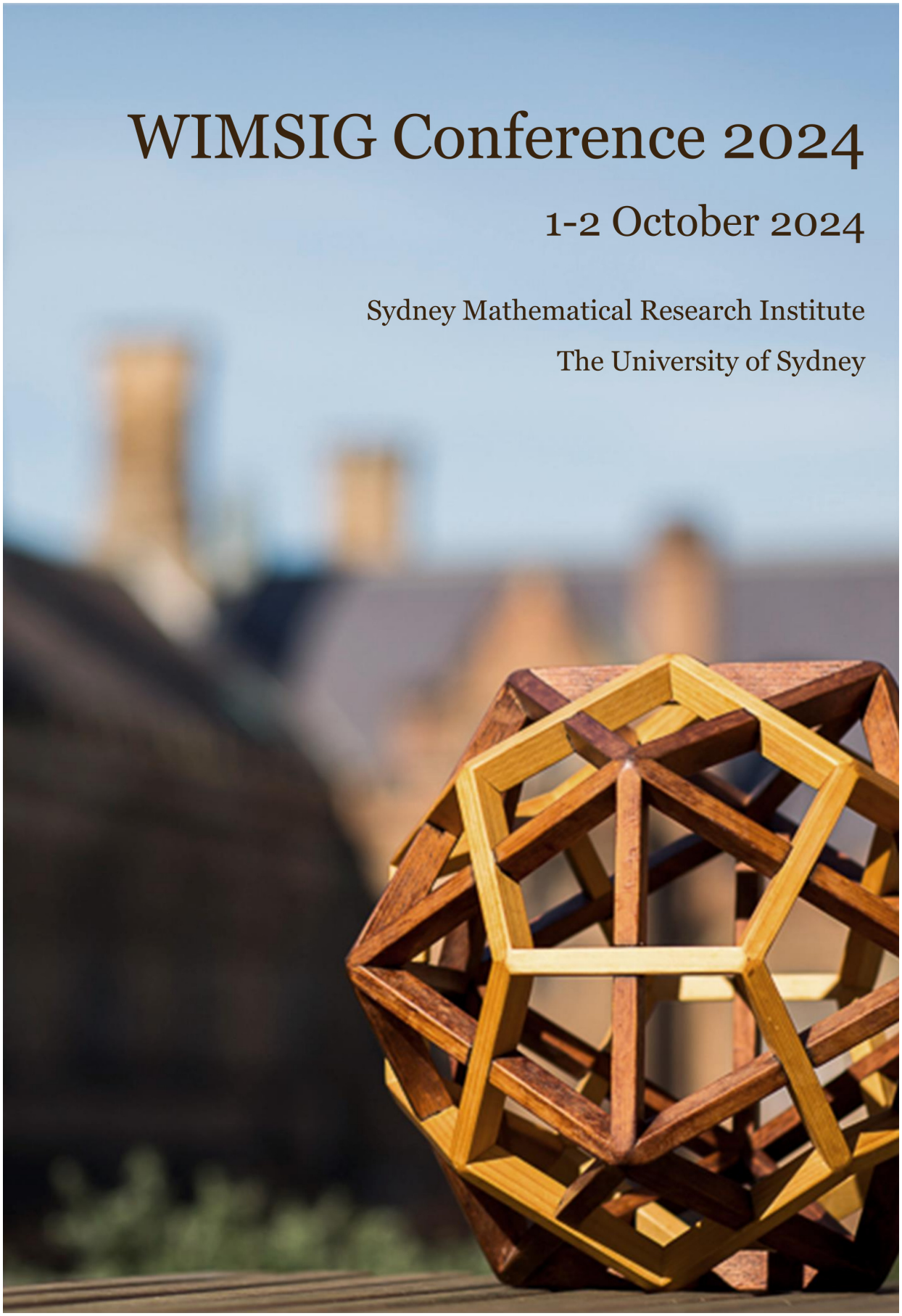
WIMSIG Conference 2024

1-2 October 2024

Sydney Mathematical Research Institute

The University of Sydney



Contents

Welcome to WIMSIG Conference 2024!

The inaugural WIMSIG Conference was held at the University of South Australia in 2017, and the second WIMSIG Conference took place in 2021 in hybrid mode, with some lucky hubs able to meet in person and others online. We are very happy to be able to meet in person again for WIMSIG Conference 2024, to celebrate the achievements of women, trans and gender diverse people in the mathematical sciences in Australia.

We have around 150 registered participants, including over 40 students. Over the two days we will hear from four plenary speakers, as well as speakers in 12 special sessions and one contributed session. Their talks span a wide range of interests encompassing applied mathematics, pure mathematics, statistics, industry and mathematics education. There will be 95 talks in the special or contributed sessions, all presented by women, trans or gender diverse speakers. Many thanks to our four plenary speakers, all special session organisers and all speakers.

Our programme also includes three parallel discussion/panel sessions, so participants can choose a topic that interests them. Thanks very much to organisers and panellists of those sessions. Social events include the Welcome Reception at the Women's College; an LGBTQI+ and Allies lunch, and the Conference Dinner which will be held at the Darling Room, Dockside, Cockle Bay Wharf. At the Conference Dinner we will be joined by Professor Bronwyn Fox, the Deputy Vice-Chancellor Research and Enterprise of UNSW Sydney, who will give a short address.

Thanks to our generous sponsors, we were able to offer Early Career Researcher Travel Awards to more than 30 participants. We have arranged free childcare, partly funded by an AustMS–WIMSIG Anne Penfold Street award. Please consider providing childcare next time you organise a conference! There are two rounds of the AustMS–WIMSIG Anne Penfold Street awards, with applications due by 1 April and 1 October each year. For more information visit

`https://austms.org.au/awards-grants/awards/penfold-street-awards/`

Many thanks to Stephan Tillmann for agreeing to host WIMSIG Conference 2024 at the Sydney Mathematical Research Institute (SMRI), and to John Banks for all his help with Register! and website questions. As final thanks, I am extremely grateful for the enthusiasm and hard work of the organising committee members.

I hope that you will find the conference interesting and inspiring, and that you will feel more strongly connected after attending. To quote Lesley Ward, the Director of the inaugural WIMSIG Conference 2017:

> Thank you for coming, and please ask each other "what are you working on?".

Catherine Greenhill
Chair, WIMSIG Conference 2024

WIMSIG Conference 2024 Organising Committee

Harini Desiraju, Sydney Mathematical Research Institute

Kate Doyle, Sydney Mathematical Research Institute

Catherine Greenhill, UNSW Sydney – Chair

Xiaoping Lu, University of Wollongong

Catherine Penington, Macquarie University

Rachel Wang, University of Sydney

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Joan Licata, ANU – Chair

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Adrianne Jenner, Queensland University of Technology

Organisers of AustMS–WIMSIG Early Career Workshop
(satellite event, Monday 30 September 2024)

Grace Garden, University of Sydney

Sophie Raynor, James Cook University

Alex Tam, University of South Australia

Thanks also to

• John Banks (Melbourne) for assistance with Register! and the website;

• Benjamin Lyall (UNSW Sydney) for his assistance with obtaining industrial sponsorship;

• Chris Baker (Melbourne), co-organiser of the LGBTQI+ & Allies Lunch.

Conference Sponsors

We are extremely grateful to all of our sponsors.

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- The University of Sydney
- UNSW Sydney
- Australian National University
- The University of Adelaide
- The University of Melbourne
- University of Wollongong
- The University of Queensland
- Monash University
- QUT

Monday 30 October 2024

5:00pm – 7:00pm, Welcome Reception, The Women's College, 15 Carillon Avenue, Newtown (light refreshments).

Schedule, Tuesday 1 October 2024

9:15am – Opening remarks, NLBA-101

9:30am – **Plenary lecture**, Leah Edelstein-Keshet, NLBA-101 9

10:30am – Morning tea

Special sessions - Tuesday morning

11:00am

scale	**AMP**	**confidence**	**PDE**	**decision**
Campbell 11	Kandanaarachchi 16	Koch 22	Sportelli 27	Korsah 33
NLBA-342	NLBA-102	NLBA-020	NLBA-107	NLBA-024
MIRD	**statistics**	**shiny**	**topology**	**contributed**
Senior 38	Wei 43	Dowling 44	Ibarra 48	Fatema 55
NLBA-340	NLBA-346	NLBA-028	NLBA-026	NLBA-105

11:30am

scale	**AMP**	**confidence**	**PDE**	**decision**
Bilgin 11	Kayanattath 17	McMahon 22	Meyer 27	Walker 35
NLBA-342	NLBA-102	NLBA-020	NLBA-107	NLBA-024
MIRD	**statistics**	**shiny**	**topology**	**contributed**
Ivory 36	Ghanbari 40	Raynor 46	Garden 47	Fernando 55
NLBA-340	NLBA-346	NLBA-028	NLBA-026	NLBA-105

12:00pm

scale	**AMP**	**confidence**	**PDE**	**decision**
Hogan 13	Nurcombe 17	Stylianou 24	Cirstea 26	Brown 32
NLBA-342	NLBA-102	NLBA-020	NLBA-107	NLBA-024
MIRD	**statistics**	**shiny**	**topology**	**contributed**
Bongiovanni 36	Raveendran 42	Harrison 45	Cantarino 47	Ay 54
NLBA-340	NLBA-346	NLBA-028	NLBA-026	NLBA-105

12:30pm – 1:30pm, Lunch (provided)

Special sessions - Tuesday afternoon

1:30pm

confidence	**history**	**shiny**	**topology**	**WIL**
Hall 21	Ward 31	Kleshnina 46	Jain 48	Rao 50
NLBA-020	NLBA-024	NLBA-028	NLBA-026	NLBA-344

2:00pm

history	**shiny**	**topology**	**WIL**
Ball 31	Jenner 45	Licata 48	Walpita Gamage 52
NLBA-024	NLBA-028	NLBA-026	NLBA-344

2:30pm – **Plenary lecture**, Grace Chung, NLBA-101 9

3:30pm – Afternoon tea

4:00pm – 5:00pm, **Parallel discussion/panel sessions:**

Careers Beyond Academia	**Community and Culture**	**Equations of balance**: work, life & part-time careers
10	10	10
NLBA-101	NLBA-104	NLBA-106

6:30pm – Conference Dinner, Darling Room, Dockside, Cockle Bay Wharf

Schedule, Wednesday 2 October 2024

9:30am – **Plenary lecture**, Valentina Wheeler, NLBA-101 10

10:30am – Morning tea

Special sessions - Wednesday morning

11:00am

scale	**AMP**	**confidence**	**PDE**	**hybrid**
Chisholm 12	Strumila 18	Collins 21	Chen 26	Titova-Shankar 30
NLBA-342	NLBA-102	NLBA-020	NLBA-107	NLBA-440
decision	**MIRD**	**statistics**	**topology**	**WIL**
Le 33	Myerscough 37	Ballouz 40	Hui 47	Vaskova 51
NLBA-024	NLBA-340	NLBA-346	NLBA-026	NLBA-344

11:30am

scale	**AMP**	**confidence**	**PDE**	**hybrid**
Winslow 15	Skelton 18	Nanayakkara 23	Gazwani 26	Kandanaarachchi 28
NLBA-342	NLBA-102	NLBA-020	NLBA-107	NLBA-440
decision	**MIRD**	**statistics**	**topology**	**WIL**
Tartaglia 34	Miller 37	Shim 42	Tobin 49	Morgan 50
NLBA-024	NLBA-340	NLBA-346	NLBA-026	NLBA-344

12:00pm

scale	**AMP**	**confidence**	**PDE**	**hybrid**
Flegg 13	Wilson 19	Tubino 24	Vaughan 27	Peiris 29
NLBA-342	NLBA-102	NLBA-020	NLBA-107	NLBA-440
decision	**MIRD**	**statistics**	**topology**	**WIL**
Mortimer 33	Weatherley 39	Imiyage Dona 41	Thompson 49	Ward 53
NLBA-024	NLBA-340	NLBA-346	NLBA-026	NLBA-344

12:30pm – Lunch (provided) and LGBTQI+ & Allies Lunch

Special sessions - Wednesday afternoon

1:30pm

scale Stadler 14 NLBA-342	**AMP** Makarova 17 NLBA-102	**confidence** Morgan 22 NLBA-020	**hybrid** Samarakoon 29 NLBA-440	**decision** Baker 32 NLBA-024
MIRD Pooladvand 38 NLBA-340	**statistics** Popovic 42 NLBA-346	**topology** Turner 49 NLBA-026	WIL Tubino 51 NLBA-344	**contributed** Sofranova 56 NLBA-105

2:00pm

scale Smith 14 NLBA-342	**AMP** Cheng 16 NLBA-102	**confidence** De Vas Gunasekara 21 NLBA-020	**hybrid** Humphries 28 NLBA-440	**decision** Windecker 35 NLBA-024
MIRD Yan 39 NLBA-340	**statistics** Huang 41 NLBA-346	**topology** Robins 48 NLBA-026	**WIL** Verma 52 NLBA-344	**contributed** Chourasiya 54 NLBA-105

2:30pm

AMP Wilkins 18 NLBA-102	**confidence** Albizu-Mallea 20 NLBA-020	**decision** Hickson 32 NLBA-024	**statistics** Wijekoon 43 NLBA-346	**shiny** Araujo 44 NLBA-028
contributed Thamwattana 56 NLBA-105				

3:00pm – Afternoon tea

3:30pm – **Plenary lecture**, Antonietta Mira, NLBA-101 9

4:30pm– Closing remarks. End of conference!

Plenary Talks NLBA-101

Grace Chung (Google Research Australia)
My Journey to AI

Grace will talk about her career journey from her days as an Electrical Engineering and Mathematics student to her role as the Head of Google Research Australia. She will talk about her experience in research and software engineering along the way. Grace will also speak to how we have arrived at a transformative juncture in technology through the evolution of AI.
(Tuesday 2:30pm, NLBA-101)

Leah Edelstein-Keshet (University of British Columbia)
Mathematical modeling applied to women's health

Several years ago, Dr Kathryn Isaac, a UBC professor and clinical surgeon contacted me with an intriguing problem. In her work on cosmetic reconstructive for post-breast-cancer -surgery patients, she encounters cases of failure that result (weeks or months later) in "capsular contraction" (CC). This painful condition arises when the healing tissue (the "capsule") that forms surrounding a breast implant undergoes pathological contraction and deformation - necessitating a new rounds of surgery. In this talk, I describe work in our team to help understand the root causes of CC, the risk factors, and possible preventative treatments. We use mathematical modeling to depict and investigate hypotheses for cell-level mechanisms involved in initiating CC. I will describe two rounds of modeling, with the most recent being a joint project with Ms Yuqi Xiao (UBC MSc student) and Prof. Alain Goriely (Oxford). (Tuesday 9:30am, NLBA-101)

Antonietta Mira (Universitá della Svizzera italiana)
From noise to insight: unveiling hidden patterns by estimating the data intrinsic dimension

Real-world datasets often exhibit a high degree of potentially non-linear correlations and constraints among their features. As a result, even though these datasets may have a high embedding dimensionality, the data usually lie on a manifold with a much lower intrinsic dimension. This intrinsic dimension may vary depending on the scale of analysis, especially in the presence of noise. This raises intriguing questions: How many variables, or combinations of variables, are necessary to accurately describe a real-world dataset without significant information loss? What is the appropriate scale for analyzing and visualizing the data? I will present a comprehensive approach to estimating the intrinsic dimension of data, where the optimal number of variables and the most suitable scale are determined self-consistently, effectively accounting for the impact of noise. I will demonstrate how, in numerous real-world scenarios, a straightforward topological characteristic like the intrinsic dimension can reveal complex data structures and enhance our understanding in subsequent statistical analyses. Applications of this approach span diverse fields, including gene expression, protein folding, pandemic evolution, fMRI analysis, finance, sports data, and the study of neural network representations. (Wednesday 3:30pm, NLBA-101)

Valentina Wheeler (University of Wollongong)
Geometric flows and partial differential equations: the mathematics of bushfires and blood cells

Geometric analysis is the intersection between geometry and partial differential equations. Curvature flows are one of the main topics in this field. I will present several theoretical results with direct applications to minimal surfaces problems and modelling a fire line or a biological membrane.
(Wednesday 9:30am, NLBA-101)

Parallel discussions/panel, Tuesday 4pm - 5pm

Participants can choose to attend one of the following three parallel discussion/panel sessions.

∗ **Careers Beyond Academia** (panel): organised by Harini Desiraju. **NLBA-101**
Hear from these panellists and ask them questions!

- Soraya McPhail (Australian Bureau of Statistics)
- Catherine Meister (SMRI Communications Coordinator)
- and two panellists from the Australian Signals Directorate.

∗ **Culture and Community** (discussion):
co-led by Natalie Thamwattana and TK Le. **NLBA-104**

This discussion session invites conversations about the culture of mathematical research in Australia, including how it works, how it can be improved and how we can affect change. Recognising that culture and community are deeply intertwined, the session will also explore ways that we can build an inclusive and welcoming mathematical community, highlighting how community practices can shape and enhance the culture of mathematics.

∗ **Equations of balance: Navigating work, life and part-time careers** (discussion):
co-led by Ajani De Vas Gunasekara and Catherine Penington. **NLBA-106**

This discussion session invites participants to share their experiences and insights on managing the balance between career and personal life, particularly within part-time roles. We will explore the challenges of setting boundaries between professional and personal responsibilities, and how these boundaries can foster both personal well-being and career success. The discussion will also address strategies for creating flexible career paths that support sustainable work-life integration, while contributing to a fulfilling career in the mathematical sciences.

Special session abstracts

A matter of scale: Mathematical modelling of infectious disease dynamics at the population, people and pathogen levels NLBA-342

Organisers: Patricia Campbell, Alexandra Hogan and Eva Stadler

Gizem Mayis Bilgin (ANU), Kamalini Lokuge, Syarifah Liza Munira, Kathryn Glass
Vaccine prioritisation at the population, people, and pathogen levels

Mathematical models provide vital tools for guiding vaccine prioritisation decisions, offering a structured approach to comparing the impacts of different health policies. Health policies compete against each other for attention, resources, and funding. Vaccines, in particular, present unique challenges in demonstrating their benefits, as infectious disease affect entire communities rather than isolated individuals.

This talk presents vaccine prioritisation case studies for COVID-19 and other emerging pandemic threats, focusing on decisions made at the population, people, and pathogen levels. I explore how differences in age structure, prevalence of comorbidities, vaccine hesitancy, and immunity contribute to the setting-specific impact of interventions. I show that prioritising individuals at the highest risk of developing severe outcomes is the best way to minimise severe disease when circulation is high. I demonstrate how the effective use of vaccines in future pandemics will depend on age-specific severity and the strength of infection- and vaccine-derived immunity. Ultimately, I illustrate how mathematical models can provide evidence to ensure that health policies are effective and equitable within specific settings. (Tuesday 11:30am, NLBA-342)

Nefel Tellioglu, **Patricia T. Campbell** (Melbourne), Yingying Wang, Xinghui Chen, Violeta Spirkoska, Kylie Carville, David J. Price, Natalie Carvalho, Jodie McVernon
Potential impact of higher valency pneumococcal vaccines on transmission and disease burden in Australia

Commonly carried harmlessly in the nasopharynx, *Streptococcus pneumoniae* is the causative organism of invasive pneumococcal disease (IPD) and a substantial contributor to the disease burden of community acquired pneumonia (CAP). Almost 100 serotypes have been identified, with different immunogenicity and associations with invasive disease, and multiple circulating serotypes compete for host resources in the same population. Pneumococcal conjugate vaccines (PCV7, PCV10, PCV13, PCV20) provide protection against both colonisation and disease for included serotypes, but higher valency vaccines tend to be less immunogenic. We investigated the potential impact on transmission and disease of higher valency vaccine introduction. We developed a serotype- and vaccine-specific model of *S. pneumoniae* immunity that linked immunogenicity with effectiveness against infection and disease. This model was then coupled with a multi-strain individual based transmission model that allowed for concurrent colonisation with up to two serotypes, subject to competition. Modelled prevalence of carriage and incidence of IPD and CAP were calibrated to

Australian and UK data. Increased transmissibility of the serotypes contained in the PCV7 vaccine was consistent with their observed higher prevalence prior to vaccine introduction. Serotype replacement, where non-vaccine serotypes replace vaccine serotypes, was an emergent property of our model. Following the introduction of PCV7, prevalence of vaccine-type IPD and CAP reduced, but within five years the disease burden returned to pre-vaccine levels due to serotype replacement. Similar behaviour occurred when PCV13 and PCV20 were introduced in the model. Our model is the first in the world to separately model each serotype, allowing incorporation of differences in immunogenicity and disease burden. Due to serotype replacement, serotype-specific surveillance is required to ensure that vaccine programs continue to deliver desired outcomes. In particular, the implications of reduced immunogenicity should be monitored to ensure that gains made to previously problematic serotypes are not eroded. (Tuesday 11am, NLBA-342)

Rebecca H. Chisholm (La Trobe), S Xu, H Shrestha, S Feleke, DA Boakye, JHN Osei, S Pi-Bansa, E Mensah, OD Asiedu, JKL Opare, T Lorenzi, WN Grant, KK Frempong, SM Hedtke

Incorporating sub-optimal response to treatment in models simulating the transmission and control of human onchocerciasis

Human onchocerciasis is a vector-born disease caused by the parasitic worm *Onchocerca volvulus* (*O. volvulus*) and transmitted by bites of blackflies. In 2019, the estimated global onchocerciasis disease burden was 1.23 million disability-adjusted life-years, with more than 99% of cases occurring in sub-Saharan Africa, despite decades of control programs in the region delivering annual or bi-annual rounds of mass drug administration of ivermectin (MDAi). One reason for the ongoing transmission of *O. volvulus* may be the presence and rise in frequency of adult worms with low susceptibility to the fertility-reducing (i.e., embryostatic) effects of ivermectin, so called, 'sub-optimal responder (SOR) worms'.

To date, transmission models that have been developed to inform MDAi guidelines have not accounted for variable fertility response of worms to ivermectin. The addition of this extra complexity into models is necessary so that models can be used to investigate whether the presence of SOR worms is impacting the effectiveness of recommended MDAi control programs, and whether changes to the current frequency and durations of MDAi programs will provide more effective control. However, including this additional complexity is complicated because (1) *O. volvulus* reproduces sexually; (2) the ivermectin fertility response phenotype is likely to be a complex genetic trait controlled by multiple loci, rather than a single locus; and (3) it is likely that there are a spectrum of fertility response phenotypes, ranging from an optimal response to ivermectin, up to no response at all.

In this presentation, I will describe how we have adapted a deterministic *O. volvulus* transmission model so that it accounts for the possible presence of two *O. volvulus* phenotypes: good responders (GR, worms assumed to have a slow return to fertility following exposure to ivermectin) and SOR (worms assumed to return much faster to fertility following exposure to ivermectin). I will demonstrate how the model can be used to explore the impact of SOR on the effectiveness of MDAi programs in hyperendemic populations, and projected changes to SOR worm frequency. I will then discuss our efforts to develop more complex versions of this model that consider more complicated population demographics and phenotypic structure. (Wednesday 11am, NLBA-342)

Jennifer Flegg (Melbourne)
Jump-Switch-Flow solutions of dynamical systems: A hybrid, adaptive and efficient approach

Many dynamical systems exhibit multiscale behaviour. The classic example being the predator-prey model, where a predator and prey interact, recreating observed oscillations, giving rise to Atto-fox problems, where populations become infeasibly small. Similar problems also arise in epidemiology, immunology and molecular biology. It is well known that at low population numbers, systems are governed by stochastic, rather than deterministic effects. One resolution to this problem is to recast the model as a continuous time Markov chain to account for the discrete nature of small populations. Unfortunately, for large populations, simulating this process is computationally expensive.

We have developed a formulation of this process such that, depending on the state of the system, we can solve the system as is appropriate, to incorporate stochastic (Jumping) effects with low populations and be computationally cheap (Flowing) when the system is sufficiently large. We call this approach 'Jump-Switch-Flow'. In addition to incorporating small population stochastic effects, our approach also has a natural notion of compartment extinction, providing a natural solution to Atto-type problems.

In this talk, I will present Jump-Switch-Flow (an Open-Source and readily available package) and demonstrate, through a simulation study of an epidemiological SIRS model with demography, that it reproduces much of the behaviour of current gold standard exact simulation techniques, while providing substantially significant computational reductions. I will also demonstrate using clinical within-host viral load data that the approach is highly appropriate for parameter estimation.
(Wednesday 12pm, NLBA-342)

Alexandra Hogan (UNSW Sydney), Daniela Olivera Mesa, David Khoury, James Wood, Azra Ghani
Modelling long-term vaccination strategies to mitigate the impact of endemic SARS-CoV-2 transmission and future variant emergence

In an era of endemic SARS-CoV-2 transmission, countries are continuing to evaluate how best to schedule ongoing COVID-19 booster vaccinations. Mathematical modelling therefore provides a useful tool to predict the benefit of future vaccination strategies, incorporating the loss of protection due to waning immunity and the emergence of new variants.

We developed a combined immunological-transmission model parameterised with data on transmissibility, severity, and vaccine effectiveness. Within our underlying immunological model, we introduced a method (the "variant fold reduction") for capturing loss of immune recognition against new variants, and the increased protection afforded by variant-adapted vaccines [1,2]. We used our model to simulate SARS-COV-2 transmission and vaccine rollout in different characteristic global settings (considering population age-structures, contact patterns, health system capacities, prior transmission, and vaccine uptake) [3]. We considered a range of future variant emergence scenarios and quantified the impact and efficiency of a different age-based annual and biannual vaccine booster scenarios. We also considered the additional value of switching to vaccines that have been adapted to match more recently circulating variants of concern.

Our modelling suggested that vaccination of the high-risk population remains an important tool to reduce morbidity and mortality from current and future SARS-CoV-2 variants. Of the vaccination strategies considered, it is anticipated that focusing vaccination in the highest-risk cohorts will be the most efficient (and hence cost-effective) strategy to reduce morbidity and mortality.

(Tuesday 12pm, NLBA-342)

Lauren Smith (Walter and Eliza Hall Institute)

PvSeroTAT: Predicting and treating individuals recently infected with Plasmodium vivax using serological markers of recent exposure

Relapses from *Plasmodium vivax* hypnozoites (latent liver-stage parasites) are a major obstacle for malaria elimination. Detecting hypnozoites remains a challenge, yet *P. vivax* blood-stage infections induce strong and enduring antibody responses. Antibodies serve as indicators of recent and ongoing infections, enabling identification of individuals recently exposed to *P. vivax* and susceptible to carrying hypnozoites. Previous work has identified several candidate serological markers for recent past *P. vivax* exposure (i.e previous nine months). Building on this work, this study has balanced performance against practical feasibility by selecting smaller subsets of serological markers predicting past *P. vivax* infection. We have trained a Random Forest classification algorithm to identify individuals with recent exposure, using cohorts with known exposure histories. In this presentation, I will discuss our assessment of how well the classification algorithm predicts relapse in a unique cohort study (n = 570), where soldiers returned to a malaria-free area from a nine-month deployment in a malaria-endemic area. Our diagnostic tool achieved an AUC of 0.92, with 86% sensitivity and specificity in identifying future relapses using antibody levels measured in blood samples from recruitment. These findings demonstrate the ability of our diagnostic test to identify individuals at risk of relapse using serological markers. I will present the results and discuss their implications for the development of a novel public health intervention *P. vivax* serological testing and treatment (PvSeroTAT) for relapse prevention. (Wednesday 2pm, NLBA-342)

Eva Stadler (UNSW Sydney), Deborah Cromer, Samson Ogunlade, Miles P. Davenport, David S. Khoury

Seeding a season of malaria: individual and population determinants of parasite carriage across the dry season

In many malaria-endemic regions, malaria transmission is seasonal with no transmission in the months-long dry season. Malaria parasites can survive the dry season within some individuals who carry parasites from one transmission season to the next. We refer to these individuals as "carriers". However, it is not clear why some individuals have these long-lasting infections while most individuals clear all parasites during the dry season. We aim to characterize carriers using a stochastic agent-based model to simulate the life history of infectious bites, parasite burden, and immunity of individuals. Our model includes stochastic seasonal infectious mosquito bites and deterministic within-host dynamics. We explore two options for who carries parasites over the dry season: (1) random carriage in a homogeneous population or (2) exposure-dependent carriage in a heterogeneous population. We simulated both scenarios and found that the distinguishing feature is the time to the first infection in the transmission season. Data from a longitudinal study in Mali shows that carriers are infected significantly earlier than non-carriers as in the case of

exposure-dependent carriage in a heterogeneous population. Thus, the most exposed individuals in a heterogeneous population are more likely to carry parasites over the dry season and start the next malaria transmission season. Moreover, since the most exposed individuals in a community are most likely to be dry season carriers, this enables a more than 2-fold faster spread of parasites into the mosquito population at the start of the subsequent transmission season.

(Wednesday 1:30pm, NLBA-342)

Mackrina Winslow (Melbourne), Vito Colella, Juan Pablo Villanueva-Cabezas, Patricia Therese Campbell

A Transmission Model for Understanding Strongyloides stercoralis Dynamics in Humans and Dogs

Strongyloides stercoralis is a soil-transmitted helminth that affects over 600 million people and is estimated to infect 6% of dogs worldwide. *S. stercoralis* has complex life cycle features, including parthenogenesis and auto-infection, which enable lifelong infection within the hosts. While the potential role of dogs in transmitting *S. stercoralis* to humans remains uncertain, experimental studies on cross-species transmission of *S. stercoralis* have identified patent infections between humans and dogs. Moreover, genomics studies have identified two distinct lineages of *S. stercoralis* — one exclusive of dogs and another shared between dogs and humans. This study aims to develop a model to describe the transmission dynamics of *S. stercoralis* with a focus on exploring the potential contribution of dogs to *S. stercoralis* infection dynamics in humans. We developed a compartmental model to represent infection transmission in humans and dogs through infective larvae present in the environment. Humans are stratified by age (children and adults) to capture the age-specific contribution to infection transmission and acquisition. Additionally, the infectious reservoir was divided into two compartments: potentially zoonotic infectious larvae and non-zoonotic infectious larvae. With this model, we explore different scenarios with varying proportions of dogs that contribute to zoonotic infection and determine the effect of these changes on human *S. stercoralis* infection dynamics. The model is calibrated to demographic and epidemiological data from Cambodia for both humans and dogs. Given the uncertainties of many parameters in *S. stercoralis* dynamics, the Latin Hypercube Sampling method was employed to estimate the parameter values critical for describing the role of dogs in each transmission scenario. For parameter estimation, we use *S. stercoralis* prevalence in children and dogs at the equilibrium as a summary statistic. We filter the model outputs to select simulations that produce endemic equilibrium prevalence within the 95% confidence interval of the observed prevalence. If genomic studies will confirm that *S. stercoralis* is a zoonotic infection transmitted from dogs, the exploration of different scenarios will help to understand the role of dogs in *S. stercoralis* transmission. In addition, this model could be employed to explore the effectiveness of preventive intervention approaches to control *S. stercoralis* infection in humans and dogs. (Wednesday 11:30am, NLBA-342)

Algebra and Mathematical Physics NLBA-102

Organisers: Asilata Bapat, Justine Fasquel, Bregje Pauwels and Milena Radnovic

Eve Cheng (ANU)
Topological analysis of the SSH family

The extensive family of SSH models started from the Hermitian two-band SSH model proposed by Su, Schrieffer and Heeger, the simplest yet fundamental topological insulator model. This simple model describes the spinless non-interacting fermion Hamiltonian on a one-dimensional finite lattice with staggered hopping amplitudes. Since then, many extensions on this model were suggested and we now have a large family of SSH models. While the topological invariants of the simple original SSH model were well-understood, the origins of the topological behaviours of the more generalised SSH models remain an active area of research.

In this talk I will introduce the topic and topological data analysis as the tool we use to search for topological invariants. The introduction of the topic includes a clear description of both how "topology" is defined in this system and the challenges associated with the search for the topological invariants. We want to then show clearly how topological data analysis can be used in problems like this and present our recent publication investigating the complex SSH model as an example of its applications. We also aim to briefly introduce our program as a tool for further exploring this problem. (Wednesday 2pm, NLBA-102)

Sevvandi Kandanaarachchi (CSIRO), Cheng Soon Ong
Representing Sparse Graphs with Graphons: Challenges and Approaches

How can we represent the limit of a graph sequence when the number of nodes increases to infinity? To represent this infinite object, graphons are used. A graphon is a function defined on a unit square. Generally, the unit square represents a scaled adjacency matrix and the function value at each point in the square represents edge probabilities of nodes. The graphon can be used as a generating model or a blueprint for a sequence of graphs. For example, if we know the graphon and we want to see how a graph with 1000 nodes looks like in this instance, we can sample a 1000-node graph from the graphon. The main challenge of graphons is that graphs generated from a graphon are dense. That is, the proportion of edges to the number of nodes squared is fixed as the graph grows. But in many real-world applications, graphs are sparse. So how do we represent sparse graphs using graphons? In this talk, we will discuss such methods and present some recent advances. (Tuesday 11am, NLBA-102)

Seethalakshmi Kayanattath (ANU), Uri Onn

Representation zeta function of the symplectic group over a finite local principal ideal ring of length 2

Let G be a group and for $n \in \mathbb{N}$, we denote by $r_n(G)$ the number of n-dimensional complex irreducible representations of G up to isomorphism. If G is topological or algebraic, we assume further that the representations are continuous or algebraic, respectively. We can gather insight into the structural properties of the group by analysing the asymptotics of the sequence $r_n(G)$.

A group G is said to have polynomial representation growth (PRG) if the sequence $r_n(G)$ is bounded by a polynomial in n. For a group G with PRG, we encode the number of irreducible representations in a Dirichlet generating function called the representation zeta function. It is given by

$$\zeta_G(s) := \sum_{n=1}^{\infty} r_n(G) n^{-s} = \sum_{\rho \in \mathrm{Irr}(G)} (\dim \rho)^{-s}$$

where s is a complex variable and $\mathrm{Irr}(G)$ is the set of isomorphism classes of finite dimensional complex irreducible representations of G. The Dirichlet generating function is a valuable tool in studying the asymptotics of a sequence. We apply Clifford theory to compute the representation zeta function of the symplectic group over a finite local principal ideal ring of length 2.

(Tuesday 11:30am, NLBA-102)

Svetlana Makarova (ANU) with Andres Fernandez Herrero, Emmett Lennen

Moduli of objects in finite length abelian categories

The classical notion of families of sheaves and representations admits a nice analog in the more general setting of abelian categories, due to the work of Artin and Zhang. I will recall this definition and show that it leads to a moduli theory of objects in abelian categories. In some cases, one can also introduce a notion of stability and prove that loci of semistable objects admit good moduli spaces, which are projective. The last result is contained in the arxiv paper https://arxiv.org/abs/2305.10543. (Wednesday 1:30pm, NLBA-102)

Madeline Nurcombe (UQ), Jorgen Rasmussen

An isomorphism of diagram algebras

A diagram algebra is an algebra with a basis of diagrams, and multiplication based on concatenation of diagrams. The dilute Temperley-Lieb algebra and the Motzkin algebra are diagram algebras, primarily used in statistical mechanics and pure mathematics, respectively. They are defined in terms of the same basis diagrams, but different multiplication rules. We show that they are isomorphic, as long as a particular parameter of the Motzkin algebra is nonzero. Existing results about each algebra can then be applied to the other, including their representation theory, presentations, and integrable loop models. (Tuesday 12pm, NLBA-102)

Amelie Skelton (Sydney)
Category O and the Jantzen Filtration

The finite-dimensional representations of a complex semisimple Lie algebra } are well understood. They are completely reducible. This is no longer true for infinite-dimensional representations, where modules can be non-semisimple.

We look at category $\mathcal{O}$, a certain class of infinite-dimensional representations of a Lie algebra $\mathfrak{g}$. The Jantzen filtration is a filtration on distinguished objects in category $\mathcal{O}$ which goes some way towards understanding their submodule structure. The filtration can be explicitly computed and has deep ties to Kazhdan-Lusztig theory. In this talk, I will introduce category $\mathcal{O}$ and the Jantzen filtration through basic examples, and explain how the filtration depends on a deformation direction. (Wednesday 11:30am, NLBA-102)

Michelle Strumila (Monash)
A decorated cobordism operad

A Topological Quantum Field Theory (TQFT) is a symmetric monoidal functor from the category of cobordisms to the category of vector spaces. Yet cobordisms may be better modelled by certain generalisations of operads, rather than categories; these operads of cobordisms have indeed been defined recently. Decorated cobordisms, which may have applications in the field of Quantum Computing, are given an operadic definition in this talk. (Wednesday 11am, NLBA-102)

Chloe Wilkins (Newcastle), David Pontin, Bishnu Lamichhane, Hannah Schunker
Characterising the magnetic field in the Sun's upper atmosphere

Understanding the dynamics of the magnetic field in the Sun's upper atmosphere is essential for studying space weather phenomena such as solar flares, coronal mass ejections, and variations in the solar wind. A pivotal research area in solar physics is the acceleration of the solar wind, which is believed to be closely tied to magnetic field interactions in the Sun's atmosphere. We can quantify these interactions by considering the mapping that defines how different points in the domain are connected via magnetic field streamlines. The squashing factor Q is a geometric measure for the deformation of the magnetic field streamlines and is defined mathematically in terms of the Jacobian of this streamline mapping. In this talk, we will present a model for the Sun's global magnetic field and explore how calculations of Q can help us to characterise the Sun's complex magnetic field structure. Our results have potential implications for understanding what drives solar wind acceleration and space weather events. (Wednesday 2:30pm, NLBA-102)

Sinead Wilson (ANU)
Parabolic subgroups of Artin groups via categorification

Recent work of Cumplido, Gebhardt, Gonzales-Meneses and Wiest, and of Morris-Wright, has defined the complex of (irreducible, spherical) parabolic subgroups associated to an Artin group. This complex plays an analogous role to the curve complex of a surface; in the case of an Artin braid group on n strands, it coincides with the curve complex of the $n+1$-punctured disk. In this talk we outline a new approach to studying the complex of parabolic subgroups using methods from the categorical representation theory of Artin groups. (Wednesday 12pm, NLBA-102)

Building confidence in mathematics of secondary and tertiary students NLBA-020

Organisers: Inge Koch, Kerri Morgan and Stella Stylianou

Uzuri Albizu-Mallea (University of the Basque Country), Marta Luxán-Serrano, Mila Amurrio
Gender and participation: moving past discriminatory inertia towards inclusive mathematics education

Participation is complex and multidimensional, and profoundly shapes students' mathematics identities. In the mathematics classroom, participation is conditioned (though not determined) by social context, as it is a product of the interplay between the individual and the social [1]. Gender systems are an important factor in this interplay. In fact, the existing literature suggests that models of classroom organization that perpetuate or reflect stereotypically masculine values can forment exclusion and place female students at a disadvantage [2]. This communication uses a case study of teachers-in-training to analyze participation dynamics in mathematics education, with a particular focus on gendered power relations. On the one hand, it identifies dynamics of participation that (re)produce the mathematics classroom as a masculinized space. However, along the same line as [3], it also acknowledges that power dynamics always leave space for alternative practices and resistance. In response, it discusses a number of practical measures that can facilitate increased participation by female students. Disruption and care work emerge as gendered elements which impact participation in repressive and productive ways. We conclude by highlighting the need for further analysis of the gendered distribution of productive and reproductive work among both students and mathematics educators, as well as of the performance-disruption-participation triad.

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[1] Black, L., Mendick, H., & Solomon, Y. (2009). *Mathematical relationships in education: Identities and participation.* Routledge.

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(Wednesday 2:30pm, NLBA-020)

Julia Collins (Edith Cowan)

Fun, Friendly, Flexible and Fearless: An approach to learning and assessment design for anxious students

Students of my mathematics units at Edith Cowan University are typically not mathematics majors; rather, they are usually studying a different course such as computer science, cyber security, engineering, or education. As a result, they are frequently very anxious and stressed about studying mathematics, and don't see its relevance to their course. In this talk I will describe my experiences in teaching these students and the strategies I have used to increase student engagement, from simple things such as discussion board introductions and humour in learning materials, to flexible and personalised assessments that allow students to tailor their learning to their skills and experiences. (Wednesday 11am, NLBA-020)

Ajani De Vas Gunasekara (Notre Dame), Iman Ardekani, George Papadopoulos, Geoff Lyons, Alan McCarthy

Resilience, Ability and Mindset Among Graduate Mathematics Students

Mathematics education in Australia is struggling with significant challenges, including a marked decline in student participation, particularly at advanced levels. A recent study by the Australian Mathematical Sciences Institute (AMSI) reveals a concerning trend: "Two in every five mathematics teachers aren't trained to teach mathematics. This is tough on teachers, tough on students." Our research project investigates the impact of a targeted program designed to retrain out-of-field high school mathematics teachers. Through a series of surveys, interviews, and a cognitive intervention focused on enhancing students' mathematics resilience, reducing anxiety, and fostering a growth mindset, we aim to evaluate the program's effectiveness. This project, initially implemented in 2023 at the University of Notre Dame Australia, has continued into 2024. In this presentation, I will share our findings. (Wednesday 2pm, NLBA-020)

Jennifer Hall (Monash)

Women's Experiences Completing Mathematics Degrees at Two Australian Universities

I will share findings from a multi-phase research study conducted at two Australian universities. The purpose of the study was to understand the supports and challenges faced by students as they completed mathematics degrees, from the undergraduate level to the doctoral level. Here, I will focus on the experiences of the women participants: undergraduate students ($n = 14$) and graduate students ($n = 4$). The women took part in individual interviews and photovoice, a participatory data collection method involving taking photographs to represent key ideas (in this case, supports and challenges) and sharing them in focus groups to spark discussion. The women reported gender imbalances in their classes and amongst their lecturers, as well as differential treatment by peers and lecturers that ranged from subtle microaggressions to serious macroaggressions, such as sexual assault. Interestingly, the participants provided varied explanations for this mistreatment, even when the examples shared were very similar. (Tuesday 1:30pm, NLBA-020)

Inge Koch (RMIT)
Mathematics, Gender and Statistics

Can girls and boys learn mathematics equally well? Can women be great mathematicians? To increase our understanding of the relationship between mathematics and gender, we consider surveys of about 8000 Year 5-9 school students that teacher of AMSI's ChooseMaths program conducted from 2016 to 2019 in 120 schools across Australia. The surveys' aims consisted in examining attitudes of students to mathematics across the genders and school years, and in evaluating the effectiveness of well-designed treatment regarding students' change of attitude to mathematics with a particular focus on confidence building. We describe the statistical analyses which range from simply summaries to multivariate analysis. The findings are encouraging and show that attitudes to mathematics and confidence in one's mathematical ability can improve with the right treatment. Although girls start at a lower confidence level in their Year 5, their gains are larger than those of boys. The analyses further highlight that the changes in confidence and attitude due to treatment are much larger than the differences between the genders. (Tuesday 11am, NLBA-020)

Leanne McMahon (AMSI/Melbourne)
Confidence starts at school: the role of teachers in building students' self-efficacy

Confidence plays a crucial role in students' success in mathematics, shaping both their academic outcomes and their long-term engagement with the subject. While early achievements in maths foster interest and confidence, many students—including high achievers—may pass exams without mastering fundamental concepts. This presentation explores strategies to build confidence through a growth mindset, emphasizing effort over innate ability and creating a safe space for mistakes and reflection. It addresses factors contributing to low confidence, such as maths anxiety, out-of-field teaching, and societal perceptions of STEM fields. By fostering collaboration and linking learning to engagement, educators can help students overcome barriers and enhance their mathematical self-efficacy. (Tuesday 11:30am, NLBA-020)

Kerri Morgan (RMIT)
Developing an inclusive introductory mathematics unit

In 2020, we re-designed a first year mathematics unit with the aim to increase student self-efficacy. Several factors can affect a student's mathematics self-efficacy including past experience of failure, mathematics anxiety, a real, or perceived, lack of mathematical background and ability, and social factors. Improved mathematical self-efficacy is key to motivating and engaging students in mathematics.

The unit content is presented as a journey through different cultures and countries and their contributions to the development of mathematics. These contributions were motivated by the practical needs (eg. engineering, building and trade) and interests (eg. astronomy and abstraction) of developing civilisations. Thus, an implicit thread is the importance of mathematics to society in a wide range of areas.

The journey is presented as a quest where students work collaboratively in workshops with the goal

of reaching the House of Wisdom in Arabia. All assessments are individual assessments but include a reflective component on how these activities facilitate learning. Students select a persona that aligns with their individual goals and attributes and behaviours that will help achieve these goals.

In this presentation, we describe some of the course components and reflect on the impacts on student learning. (Wednesday 1:30pm, NLBA-020)

Ravindi Nanayakkara (La Trobe), Rheny Pulungan

Evaluating the Effectiveness of a University-Wide Mathematics, Statistics, and Data Science Support Facility: The Maths Hub in Blended Learning Mode

The Maths Hub is La Trobe University's multi-campus, multi-disciplinary mathematics support centre, primarily facilitating the areas of Mathematics, Statistics, Business and Finance, Education, and Mathematics Skills. Mathematics and Statistics play a crucial role in both mathematical and non-mathematical fields, making comprehensive knowledge in these areas essential for successfully completing undergraduate and postgraduate degrees. A persistent challenge is that many students enter university with insufficient mathematics preparation, which often leads to Mathematics and Statistics anxiety. Therefore, to address these diverse needs, the Maths Hub was established to support undergraduate and postgraduate students, as well as those preparing for the Literacy and Numeracy Test for Initial Teacher Education (LANTITE), see [2] and [3]. It serves as a central resource for tutoring, workshops, and online tools designed to enhance understanding and application of these subjects across various disciplines. Students can receive help with their Mathematics and Statistics coursework through both face-to-face and online Zoom help sessions.

Initially, the Maths Hub provided only face-to-face support until early 2020. However, due to the COVID-19 pandemic, it transitioned to an online-only model until early this year. Then, in the beginning of this year, the Maths Hub was transformed into a blended learning mode by reintroducing face-to-face help sessions. This blended approach, which combines online and in-person interactions, has gained prominence in higher education for its flexibility and effectiveness, creating an ideal platform for active learning in Mathematics and Statistics. It accommodates the diverse needs of university students, regardless of their campus location. Blended learning models, such as those employed by the Maths Hub, offer students greater flexibility, allowing them to access resources and support at their convenience, see [1]. This flexibility is particularly beneficial for complex subjects like Mathematics and Statistics, where students may require varying amounts of time to fully grasp concepts.

This research study aims to assess the effectiveness of the Maths Hub in blended learning mode. The evaluation utilizes a mixed-methods approach, combining quantitative data from student performance metrics with qualitative feedback gathered from the Library Discipline Hub surveys. The results suggest that the Maths Hub, in blended learning mode, enhanced accessibility, improved learning outcomes, increased student engagement and motivation, boosted student confidence, and fostered overall student success. These findings highlight the promise of blended learning environments in enhancing student success in quantitative disciplines and offer a model for implementing similar initiatives in higher education.

Keywords: Mathematics Education, Blended Learning, Interdisciplinary Mathematics, Student Engagement, Student Success

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[2] Jackson, D.C., and Johnson, E.D. (2013). A hybrid model of mathematics support for science students emphasizing basic skills and discipline relevance. International Journal of Mathematical Education in Science and Technology, 44(6), 846-864.

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(Wednesday 11:30am, NLBA-020)

Stella Stylianou (RMIT)

Boosting Mathematical Confidence in Diverse Students

The challenge of fostering mathematical confidence among diverse student populations, particularly those from non-mathematical backgrounds and females, is well-documented in educational literature. Research indicates that individuals lacking strong mathematical foundations often exhibit lower confidence levels in mathematical tasks. Moreover, gender disparities in mathematical confidence persist, with females reporting lower confidence levels than their peers, despite comparable academic performance. This talk explores effective pedagogical approaches, interventions, and support systems aimed at bolstering confidence in mathematics and statistics, specifically among female students with non-mathematical backgrounds. Practical strategies such as active learning methodologies, mentoring sessions, and inclusive classroom practices are highlighted as promising avenues to empower female students and bridge confidence gaps in mathematical education. By fostering a supportive environment, the aim is to enable all students, particularly those with non-mathematical backgrounds, to thrive and excel in mathematics and statistics education.

(Tuesday 12pm, NLBA-020)

Laura Tubino (Deakin)

Empowering Student Agency Through Grade-Aligned Personas: Enhancing Engagement and Learning in Mathematics

This presentation introduces the agentic-persona model, an innovative framework designed to enhance learning and assessment for diverse learners in secondary and tertiary mathematics education. Inspired by Kegan's Constructive-Developmental Theory, this framework offers coherent representations of grade-specific qualities, providing a meaning to grades based on students' demonstrated competencies and the discipline's aspirational goals. By emphasizing the development and assessment of behaviours that contribute to overall student success, beyond just mathematical concepts, this model enables a more personalised approach to teaching and learning that supports students

at their individual developmental levels. Grade-aligned student personas provide diverse learning pathways, promoting learner agency and accommodating student diversity. This model not only offers an innovative alternative to conventional grade differentiation but also ensures that minimum standards are met while fostering a sense of learning agency and promoting engagement in mathematics. (Wednesday 12pm, NLBA-020)

Geometric and analytic properties of Partial Differential Equations
NLBA-107

Organisers: Serena Dipierra and Valentina Wheeler

Ben Andrews, **Sophie Chen** (ANU)
Counterexample to the second eigenfunction having one zero for a non-local Schrödinger Operator

We construct a counterexample to the second eigenfunction having only one zero of a perturbed fractional Laplace operator on a bounded interval with Dirichlet 'boundary' data off the interval. At the time of writing, this appears to be one of the first analytical results on the qualitative behaviour of eigenfunctions of perturbed non-local Schrödinger operators. The key step in our construction is solving a related infinite potential well eigenvalue problem using the Kato-Rellich (degenerate) regular perturbation theory. We then employ an energy minimisation argument to produce the final counterexample. While our result focuses on the case $s = 1/2$, it appears to hold more generally for rational values of s in $(0, 1)$. (Wednesday 11am, NLBA-107)

Huyuan Chen, **Florica Cirstea** (Sydney) and Aleksandar Miladinovic
Singular solutions for nonlinear elliptic equations with mixed reaction terms

In this talk, we present new results on the behaviour near zero of the positive solutions of elliptic equations of the form

$$\Delta u - (N - 2 + 2\rho)\,\frac{x \cdot \nabla u}{|x|^2} + \lambda \frac{u^\tau\,|\nabla u|^{1-\tau}}{|x|^{1+\tau}} = |x|^\theta\, u^q \quad \text{in } \Omega \setminus \{0\},$$

where $\Omega \subseteq \mathbb{R}^N$ is a domain containing zero, whereas $\rho, \lambda \in \mathbb{R}$, $\theta > -2$, $0 \leq \tau < 1$ and $q > 1$. The case $\tau = 1$, corresponding to equations with a Hardy-type potential, has been intensively studied by many authors for various ranges of λ, θ and ρ. However, new phenomena arise when $\tau \in [0, 1)$. In our framework, we show that every positive solution tends to zero as $|x| \to 0$ and reveal up to five possible asymptotic profiles in optimal regimes of our parameters. This is joint work with Huyuan Chen and Aleksandar Miladinovic. (Tuesday 12pm, NLBA-107)

Mashniah A. Gazwani (Newcastle) and James A. McCoy
Length-constrained, length penalised and free elastic flows of planar curves inside cones

We study families of smooth, embedded, regular plane curves $\alpha : [-1, 1] \times [0, T) \to \mathbb{R}^2$ with generalised Neumann boundary conditions inside cones, satisfying three variants of the fourth-order nonlinear L^2-gradient flow for the elastic energy: (1) elastic flow with a length penalisation, (2) elastic flow with fixed length and (3) the unconstrained or 'free' elastic flow. For general initial data, we show that in all cases, a smooth solution exists for all time, provided neither end reaches the cone tip. For cone angles not too large and with suitable smallness conditions on the oscillation of curvature of the initial curve, in cases (1) and (2), we prove smooth exponential convergence of solutions in the C^∞ topology to particular circular arcs, while in case (3), we show smooth exponential convergence to an expanding self-similar arc. (Wednesday 11:30am, NLBA-107)

Jahne Valentin Meyer (Newcastle)
Semi-discrete geometric flows of closed polygons

We outline results regarding two linear semi-discrete analogues of polyharmonic curve diffusion for closed polygons in $\mathbb{R}^p, p \geq 2$. We consider both parabolic and hyperbolic evolutions including self-similar solutions under each flow. Parabolic evolution only has non-trivial scaling self-similar solutions, whereas in the undamped hyperbolic case, self-similar solutions by pure rotation exist. Polygons evolving by the parabolic flow converge exponentially to a point, where under appropriate rescaling the limiting shape is an affine transformation of a regular polygon. This is also true in some cases for damped hyperbolic motion of polygons dependent on the damping term. Otherwise we also get oscillating motion under this flow. The hyperbolic flow also allows for prescription of an intermediate polygon state at a distinct time. As an application, we set up a semi-discrete Yau difference flow for both the parabolic and hyperbolic cases where an initial polygon converges to a target polygon in infinite time. Hyperbolic evolution further allow for an intermediate state to be obtained at a distinct time during this process. (Tuesday 11:30am, NLBA-107)

Caterina Sportelli (UWA)
The superposition of operators of mixed fractional order

In this talk we introduce the superposition operator

$$\int_{[0,1]} (-\Delta)^s u \, d\mu(s),$$

where μ denotes a (Borel) signed measure on the fractional interval $[0, 1]$. We discuss the existence of solutions for some problems in presence of this superposition operator and subject to different types of boundary conditions.

These results are part of some joint works with Serena Dipierro, Enrico Valdinoci and Edoardo Proietti Lippi. (Tuesday 11am, NLBA-107)

Serena Dipierro, Stefania Patrizi, Enrico Valdinoci, **Mary Vaughan** (UWA)
Asymptotic expansion of a nonlocal phase transition energy

In this talk, we first present the notion of asymptotic development in the sense of Γ-convergence for the fractional Allen–Cahn energy functional in bounded domains with prescribed boundary conditions. When the fractional power $s \in (0, \frac{1}{2})$, we establish the complete asymptotic development by showing that the first-order term is the nonlocal minimal surface functional and all higher-order terms are zero. Then, for $s \in [\frac{1}{2}, 1)$, we prove that the first-order term is the classical perimeter functional plus a penalization on the boundary. (Wednesday 12pm, NLBA-107)

Hybrid Modelling: Leveraging the nexus between domain-based modelling and machine learning NLBA-440

Organisers: Melissa Humphries, Sevvandi Kandanaarachchi, Rachael Quill and Ainura Tursunalieva

Melissa Humphries (Adelaide)
Hybrid AI: Where math meets

The convergence of computational mathematics and artificial intelligence has ushered in a new era of problem-solving capabilities, particularly through the development of hybrid AI systems. Hybrid AI combines the strengths of rule-based systems and machine learning algorithms, creating a powerful synergy that addresses complex challenges more effectively than traditional approaches. These systems offer enhanced performance, accuracy, and adaptability alongside explainability and insights that can only come from transparent systems.

This talk explores two applications: Forensic science, where Generative Adversarial Networks (GANs) are employed for DNA simulation. This approach allows for the generation of synthetic DNA profiles, aiding in the development and testing of forensic techniques while preserving privacy and addressing ethical concerns related to real DNA samples. And healthcare, in predicting emergency department load using a combination of hospital-based metrics and real-time scraped historical data. This innovative approach optimizes hospital operations by forecasting patient influx and resource requirements, ultimately improving patient care outcomes and operational efficiency.

Hybrid AI in mathematical research offers a unique combination of interpretability and enhanced accuracy. By integrating traditional mathematical models with machine learning techniques, these systems provide insights that are both explainable and highly precise. This approach allows for the development of more robust optimization algorithms and improved analysis of complex datasets, leveraging the strengths of both statistical methods and AI-driven pattern recognition. As a result, hybrid AI accelerates the creation of mathematical models for real-world phenomena that are not only more accurate but also more interpretable, bridging the gap between theoretical mathematics and practical applications. This synergy between classical mathematical approaches and cutting-edge AI techniques opens up new possibilities for solving long-standing mathematical problems while addressing real-world challenges across various industries. (Wednesday 2pm, NLBA-440)

Sevvandi Kandanaarachchi (CSIRO), Ziqi Xu, Stefan Westerlund
Predicting Dynamic Networks

Networks are everywhere; from protein-protein interaction networks in biology to social networks on social media platforms, we are surrounded by networks in different mediums and scales. Dynamic networks are networks that change with time. That is, nodes and edges can get added or deleted in a dynamic network. Thus, the structure can constantly change in a dynamic network. Predicting the structure of a dynamic network is challenging and is underexplored. Mathematically, we are talking about a sequence of adjacency matrices of different sizes. Therefore, predicting the adjacency matrix at a future time point is difficult because the size of the future matrix is different from the already

seen matrices and there is no direct way to extrapolate from the seen matrices to the future one.

In this talk we present a method to predict the structure of a dynamic network. We use time series methods to predict the node degree at future time points and combine it with flux balance analysis – a linear programming method used in biochemistry – to obtain the structure of future networks. We illustrate the method using known datasets. (Wednesday 11:30am, NLBA-440)

Vinesha Peiris (Curtin)
Enhancing classification with rational approximation techniques

In this talk, an application of generalised rational uniform (Chebyshev) approximation to neural networks is demonstrated. In particular, our activation functions are rational functions of degree $(1, 1)$, and the loss function is based on the uniform norm. In this setting, when the coefficients of the rational activation function are fixed, overall optimisation problem of the neural network can be formulated as a generalised rational approximation problem with additional linear constraints. In this case, the weights and the bias of the network are the decision variables. To optimise the decision variables, we suggest using two prominent methods: the bisection method and the differential correction algorithm. We illustrate the efficiency of this application by performing numerical experiments on classification problems with two classes and report the classification accuracy obtained by the network using the bisection method, and differential correction algorithm along with the standard MATLAB toolbox which uses the least square loss function. We show that the choice of the uniform norm-based loss function with the rational activation function leads to better classification accuracy in some special cases. (Wednesday 12pm, NLBA-440)

Jamintha Samarakoon (QUT), Gentry White, Helen Thompson
Hybrid Statistical Algorithmic Approach for Identifying Labour Market Areas

In the intricate landscape of economic, demographic, and geographic factors, understanding the boundaries and characteristics of labour market areas (LMAs) has become a fundamental requirement for informed decision-making in policymaking and resource allocation. LMAs are functional regions representing areas where job seekers and employers interact to exchange labour services. Labour markets play a crucial role in determining employment patterns, regional development, and economic growth, making their accurate delineation essential for addressing regional disparities and guiding targeted interventions. Existing methods for labour market delimitation face significant challenges in accuracy and efficiency due to inherent limitations, including the failure to account for additional factors that help define labour markets, and the need for manual boundary adjustments. This research addresses these issues by developing an innovative, automated methodology that integrates multiple influential factors, offering a more precise and comprehensive analysis of labour markets and improving the overall accuracy of the delimitation process. The study begins with a comprehensive evaluation of the most contemporary and robust methodologies currently used to identify labour markets. These methodologies are then applied to simulated datasets, yielding distinct clusters that represent individual labour market areas. By critically examining the strengths and weaknesses of these methods, the study seeks to enhance the accuracy of labour market analysis and delimitation. The ultimate goal is to design a novel hybrid methodology that integrates statistical spatial modelling and simulated annealing, providing a more flexible and ro-

bust framework for labour market delimitation. This new approach will be better equipped to handle the complexities of modern labour markets and will be adaptable to evolving economic and demographic conditions, ensuring more effective and forward-looking policy decisions.

Keywords: Labour market areas, Hybrid, Spatial models, Simulated annealing

(Wednesday 1:30pm, NLBA-440)

Evgenia Titova-Shankar (DTN), Rachael Quill

Enhancing Renewable Wind Forecasts through Machine Learning and Statistical Post-processing

Forecasting intermittent wind energy sources presents significant challenges in the operation of the power systems. Numerical weather prediction models do not explicitly provide turbine-hub wind speed forecasts and tend to exhibit significant biases complicating their integration into energy models. Some degree of statistical calibration is often desirable to address both systematic model errors and derive risk information related to wind ramp events, large and rapid variations in wind power production causing disruptions across electricity markets.

Here we demonstrate a supervised learning system aiming to derive hub height wind and generation forecasts suitable as an input into national electricity market models and for the purposes of operational awareness. Forecasts are made available for up to 14 days ahead at minute-scale resolution. We illustrate core features of the system such as statistical enhancement and tuning of numerical weather prediction forecasts against the nacelle anemometer data, the machine learning approach to estimate wind power. The system employs an analogue approach which involves finding historical spatio-temporal weather patterns in the wind farm neighborhoods similar to the forecasted conditions. The analogue search algorithm in the context of hub-height forecasting matches the vertical wind profiles and stability conditions along with standard weather parameters. Information obtained via analogue search is used to improve on the model error predictions and to derive expected characteristics of minute-scale wind ramping. Verification analysis of the realtime forecasts for select Australian wind farms is presented. (Wednesday 11am, NLBA-440)

Mathematical histories NLBA-024

Organiser: Rowena Ball

Rowena Ball (ANU)
Growing the cultural capital of mathematics

Beginning with a story of Indigenous mathematics in the 19th century, I shall follow mathematical connections that have not previously been recognized in 'mathematical genealogy'. A rich global landscape of Indigenous and non-Western mathematical knowledge and links is coming to light that provides a golden opportunity for cultural diversification and inclusion, and which may expand and enrich the horizons of the discipline as a whole. I shall say a few words about how this research is informing our research and teaching program, Mathematics Without Borders, discuss national and international plans, and invite inputs. (Tuesday 2pm, NLBA-024)

Lesley Ward (UniSA)
From the Marriage Bar to the Hypatia Scholarship: Women in Mathematics in Australian Universities

The first woman lecturer in the Australian mathematical sciences was appointed in 1921, almost 70 years after the first Australian university was established in 1852. Since then the proportion of women among mathematical sciences students and academic staff has gradually increased, though it has not reached 50% even at the bachelor's completion level. Why so low, and why so slow? What can we do now to create a more inclusive and equitable higher education sector that allows everyone to contribute more fully? What does the past tell us about what works? I'll outline some of the history of women working in the mathematical sciences in Australian universities, with a focus on the national Women in Mathematics Special Interest Group (WIMSIG, founded in 2012) of the AustMS. Some of this history was reported in a recent article in the AustMS Gazette and book chapter in the US Association for Women in Mathematics (AWM) book Fifty Years of Women in Mathematics: Reminiscences, History, and Visions for the Future of AWM, both co-authored with Cheryl Praeger. I'll offer insights into our evolving understanding of why women and others have been underrepresented, and the initiatives we've used to address inequity. In addition to describing the Australian historical, societal and legal contexts, I'll consider broader explanatory factors that have acted to inhibit participation of women and other underrepresented groups worldwide. Juicy topics such as the marriage bar and its impact, the female minimum wage, and the Jennifer and John correspondence study will be addressed. (Tuesday 1:30pm, NLBA-024)

Modelling for decision making NLBA-024

Organisers: Isobel Abell and Lucinda Harrison

Chris Baker (Melbourne)
Developing real-time modelling capabilities for animal disease outbreak response

Successful management of disease outbreaks requires deliberate and rapid response. As seen throughout the COVID-19 pandemic, mathematical modelling can provide important and novel insights from data as it gets collected, which provides an evidence base to support policy and decision-making. To improve modelling capability to support decision making in animal disease outbreak response in Australia, we are developing a suite of modelling workflows to estimate current spread and forecast future spread using outbreak data. We are also developing a range of decision-support workflows to improve how modelling can be used to support evidence-based policy. In this presentation I will provide an overview of forecasting and modelling workflows and describe how we are using them as the basis of simulation exercise workshops. These workshops will provide important insights on the uptake of modelling to support decision-making.
(Wednesday 1:30pm, NLBA-024)

Kaitlyn Brown (QUT), Robyn P. Araujo, Paul Corry, Adrianne L. Jenner
A mechanistic model of coral bleaching on the Great Barrier Reef

Coral reefs across the world are at serious risk due to the ongoing effects of mass bleaching incidents that have been observed over the last three decades. The destabilisation of coral reef ecosystems is expected to have catastrophic implications for essential ecosystem services. There is an urgent need to improve our mechanistic understanding of coral bleaching dynamics to inform effective intervention and conservation efforts. We have developed a model of community-scale coral dynamics via a coupled system of nonlinear ordinary differential equations. Coral bleaching is represented as a continuously evolving state of the modelled population and underlying symbioses are captured implicitly. System dynamics analysis was used to validate the conceptual framework and provided valuable insights into the mechanisms driving the resilience and robustness of a reef's bleaching response. Using data observed on the Great Barrier Reef, we parametrised the model and observed multiple correlations providing further insight into the mechanisms of bleaching and inspiring future data collection. (Tuesday 12pm, NLBA-024)

Roslyn Hickson (CSIRO and James Cook University)
Infectious diseases modelling for decision making

The recent COVID-19 pandemic has highlighted the utility of modelling infectious diseases transmission to help inform decisions. I will take you on a whirlwind adventure of different ways this type of work has come about for me, and highlight different outcomes. I will leave you with some dos and don'ts, from the perspective of a modeller. (Wednesday 2:30pm, NLBA-024)

Maame Akua Korsah (Melbourne), Stuart T. Johnston, Kathryn E. Tiedje, Karen P. Day, Jennifer A. Flegg, Camelia R. Walker

Mathematical assessment of the role of intervention programs for malaria control

Malaria remains a global health problem despite the many attempts to control and eradicate it. There is an urgent need to understand the current transmission dynamics of malaria and to determine the interventions necessary to control malaria. In this paper, we seek to develop a fit-for-purpose mathematical model to assess the interventions needed to control malaria in an endemic setting. To achieve this, we formulate a malaria transmission model to analyse the spread of malaria in the presence of interventions. A sensitivity analysis of the model is performed to determine the relative impact of the model parameters on disease transmission. We explore how existing variations in the recruitment and management of intervention strategies affect malaria transmission. Results obtained from the study imply that the discontinuation of existing interventions has a significant effect on malaria prevalence. Thus, the maintenance of interventions is imperative for malaria elimination and eradication. In a scenario study aimed at assessing the impact of long-lasting insecticidal nets (LLINs), indoor residual spraying (IRS), and localized individual measures, our findings indicate that increased LLINs utilization and extended IRS coverage (with longer-lasting insecticides) cause a more pronounced reduction in symptomatic malaria prevalence compared to a reduced LLINs utilization and shorter IRS coverage. Additionally, our study demonstrates the impact of localized preventive measures in mitigating the spread of malaria when compared to the absence of interventions. (Tuesday 11am, NLBA-024)

Sarita Rosenstock, **Thao P. Le** (Melbourne), Isobel Abell, Chris Baker

Understanding the use of real-time modelling capabilities for animal disease outbreak response

Potential outbreaks of animal diseases such as Lumpy Skin Disease (LSD) and Foot and Mouth Disease (FMD) in Australia pose a significant risk to animal populations. Outbreaks would impact livestock industries, lead to negative animal health and welfare, and affect food security. We are collaborating with policy makers to design modelling tools aimed to give decision makers the information they need to quickly and effectively respond to such outbreaks. In addition to this modelling work, we will also conduct qualitative research to ensure that these models are useful to policymakers. This talk will present some initial preliminary results of our modelling work and our upcoming plans to hold focus groups with state agencies to evaluate how policymakers are able to understand and use these tools to make more informed policy choices.

(Wednesday 11am, NLBA-024)

Katie Mortimer (Defence Science and Technology)

Delivering a More Efficient Training System through Optimisation Models

The Australian Defence Force (ADF) currently faces a challenge in supplying and sustaining its workforce. New platforms and capabilities are driving changes in Defence, requiring robust workforce plans that will minimise workforce supply risks in the future. However, defence workforces are highly complex, with strict hierarchical and highly interconnected structures. Complex ongoing and specialised training requirements make planning, forecasting and analysis difficult. Despite these complexities, student planning and timetabling in the ADF is performed manually across hundreds

of courses and associated sessions, resulting in inefficient or incorrect timetables. Further, this manual process does not easily allow decision-makers to conduct 'what-if' analysis, to determine how training and organisational changes impact the training system.

To address this, we have created an optimisation model to improve timetabling efficiency, reduce administrative workloads, and allow exploration of training bottlenecks and possible solutions. For this problem, there are a number of hard constraints, including: a maximum number of students per session, students cannot attend overlapping courses, and a number of fixed training pathways or course sequences. Soft constraints such as prioritisation of students is also important. In this domain efficiency is defined in terms of the total time delays in students being able to complete their training.

The algorithm uses Dynamic Programming (DP) to find the optimal timetable for each student over course pathways and session options - which decrease as each timetable is generated over the student priority queue. The results showed a large increase in efficiency, reducing the median student delay by 82% compared to the manual solution, and in a fraction of the time.

A Genetic Algorithm (GA) is then used to, where possible, improve upon these initial solutions by considering more efficient permutations and combinations of specific course and sessions over all the student DP solutions. In the case where no further improvements are possible, analysis of the trade-off between student throughput, individual student delays and training constraints can be conducted by relaxing the session size and timing constraints in the GA. Thereby identifying key bottlenecks and providing decision-makers with the tools to make more informed decisions about their training system. (Wednesday 12pm, NLBA-024)

Elena Tartaglia (Department of Energy, Environment and Climate Action), Kristy Butler, Jason Rennie, Stephen Deutsch, Nick McCarthy

Estimating the difficulty of suppressing a bushfire to support firefighting resource allocation

Bushfires are a natural hazard that pose a risk to life, property and the environment in Victoria, Australia. Initial attack refers to the initial set of firefighting resources sent to a fire and is crucial to prevent the fire becoming a disaster. On days of elevated fire danger, there are often multiple fires burning at the same time and a need to allocate resources effectively between events. Decisions about how to allocate resources between fires are based on the expected difficulty of controlling the fire. One common way to estimate this expected difficulty is the McArthur Fire Danger Index (FDI), which indicates the danger of a fire based on weather and fuel inputs. Statistical models present the opportunity to directly estimate the probability of a fire remaining uncontrolled after initial attack. Our study models the probability the fire will be unable to be controlled by initial attack based on weather, vegetation, topography and accessibility. We compare the model's predictions to current common practice of using FDI and discuss the practicality of using the model in operations to assist with resource allocation. (Wednesday 11:30am, NLBA-024)

Camelia Walker (Melbourne)
Fitting stochastic epidemic models to multiple dependent data sets

During infectious disease outbreaks, data are used to infer parameters of epidemic models, project future outcomes, and optimise interventions. However, many epidemic models are so complex that an individual data set cannot precisely inform all model parameters. Fortunately, any one outbreak may be observed via multiple surveillance systems and using these data in combination reduces the variance of parameter estimates. For stochastic epidemic models this poses a challenging inference problem because the data sets are dependent (being observations of the same outbreak), data may not be linked, and the likelihood function is often intractable.

In this talk I present a particle marginal Metropolis-Hastings approach for inferring parameters of a stochastic epidemic model while accounting for dependencies between data sets. This method computes point estimates of the likelihood function by simulating from the model and integrating over latent variables that partition the data. I apply this method in a simulation study to explore how combining influenza surveillance systems in Australia improves parameter estimates and model projections. (Tuesday 11:30am, NLBA-024)

Saras M. Windecker (Telethon Kids Institute), Kate Senior
Reusable research code for reliable decision-making

Research code underpins a wide array of applied decision-making. Researchers increasingly rely on open-source software to write code to clean, manipulate, analyse, and visualize data. Code is still not subject to the same rigor of peer review as others part of the scientific process, however, and can easily result in propagation of errors and irreproducible results. These problems raise concerns about the credibility of research and the reliability of decisions they inform. Research software must be written and shared in a way that minimised these errors, and allows for others to inherit and reuse the work. Best practices include having clear instructions for use/customisation, good organisation, and metadata for input and output information. In this talk, we will highlight and explain these key principles for research software best practice using a case study of a code base we inherited. We will give high level guidance on ensuring your research software can be used by your team and others well in the future for reliable decision-making. (Wednesday 2pm, NLBA-024)

Modelling the Immune Response to Diseases NLBA-340

Organisers: Punya Alahakoon and Claire Miller

Felicia Bongiovanni (WEHI), Eamon Conway, Lauren Smith, Jodie McVernon, Ivo Mueller
Inferring time of infection based on antibody data through a hierarchical Bayesian framework

Modelling of the humoral immune response to pathogens can help us better understand protection against disease. Multiple models have been created to describe the production and waning of antibodies against pathogens, with some assuming a simple exponential decay, others a more complex biphasic decay, and some employing a power-law approach. These provide a powerful tool to better understand the serological response to infection, which in turn can be used to translate a single antibody titre to a time of infection, which is usually unobserved data.

This work will present a hierarchical Bayesian framework to estimate the time of infection of an individual by fitting antibody kinetics model parameters to data. Methods that have already been established to infer exposure times usually involve machine learning algorithms, ignore people with reinfections, or assume a simple decay of antibodies. Our approach will provide a powerful way to utilise all serological data, including reinfections, to understand the boosting and biphasic decay of antibodies over time. This information will be used to inform population-level parameters, which will then serve to estimate the time of infection for an individual with a single antibody measurement. This has important implications in incidence estimation and understanding the window of protection for an individual. (Tuesday 12pm, NLBA-340)

Elizabeth Ivory (Melbourne)
Agent-Based Modelling of Plasmodium Vivax Under Radical Cure Treatment Policies in Cambodia

Plasmodium vivax is the most geographically widespread malaria-causing parasite. It can produce latent, liver-stage parasites (hypnozoites) which may cause multiple malaria relapses from a single new infection. In order to kill these hypnozoites and prevent *Plasmodium vivax* relapses, a liver-stage treatment such as primaquine or tafenoquine is required. When paired with a blood-stage treatment to treat the active infection, it is termed "radical cure". However, those with a deficiency of the glucose-6-phosphate dehydrogenase (G6PD) enzyme (up to 30% of a population) are at high risk of adverse reactions to radical cure treatment, such as haemolysis (red blood cell death).

We create a novel multi-scale stochastic and agent-based transmission model that builds on previous work, explicitly using G6PD enzyme activity levels of individuals to simulate screening for G6PD deficiency before treatment. We stochastically model the number of hypnozoites and the corresponding relapse rate for each person within a tropical setting, integrating it into our human stochastic model for *Plasmodium vivax*.

Together, this model can provide valuable insight relating to *Plasmodium vivax*, relapses, and hypnozoites. We use it to evaluate the outcomes of different radical cure treatment policies and the importance of swift, effective, radical cure in the context of Cambodia.

(Tuesday 11:30am, NLBA-340)

Claire Miller (Auckland), Domenic Germano, Alicia Chenoweth

Modelling immune cell-endometrial cell dynamics in endometriosis

Endometriosis is a chronic gynaecological condition affecting around one in nine people with a uterus. The disease is characterised by the growth of lesions of endometrial-like cells outside of the uterus, such as in the peritoneum (lining of the abdomen and pelvis). Symptoms include chronic pain and fertility issues. The hypothesised root cause of endometriosis is retrograde menstruation—where menstrual debris is ejected through the fallopian tubes and into the peritoneal cavity rather than out the cervix. However, the cause must be more complex than this as retrograde menstruation is more common than endometriosis.

The pathophysiology of endometriosis closely resembles that of cancer, with abnormal cell growth and angiogenesis to support lesion growth. Like cancer, a hypothesised factor in disease onset is the local immune system which not only fails to eliminate ectopic cells, but potentially aids lesion formation. Supporting this hypothesis, abnormal immune profiles have been observed in peritoneal fluid of endometriosis patients. This raises the question as to whether these abnormal profiles are due to an abnormal immune response to the endometrial cells, or simply due to a consistent presence of endometrial cells in the peritoneal cavity.

We have developed a population dynamics model for immune cell response to endometrial cells in peritoneal fluid, inspired by previous models of immune cell responses to cancer and viral attack. Altered macrophage and natural killer cell behaviours are commonly implicated in endometriosis in the literature. Consequently, we focus on these cell types in the model, which are each expressed with three activation states. Using this model, we determine the parameter regimes under which endometrial cells do or do not persist as lesions. In particular, those related to three hypotheses that could contribute to altered immune profiles: immune escape, decreased immune cell efficacy, and increased endometrial cell reflux. (Wednesday 11:30am, NLBA-340)

Mary Myerscough (Sydney) and Adelle Coster

A simple, data-informed model for macrophage lipid trafficking via efferocytosis

Accumulation of cholesterol drives the growth of atherosclerotic plaques in artery walls. These plaques are a major cause of vascular disease, particularly heart attacks and strokes. Some of this cholesterol enters the artery wall on low density lipoproteins (LDL), which carry so-called bad cholesterol. But a significant proportion of plaque cholesterol enters in the cell membranes of immune cells that are recruited to the plaque. Macrophages, a large subset of these immune cells ingest lipid, both from LDL and in the form of membrane and ingested lipid in dead and dying cells. This ingestion of dead cells is known as efferocytosis.

Hugh Ford and colleagues (Ford et al 2019, Proc Roy Soc B) measured macrophage accumulation

of ingested lipid in an experiment where macrophages were kept in vitro, without additional lipid and could only acquire internalised lipid via efferocytosis. We present a very simple model for this experiment and formally fit it to the experimental data. This fitting enables us to determine the best-fitting form of macrophage cell death rate for the model and to find parameter values that can inform more complicated models for atherosclerosis. (Wednesday 11am, NLBA-340)

Pantea Pooladvand (UNSW Sydney), Lisette de Pillis, Peter P. Lee, Peter S. Kim

Connecting the dots: cis PD-L1/CD80 interactions on antigen presenting cells and the implication for checkpoint inhibitors

Antigen-presenting cells (APCs) are essential for activating T cells to mount an effective immune response against infections or cancer. APCs achieve this by presenting antigens on their MHC receptors and providing a secondary activation signal, such as CD80. Counterintuitively, APCs also express PD-L1 proteins, which dampens T cell activation through PD-1/PD-L1 interaction. Consequently, PD-L1 has become a target for immune checkpoint therapies, but with varying success. Adding further complexity, recent studies suggest that PD-L1 may also enhance T cell activation via cis binding with CD80 on the surface of APCs. This finding has significant implications for immune checkpoint therapies that inhibit PD-L1.

In this project, we investigate the impact of cis PD-L1/CD80 binding on APCs in the context of T cell activation. Our results suggest that the ratio of certain proteins on APCs and T cells could be critical to the outcome of T cell activation. Additionally, we explore how cis PD-L1/CD80 interactions affect the efficacy of immune checkpoint inhibitors. These findings offer a potential explanation for the variability in patient outcome. (Wednesday 1:30pm, NLBA-340)

Katharine Senior (Telethon Kids Institute), Tianxiao Hao, Saras Windecker, Freya Shearer, James McCaw, Gerry Ryan, Nick Golding

Incorporating immunity into infection incidence models using serological data

There is a need for models that report numbers of infections – and associated values such as the effective reproduction number – in near-real time to support epidemic response and situational assessment. We have proposed and developed a new model that can fit to multiple types of epidemiological observations to infer latent infection dynamics, with several improvements over traditional discrete renewal models fit to case data only.

One data source our model can leverage is serological data, which allows us to gain a better understanding of overall case ascertainment and levels of immunity in the population. However, infections by many pathogens do not provide for life-long immunity, and so models that incorporate serological data must allow for seroprevalence to decay over time since infection and for reinfection to occur. This reinfection is time-varying and dependent on the phase of the epidemic. Fortunately, we can incorporate these dynamics using a simple Susceptible-Infectious-Susceptible compartment model to represent the time-varying proportion of individuals who will be reinfected at different times since infection. In this talk I will give an overview of our infection incidence model focusing on how we account for immunity dynamics when incorporating serological data and present an example use with data on COVID-19. (Tuesday 11am, NLBA-340)

Georgia Weatherley (QUT)
The immune system as a disease driver: an agent-based model of myelin loss in Multiple Sclerosis

In patients with multiple sclerosis, the immune system drives a persistent, mistaken attack on the protective myelin sheaths of nerve fibres in the brain and spinal cord. As a result, these people experience diverse neurological symptoms that can be intermittent in their presentation and increase in severity with neuron loss. Current therapeutics (immunosuppressives) are designed to suppress harmful immune activity in a preventative approach but do little to address the wellbeing of patients with large accumulations of existing myelin damage. Here, we turn our attention to the modelling of new therapeutic ideas designed to target the perseveration of myelin-synthesising cells called oligodendrocytes. I will discuss our development of an on-lattice agent-based model of key immune dynamics to understand when oligodendrocytes are driven to stop myelinating and undergo apoptosis. Excitingly, introducing oligodendrocyte-targeted therapies enhancing their innate resilience suggests the ability to restore damage in patients rather than simply preventing it. This is an important step in ensuring treatment efficacy across all MS subtypes, given only select patients benefit from the current immunosuppressive approach. (Wednesday 12pm, NLBA-340)

Ada Yan (Melbourne)
Modelling between-cell heterogeneity in within-host influenza virus infection

Recent studies have uncovered vast amounts of heterogeneity in the behavour of individual cells within he same host during an influenza virus infection. However, the effects of this heterogeneity on the transient dynamics and outcome of infection remain unknown. Meanwhile, for influenza viruses to transmit between humans, they must adapt to infect one particular cell type efficiently. This requirement has been attributed to the abundance of that cell type in the human upper respiratory tract, but heterogeneity between cell types could play a further role in this fitness advantage.

To explore this hypothesis, we have generated data in the lab, and constructed mathematical models to capture this heterogeneity. These models are based on the target cell-infected cell-virus (TIV) ODE models which are prevalent in within-host virus dynamics literature, with extensions to include the innate immune response. In this talk, I will discuss the effect of heterogeneity in cell-specific susceptibility, viral production rate and innate immunity on viral load, including potential fitness tradeoffs for viruses evolving to preferentially infect certain cell types. I will also discuss observation models for new data sources required to infer parameters associated with heterogeneity, and challenges in performing this infererence. (Wednesday 2pm, NLBA-340)

Recent Advances in Statistics and Biostatistics NLBA-346

Organisers: Shila Ghazanfar and Rachel Wang

Sara Ballouz (UNSW Sydney), Anna Liza Kretzschmar

Exploring the sex differences in myalgic encephalomyelitis/chronic fatigue syndrome (ME/CFS) in biobank data

Myalgic encephalomyelitis/chronic fatigue syndrome (ME/CFS) can be debilitating for the people suffering from it, with 25% housebound. The disease mechanisms behind it are difficult to study in part due to the nature of fatigue: it is co-morbid with many other illnesses and thus hard to define and diagnose. Furthermore, several sets of disease definitions and diagnostic criteria are in use, obscuring the estimation of ME/CFS prevalence and diagnosis. However, one aspect universally agreed upon is the stark sex differences – with 75-85% of women among those afflicted. As ME/CFS and autoimmune diseases are both sex-biased, there is evidence that the immune system, along with pathogenic infections, may be involved in the cause and progression of the disease. With data from Australian and US ME/CFS biobanks, we aimed to characterize ME/CFS and explore common features of the disease. We first report on the demographics of the individuals within the biobanks and replicate known characteristics of ME/CFS. We also observe that viral infections were the most common triggers for ME/CFS. We then applied a supervised simple linear regression classifier to test whether we could use phenotypic and survey features to classify individuals. We find that even broad quality of life scores are highly good predictors of disease status. Future work will improve on this classifier through an unsupervised approach to select better discriminatory features. (Wednesday 11am, NLBA-346)

Bahareh Ghanbari (RMIT), Laleh Tafakori, Pavel Krupskii, Yan Wang

A Non-parametric estimator for high-dimensional factor copula models with the use of proxy variables

Factor copula models have emerged as parsimonious tools for capturing dependence in observed variables based on one or multiple unobserved common factors. These models represent canonical vine copulas, integrating both observed and latent variables, thereby facilitating the representation of tail, asymmetric, and non-linear dependence structures. Most of the literature on factor copulas focuses on parametric modeling, but most of the time parametric assumptions are made solely for practical convenience. However, relying on parametric assumptions in many cases results in a mis-specified model, leading to a loss of consistency in estimators. This issue is particularly critical when one or more linking copulas deviate from popular parametric copula families. Although nonparametric approaches offer a potential solution, they typically involve more intricate and computationally intensive methods. In light of this, we propose a novel nonparametric kernel estimator for such models and compute its rate of convergence. The efficacy of our estimation method is demonstrated through an extensive simulation study. (Tuesday 11:30am, NLBA-346)

Yuxin Huang (QUT), Jessica Cameron, Susanna Cramb, Peter Baade, Kerrie Mengersen, Helen Thompson

Bayesian spatial relative survival model to estimate the loss of life expectancy for cancer patients in Australia

To date, there have not been any population-based cancer studies quantifying geographical patterns of the loss of life expectancy (LOLE) of people diagnosis with cancer. This absolute measurement of survival provides a fuller understanding of geographical disparities in survival outcomes for cancer patients. We propose using a spatial flexible parametric relative survival model in the Bayesian framework, which allows for the inclusion of spatial effects in hazard-level model components. This approach does not require information on the cause of death and allows complex and robust small-area estimation. The model was applied to Australia cancer data across 2238 geographical areas. The associated computer program scripts are available to support the understanding and implementation of our methodology to other spatial cancer modelling applications.

(Wednesday 2pm, NLBA-346)

Malathi S. Imiyage Dona (La Trobe), Maria Jelinic, Tayla Gibson Hughes, Gabriella E. Farrugia, Rebecca Harper, Grant R. Drummond, Anthony Vinh, Alexander R. Pinto

Advanced Bioinformatics Approaches to Understand Cardiovascular Fibrosis using Single-Cell Profiling

Cardiovascular fibrosis drives many cardiovascular diseases, leading to high global morbidity and mortality. While recent research has discovered complex cellular landscapes of cardiovascular tissues, the role of specific cell populations under pathological stress remains unclear. To address these gaps in knowledge, we utilized single-cell transcriptomics to study the cardiac and aortic cellular landscapes in mouse models of Angiotensin II-induced pathological stress.

Utilizing advanced bioinformatics techniques, we generated detailed cellular maps of the mammalian heart and aorta under chronic pathological stress, identifying critical cellular and molecular drivers of cardiovascular fibrosis. In the heart, our analysis uncovered heterogeneous cell populations contributing to fibrosis—a defining feature of hypertrophy—and revealed multiple cell types involved in the pathological remodeling of the extracellular matrix (ECM). Specifically, we identified two distinct fibroblast populations, Fibroblast-Cilp and Fibroblast-Thbs4, which emerged in response to tissue stress and are associated with the progression of cardiac fibrosis. In the aorta, we detected a unique fibroblast population, Fibroblast-Cthrc1, which appears exclusively under hypertensive conditions and plays a pivotal role in vascular ECM remodeling. These fibroblast populations were characterized by unique expression profiles of fibrosis-related genes and were distinct from myofibroblasts, which lack smooth muscle actin expression.

Our findings offer valuable resources for cardiovascular research, providing novel insights into the complex structure of the cardiovascular system and identifying new therapeutic targets that could be leveraged to prevent and treat cardiovascular fibrosis and heart failure.

(Wednesday 12pm, NLBA-346)

Gordana Popovic (UNSW Sydney), Tamar Hopkins
Analysing haphazard Surveys with mild-ish Assumptions

While statisticians generally recommend collecting data via probability sampling, applied researchers studying humans frequently use haphazard and other non-probability samples to conduct surveys, and statistical consultants are regularly asked to help analyse such data. Principled analysis of non-probability samples relies on having reference data from probability samples or censuses, to adjust for non-response bias by say weighting or covariate adjustment. What can be done without auxiliary information?

It is well known that odds ratios are invariant under certain types of selection bias, for example outcome dependent sampling, which is why we use them in case control studies. We extend these results to selection bias on both the outcome and predictor, by way of some assumptions about how these biases are related.

In a collaboration on racial bias in police searches from a haphazard Facebook survey, where no auxiliary data was available, we used these assumptions to estimate odds ratios. We discuss how the assumptions were communicated with researchers so that their plausibility could be assessed by domain experts. (Wednesday 1:30pm, NLBA-346)

Nishanthi Raveendran (Western Sydney University)
Wildfire Loss Modeling: A Flexible Semi-parametric Approach

This study explores flexible Generalised Additive Models for Location, Scale, and Shape (GAMLSS) to analyse wildfire property losses in the United States. Through the integration of climate, socioeconomic, and geographical variables, our approach enhances catastrophe risk management for insurance companies and government agencies. (Tuesday 12pm, NLBA-346)

Sandeep Santhosh Kumar, Davis J. McCarthy, **Heejung Shim** (Melbourne)
An annotation-guided deep neural-network method for factor analysis of single-cell RNA-seq data

Single-cell RNA sequencing (scRNA-seq) technology has made significant contributions to various research areas in biology. Since scRNA-seq data is high-dimensional, common analysis techniques often require learning low-dimensional latent representations that capture underlying gene expression patterns. Variational autoencoders (VAEs) have been popular tools for this task, as they efficiently capture nonlinearity through the use of deep neural networks.

In this talk, I will introduce PALAVA, a VAE-based method my team has developed to incorporate annotated gene sets in guiding the inference of low-dimensional latent factors. These gene sets are annotated from previous studies and can be obtained from databases such as MSigDB, though they may contain errors. Our method incorporated annotated gene sets flexibly, accounting for such potential errors. It uses the single-cell variational inference framework, which models raw counts. We are also interested in understanding the factor-to-gene relationship in our method

by interpreting the neural networks. I will illustrate the advantages of our approach through simulation studies and an analysis of scRNA-seq data from differentiating iPS cells (Cuomo et al., 2020). (Wednesday 11:30am, NLBA-346)

Susan Wei (Melbourne)
A singular learning theory perspective on variational Bayesian neural networks

In this work, we advocate for the importance of singular learning theory (SLT) as it pertains to the theory and practice of variational inference in Bayesian neural networks (BNNs). To begin, we lay to rest some of the confusion surrounding discrepancies between downstream predictive performance measured via the test log predictive density and the variational objective. Next, we use the SLT-corrected asymptotic form for singular posterior distributions to inform the design of the variational family itself. Specifically, we build upon the idealized variational family introduced in Bhattacharya et al. [2020] which is theoretically appealing but practically intractable. Our proposal takes shape as a normalizing flow where the base distribution is a carefully-initialized generalized gamma. We conduct experiments comparing this to the canonical Gaussian base distribution and show improvements in terms of variational free energy and variational generalization error.
(Tuesday 11am, NLBA-346)

Sithara Wijekoon (QUT), Helen Thompson, Edwin Lu, Gentry White
Missing Data Imputation using Vine Copula

Missing data is a common challenge in observational studies, leading to potential bias and inaccurate conclusions. Imputation is a standard technique to overcome this problem. However, traditional imputation methods often fail to preserve the multivariate dependence structure in datasets with complex, nonlinear relationships. To address this limitation, we present novel imputation methods for continuous variables based on two types of vine copulas: canonical vines (C-vines) and drawable vines (D-vines) which capture complex data features, including tail dependence, enabling more accurate imputation. The proposed methods impute missing values by sampling from a C- or D-vine model of the conditional distribution of missing data given the observed data. These methods offer several advantages over existing imputation methods: they implement modified algorithms for conditional sampling from C- or D-vines, which simulate multiple conditional values to estimate imputed values instead of relying on a single sample, improving the robustness of the imputation process. Additionally, they are adaptable to various copula families, making them suitable for diverse dependencies. Notably, our C-vine-based method represents the first application of a C-vine copula model in missing data imputation. The methods are specifically designed to handle non-monotonic missing patterns classified as Missing Completely at Random. We compare our proposed methods with two existing imputation techniques: predictive mean matching and the copula-based imputation method (CoImp) through simulation studies, focusing on both univariate and multivariate imputation. The results indicate that our methods consistently outperform other approaches, resulting in significantly lower error values in terms of Mean Absolute Error and Root Mean Square Error. (Wednesday 2:30pm, NLBA-346)

Shiny Math Bio: Non-traditional approaches to mathematical biology NLBA-028

Organisers: Agnese Barbensi, Meagan Carney and Adriana Zanca

Robyn Araujo (Melbourne)
Algebraic methods for complex cellular networks

The complex biochemical reaction networks (bCRNs) inside a living cell, composed mostly of proteins, represent a kind of 'cellular brain' that allows each individual cell to formulate 'intelligent' decisions and responses from complex high-dimensional signals. These biochemical interaction networks are often characterized by tremendous complexity – both in terms of the number of interacting molecules, and in terms of the varied and incompletely understood interactions among these molecules. How such complex networks could possess the kind of cognitive sophistication that supports life remains one of the most tantalizing open questions in the life sciences. In this talk I'll briefly discuss our recent mathematical contributions to this problem, which now provide a definitive picture of robust perfect adaptation in bCRNs of arbitrary size and complexity.
(Wednesday 2:30pm, NLBA-028)

Celia Dowling (Melbourne)
Investigating zooplankton abundance using a seasonally forced model with ocean dynamics

Rising sea-surface temperatures are causing spatial and temporal changes in the distribution of zooplankton in our oceans. This complicates foraging for higher-trophic species who feed primarily on zooplankton. Therefore, understanding the impact of temperature on planktonic dynamics is of great import to wildlife conservationists and researchers. The Nutrient-Phytoplankton-Zooplankton (NPZ) model is a type of population-level continuum model that has been used for decades to model the relationship between nutrients entrained from deep nutrient-rich waters, phytoplankton biomass, and zooplankton concentrations in the well-mixed layer of the ocean. However there are few NPZ-type models that have been extended to take into account seasonal changes in the mixed-layer depth, the stratification of water columns due to heat, and ocean dynamics, and can undergo dynamics and stability analysis. In this talk, I extend Edwards and Brindley's 1996 NPZ model and 2001 $NPZD$ model to include dependence on a seasonally changing mixed-layer depth and heat-induced vertical stratification. I detail how the mixed layer depth and a proxy for quantifying the impact of stratification can be computed from temperature-depth profiles made accessible by the Environmental Research Division's Data Access Program (ERDDAP). To accurately represent the ocean, I add ocean current dynamics (via advection and diffusion) to the model. I parameterise and solve the resulting rectangular mesh of partial differential equations for a case study in the North Atlantic Ocean near the Canary Islands archipelago. Summer phytoplankton blooms assisted by strong eddies and autumnal phytoplankton blooms induced by severe vertical stratification of the water column are recovered by my constructed model, qualitatively matching the dynamics of the Canary Island region. (Tuesday 11am, NLBA-028)

Lucinda Harrison (Melbourne)
Spatial optimisation of the surveillance of Japanese encephalitis virus in Australia

Disease surveillance aims to collect data at different times or locations, to improve our understanding of the spatial and/or temporal distribution of a disease. Surveillance data assist public health authorities to distribute resources where and when they are needed; data collection is typically limited by budget, time and resources. Surveillance activities should therefore be optimised subject to specific stakeholder priorities. Japanese encephalitis virus is a leading cause of viral encephalitis worldwide, causing life-changing disability and death in humans. The transmission cycle of the mosquito-borne virus is complex, with many species implicated as potential reservoir hosts. In this work, we draw on predictions of the geographic distributions of wildlife host and vector species in Australia, modelled using environmental data: the intersection of host and vector distributions constitutes the potential extent of virus transmission. We then consider site selection for mosquito surveillance: given the modelled potential extent of virus transmission and defined stakeholder priorities, what is the optimal set of sites for surveillance of Japanese encephalitis virus in mosquitoes? We apply a simulation-based multiobjective optimisation framework to find near-optimal designs for Japanese encephalitis surveillance in mosquitoes. (Tuesday 12pm, NLBA-028)

Adrianne Jenner (QUT)
In silico clinical trials help us improve immunotherapy and virotherapy for cancer

Immunotherapies have become an integral part of cancer therapy in recent years. Bispecific T-cell engagers (BiTEs) are one promising immunotherapy that enhance cellular antitumour immunity by targeting T cells and priming them to recognize cancer cells. Recent evidence has suggested that BiTE efficacy can be heightened through encoding in oncolytic measles virus (MV-BiTE) vectors. Infection of cancer cells with MV-BiTEs causes the local production of BiTEs and has shown efficacy and safety in a murine model, however, the translated efficacy of this treatment in a heterogeneous population is unknown. In this work, we generate an in silico clinical trial of MV-BiTE therapy using a system of ordinary differential equations. We capture potential heterogeneity of individual patients, using variability in in vivo responses to therapy and change in baseline from a clinical trial for combination virotherapy and immunotherapy. Our predictions show that one main driver of heterogeneity is the underlying T cell effector killing rate. Furthermore, we find that if individuals are classified as non-responders to the standard therapy (5 daily injections), they are likely to respond to more injections given further apart. This work serves as a guide for how mathematical in silico clinical trials can provide predictions that may be used to tailor future treatments. (Tuesday 2:00pm, NLBA-028)

Maria Kleshnina (QUT)
Optimal sharing in social dilemmas

Public goods games are frequently used to model strategic aspects of social dilemmas and to understand the evolution of cooperative behaviour among members of a group. While providing a baseline case, a (local) public goods model implies an equal sharing of returns. This appears an unsatisfying modelling choice in contexts where contributors are heterogeneous, and returns can be divided freely. Furthermore, it is intrinsically linked to the negative effect of inequality on cooperation, which is observed both theoretically and experimentally. To better understand the link between inequality and cooperation when returns can be shared flexibly, we characterise sharing behaviour that maximises contributions in an infinitely repeated voluntary contribution game, where players differ in both their endowments as well as the productivities of their contributions. In sharp contrast to egalitarian sharing, we find that endowment inequality makes cooperation easier to sustain when returns can be shared unequally. Maybe surprisingly, this qualitative relation between endowment inequality and cooperation is independent of players' productivities. We derive a unique sharing rule as a function of productivities and endowments that is weakly superior to all other sharing rules. This rule generically departs from both equal as well as proportional sharing. If inequality is high, for example, individuals with the highest endowment need to be compensated more in absolute terms, but their relative share may be significantly less than their proportional contribution. Our analytical findings are qualitatively supported by numerical simulations of simple evolutionary learning dynamics. (Tuesday 1:30pm, NLBA-028)

Sophie Raynor (James Cook University)
New mathematical tools for coral taxonomy

In recent decades, traditional coral taxonomy – based solely on morphology (shape) of the coral skeleton - has been thrown into disarray by advances in molecular phylogenetics. This means that biologists are currently unable to identify species in the field or using museum collections. Together with coral scientists at the Queensland Museum, we're asking whether topology and geometry can help overcome this problem. I will tell you about some of the ideas we're discussing so far, and invite you to join our team! (Tuesday 11:30am, NLBA-028)

Topology NLBA-026

Organisers: Zsuzsanna Dansco and Jessica Purcell

Carlos F. Álvarez and **Marisa Cantarino** (Monash)
Inverse limit and existence of equilibrium states for partially hyperbolic endomorphisms

We present the fibre bundle given as the inverse limit of a continuous surjection f on a metric locally simply connected space (M, d). This construction is a tool to understand the ergodic theory of endomorphism (local diffeomorphisms) with dominated splitting on the tangent bundle, which we introduce via examples. We prove that, if f is a partially hyperbolic endomorphism and the center direction is one dimensional, then there are always equilibrium states — measures that maximize the topological pressure — for any continuous potential, extending a result by W. Cowieson and L.-S. Young. This is a joint work with Carlos F. Álvarez (PUC - Valparaíso).

(Tuesday 12pm, NLBA-026)

Grace Garden (Sydney), Stephan Tillmann
Character varieties and essential surfaces in arbitrary characteristic

In the seminal work of Culler and Shalen (1983), a method is outlined to detect essential surfaces in a three-manifold by studying their $\mathrm{SL}(2, C)$-character variety. The method underscores connections between the theory of incompressible surfaces in three-manifolds, the geometry of representation varieties, and group actions on trees. In this talk, we lay a general foundation for this theory in arbitrary characteristic by using the same approach instead over F, is an algebraically closed field of positive characteristic. We then apply the theory to a variety of settings.

(Tuesday 11:30am, NLBA-026)

Connie On Yu Hui (Monash)
Geodesic link complements in the 3-torus

Rod packings are used in crystallography to describe crystal structures with chains of particles, and each rod packing can be viewed as a collection of disjoint geodesics in the 3-torus. In a joint work with Jessica Purcell, we used 3-dimensional geometry and tools from the 3-sphere to study the complements of geodesic knots and links (also called rods) in the 3-torus. In this talk, I would like to share results on how to classify the geometry of all rod complements in the 3-torus and some related results on triangulation complexity and volume estimates. (Wednesday 11am, NLBA-026)

Dionne Ibarra (Monash), Daniel V. Mathews, and Jessica S. Purcell
Triangulations of the complement of double twist knots

In this talk we will present and explain the construction of two different geometric triangulations of the complements of double twist knots of the form $K_{p,q}$ obtained by Dehn filling the crossing circles of the Borromean rings. This is joint work with D. V. Mathews and J. S. Purcell.
(Tuesday 11am, NLBA-026)

Sakshi Jain (Monash), Carlangelo Liverani
Multi-dimensional piecewise contractions

We study piecewise contractions on compacts subsets of $\mathbb{R}^d$, and we prove that under some simple assumptions, the attractor of such a function consists of finitely many periodic orbits. Additionally, we show that piecewise injective contractions are topologically stable. This is based on joint work with Carlangelo Liverani. (Tuesday 1:30pm, NLBA-026)

Joan Licata (ANU) and Vera Vertesi
Braids and branched covers

Given a disc with marked points, we can consider covers of the disc branched over those points. On the other hand, the braid group acts by homeomorphisms on the disc with marked points. In this setting, it's natural to ask when a homeomorphism of the disc lifts to a homeomorphism of its branched cover, and the answer is "sometimes". This will be a largely expository talk about this classical question, but I'll try to say a few words about a new interpretation that turns "sometimes" to "always". (Tuesday 2pm, NLBA-026)

Vanessa Robins (ANU) and Katharine Turner
The Extended Persistent Homology Transform for Manifolds with Boundary

The Persistent Homology Transform (PHT) is a topological transform introduced by Turner, Mukherjee and Boyer in 2014. Its input is a shape embedded in Euclidean space; then to each unit vector the transform assigns the persistence module of the height function over that shape with respect to that direction. The PHT is injective on piecewise-linear subsets of Euclidean space, and it has been demonstrably useful in diverse applications as it provides a landmark-free method for quantifying the distance between shapes. One shortcoming is that shapes with different essential homology (i.e., Betti numbers) have an infinite distance between them.

The theory of extended persistence for Morse functions on a manifold was developed by Cohen-Steiner, Edelsbrunner and Harer in 2009 to quantify the support of the essential homology classes. By using extended persistence modules of height functions over a shape, we obtain the extended persistent homology transform (XPHT) which provides a finite distance between shapes even when they have different Betti numbers.

It may seem that the XPHT requires significant additional computational effort, but recent work

by Katharine Turner and myself shows that when A is a compact manifold with boundary X, embedded in Euclidean space, the XPHT of A can be derived from the PHT of X, and a signature for each local minimum. James Morgan has implemented the required algorithms for 2-dimensional binary images as an R-package. This talk will provide an outline of our results and illustrate their application to shape clustering, and symmetry quantification. These applications were studied by our former students Jency Jiang, Nicholas Bermingham, and Thomas Burnett.

(Wednesday 2pm, NLBA-026)

Em Thompson (Monash)

Families of census knots and their triangulations

Since the 90s, an evolving effort by numerous authors has resulted in a census of 1267 hyperbolic knots whose complements can be triangulated by up to 9 ideal tetrahedra. This talk will be an overview of an upcoming preprint in which I consider census knots that arise by Dehn filling 2 components of the 3-component chain link M, a.k.a. the 'magic manifold'. Using 5 different triangulations of M that are compatible with well-known constructions of triangulated Dehn fillings, I describe explicit minimal triangulations for 229 census knots. Moreover, I organise these into 42 infinite families of knots related by twisting, and conjecture that the same triangulations can be extended to obtain minimal triangulations for all knots in each family.

(Wednesday 12pm, NLBA-026)

Lucy Tobin (Sydney), Jonathan Spreer

Small Triangulations of Simply Connected 4-Manifolds

In this talk, I'll construct a series of triangulations representing all connected sums of the PL-standard $\mathbb{CP}^2$ and $S^2 \times S^2$, which we conjecture to be minimal. This leaves us one more missing piece and one long-standing conjecture away from having a (probably) minimal triangulation for *every* topological type of PL simply connected closed 4-manifolds. I'll discuss why that is, how we prove the PL type of these triangulations, and why we believe them to be minimal.

(Wednesday 11:30am, NLBA-026)

Musashi Koyama, Facundo Memoli, Vanessa Robins and **Katharine Turner** (ANU)

Computing the degree-1 persistent homology of a Rips Filtration over a million points on a desktop computer

The persistent homology of Rips filtrations is a powerful tool in Topological Data Analysis as a way to describe the shape of datasets. A major obstacle to more widespread take up is the long computation time and, more importantly, the large memory requirements needed to store the Rips complex in order to compute it. We bypass these issues by finding a "Reduced Rips Filtration" which has the same degree-1 persistent homology but with dramatically fewer simplicies in the underlying complex for the filtration. We can compute Rips filtrations over large point clouds even on a desktop computer, in cases where Ripser just ran out of memory and stopped. For Poisson points clouds we can even compute the degree-1 persistent homology for the entire Rips filtration for point clouds of a million points! Joint work is with Musashi Koyama, Facundo Memoli and Vanessa Robins. (Wednesday 1:30pm, NLBA-026)

Work Integrated Learning (WIL) for Mathematics and Statistics
NLBA-344

Organisers: Asha Rao and Geetika Verma

Kerri Morgan (RMIT)
Incorporating work readiness skills in first year mathematics

Traditionally mathematics has assessed applications of knowledge using problems that encapsulate pseudo-real-world scenarios, but has not incorporated actual physical phenomena and hands-on experiences. Assessment that investigates how mathematical models perform and compare to real phenomena encourages students to understand these relationships and to demonstrate their abilities to apply mathematical techniques.

Mathematics fundamentally requires collaboration, sharing skills and knowledge to building solutions and models and testing and refining those models based on their behaviour in the real world. A failure to recognise that maths is more than the solitary activity of doing sums results in students failing to realise that they have obtained and can evidence key graduate requirements including problems solving, modelling, collaboration, communication and team work.

In this presentation we describe a practical activity and assessment that we introduced in a large first year engineering mathematics course. The assessment explicitly links to graduate attributes, and a reflection that encourages students to formulate a concise account evidencing how they have applied these attributes. (Wednesday 11:30am, NLBA-344)

Asha Rao (RMIT)
Knowledge-in-Action: Designing Undergraduate Work Integrated Learning for the RMIT Bachelor of Applied Mathematics and Statistics

The US Bureau of Labor Statistics 2020-2030 job outlook indicates a 33% growth in jobs for mathematicians and statisticians – a growth much faster than average. The World Economic forum Future of Jobs 2023 report states that employers highly value the analytical, creative thinking, curiosity and adaptability, all skills that maths and stats students learn in their degree. However, maths/stats students still need training to be able to go and get jobs at the end of their degree. That's where a Work Integrated course (or two) come into play. At RMIT, I have (with help from a variety of people) designed two courses, one which introduces the industry to 2nd year students and prepares them for their future careers, while the other places them in internships or placements in industry. In this talk I will talk about how I achieve this ongoing journey.
(Tuesday 1:30pm, NLBA-344)

Laura Tubino (Deakin)
Authentic individual assessment for team-based projects

This presentation explores an innovative assessment strategy within a capstone experience, designed to enable individual assessment in team-based projects. By moving away from traditional group-based marks, this model aligns with industry practices that recognize diverse contributions. Guided by Kegan's Constructive Developmental Theory, the assessment integrates both cognitive and affective outcomes, reflecting the varied roles students play within dynamic team environments.

Students compile a portfolio demonstrating their achievement of learning outcomes, highlighting their capabilities, and reflecting on personal growth. A holistic rubric links grade criteria to developmental levels, promoting engagement in complex tasks and encouraging deeper self-reflection, thereby rewarding students for meaningful learning.

The assessment model supports a "company" structure where students begin as junior members under senior guidance and, in a subsequent unit, transition to leadership roles. They mentor new members and manage IT projects commissioned by industry and academic partners. This structure enhances professional skills, adaptability, and readiness for real-world challenges, creating an authentic learning environment that mirrors professional practice.

(Wednesday 1:30pm, NLBA-344)

Maria Vaskova (RMIT) and Christopher James
WIL Industry Engagement in Mathematical Sciences at RMIT University - Scaling impact and student success

The Work-Integrated Learning (WIL) Engagement team and academic WIL Course Coordinators manage over 12,000 WIL activities annually at the RMIT STEM College overall. About 500 activities are in Mathematical Sciences - Mathematics, Statistics, Cyber Security and Analytics). In our presentation we will outline how we have been able to manage WIL at scale, our collaborative structure and tools we use. Given the University Accord recommendations, the discussion of this topic is quite timely.

1. STEM WIL Approach: Discussing our strategic approach to WIL, emphasising industry collaboration, student readiness and real-world problem-solving.
2. Team Structure: 3 sub-teams working in an agile and cohesive team model to ensure seamless execution of WIL initiatives.
3. Team Collaboration: WIL academics and the W&E teams collaborating seamlessly to deliver experiences.
4. Multidisciplinary Approach: We work with one partner to deliver WIL in multiple disciplines or integrate different disciplines to work on one project.
5. Long-Term Partnerships: We recognise sustained collaborations with returning partners while actively forging new relationships.

6. From WIL to Employment: Showcasing instances where WIL experiences directly translated into job opportunities.
7. Other benefits to partners: Companies benefit from exposure, new ideas and the University's shared expertise.
8. Project Submissions: Utilising automated systems such as Smartsheet to capture submissions in one place and alert the relevant parties.
9. Scalability: Discussing how our systems are designed to accommodate growth without compromising quality.
10. Student Impact: Bespoke industry engagement to source WIL for areas students have identified as valuable.
11. Onboarding and Immersive Learning: Outlining how we prepare students and industry partners to go on placement at scale using shared university resources.
12. Encouragement of student for self-sourcing placements.

Through the above discussion, we consider the ability to scale WIL without a direct investment in additional headcount or substantially changing processes. Fresh ideas, digital enhancements and long-term industry partnerships can drive commitment to producing industry-ready graduates at scale. (Wednesday 11am, NLBA-344)

Geetika Verma (RMIT)
Enhancing Student Learning in WIL Courses through Micro-WIL

The Master of Cyber Security Program delivered by RMIT School of Science is a 16-course program delivered over two years with eight core courses.

This talk will present highlights of this program that includes an industrial WIL course, Industry Linkage Project, in the concluding semester of the program. To prepare the students for this final WIL project, the teaching team has designed a pathway of three core courses as scaffolding. This scaffolding includes the two core courses (Case Studies in Cyber Security, and Introduction to Information Security), as well as a micro-WIL course (Industry Awareness Project).
(Wednesday 2pm, NLBA-344)

Sithara Walpita Gamage (UniSA)
Work Integrated Learning in UniSA's undergraduate Engineering Programs

Work Integrated Learning (WIL) is a critical component of undergraduate engineering programs, required by Engineers Australia (EA) for accreditation. At University of South Australia (UniSA), students must complete a minimum of 450 hours of WIL also known as professional practice, embedding essential EA Stage 1 Competencies throughout their studies.

UniSA's Professional Practice Program (PPP) provides a structured, three-stage pathway that enables students to progressively meet their WIL requirements, integrating real-world learning from the first year of university.

This presentation will explore the systems and processes developed to incorporate professional practice into the engineering curriculum, ensuring that students are fully prepared for industry demands upon graduation. Attendees will gain valuable insights into the program's design, its role in supporting accreditation, and its impact on student success in the professional world. Additionally, you will learn about the strategies used to promote WIL opportunities through collaboration with industry peak bodies and employers.

Join us to discover how UniSA's approach to WIL is shaping engineering graduates for a dynamic and evolving workforce. (Tuesday 2pm, NLBA-344)

Lesley Ward (UniSA)

The UniSA Mathematics Clinic: How to build a Work-Integrated Learning ecosystem

The Mathematics Clinic of the University of South Australia, now in its 21st year, runs year-long authentic industry-sponsored research projects for small teams of final-year undergraduate mathematics students. Mathematics Clinic projects give students professional skills, experience, accomplishments, and employability. They also generate research progress and publications. I will outline how to build the necessary commitment and structure for such a programme, touching on curriculum; articulation with other mathematics courses; coaching students in professional skills and leadership roles; pitching and recruitment of industry sponsors; engaging students and academic staff; intellectual property, confidentiality, and contracts; and scoping and development of suitable projects. I'll offer some case studies, suggestions, and principles, drawn from Mathematics Clinic experience. (Wednesday 12pm, NLBA-344)

Contributed Talks NLBA-105

Organisers: Catherine Greenhill and Xiaoping Lu

Hatice Ay (RMIT), Melih Ozlen, Sona Taheri
Multi-Skilled Resource Constrained Multi-Project Scheduling and Routing Problem for Project Management

Project scheduling is a critical challenge across many sectors where sequential tasks must be organised efficiently. This problem becomes particularly complex in multi-project management due to constraints such as limited resources, deadlines, and the intricacy of managing multiple projects simultaneously. A specific class of scheduling problems, known as "multi-skilled resource-constrained multi-project scheduling" (MS-RCMPS), involves coordinating shared resources across multiple projects, each consisting of precedence-related activities. Our study enhances the MS-RCMPS framework by integrating routing of multi-skilled resources and multi-period planning. Unlike standard routing and scheduling models minimising costs, our approach focuses on maximising the priority of completed projects, potentially factoring in customer waiting times, livability impact and size of project. We have developed a new mathematical model to solve this very practical problem. As the number of projects and teams increased, the performance of commercial solvers in solving the mathematical model deteriorated, struggling to find even feasible solutions to large problems involving more than 80 projects. To address this, we developed a spatial and temporal decomposition algorithm to identify good-quality solutions in a timely manner. We demonstrated the near-optimal performance of our heuristic approach using instances with optimal solutions. Our approach efficiently handles large problem instances and consistently outperforms using a commercial solver and the mathematical model as the problem size increases.

Keywords: routing, scheduling, project management, multi-skilled resource, multi-project scheduling

(Tuesday 12pm, NLBA-105)

Shashi Chourasiya (UNSW Canberra)
An explicit version of Carlson theorem

Zeros of the Riemann zeta function have always been a center of attention of mathematicians. There are several zero density estimates using various techniques. In this article, we will provide an explicit version of Carlson's zero density estimate, that is, $N(\sigma, T) \leq K(\sigma)T^{4\sigma(1-\sigma)}\log^4 T$, which is the sharpest estimate close to the line $\sigma = 2/3$ with some restriction on T. One of the main ingredients is an elementary approximate functional equation which gives not only the aforementioned estimate but also the second moment of the zeta function.

(Wednesday 2pm, NLBA-105)

Kaniz Fatema (RMIT), Sona Taheri, Adil M. Bagirov

Solving Difference of Convex (DC) Optimization Problems with Constraints

We design a new optimisation algorithm to solve constrained difference of convex (DC) programs. The proposed algorithm is based on the new local DC optimisation method and the well-known modified subgradient method which can be viewed as an extension of aggregate subgradient method for unconstrained DC optimisation problem. We first utilise the sharp augmented Lagrangian to reformulate the constrained DC problem to unconstrained problem and then construct it's dual. The local DC optimisation method is then applied to minimize the sharp augmented Lagrangian function for given values of dual variables. The new algorithm stops or updates the dual variables using the modified subgradient method, based on the solution obtained. We investigate the convergence of the proposed method, evaluate and compare its performance with numerous constrained nonsmooth optimisation solvers with various academic test problems. Our further research aims to develop suitable global DC optimisation method for solving constrained nonsmooth optimisation problems. (Tuesday 11am, NLBA-105)

Vishmi Fernando (RMIT), Melih Ozlen, Sona Taheri

A Single Nurse Routing and Scheduling Problem for Home-Based Chemotherapy and Infusion Services

Home health care has expanded to include infusion treatments for chemotherapy and other diseases requiring periodic infusions. Scheduling these appointments is crucial and complex due to the urgency of treatment and their unique cyclic patterns over several months. This complexity arises because adding a new patient affects not only the immediate schedule but also has long-term implications. In this study, we present a mathematical model for a single nurse routing and scheduling problem for home-based chemotherapy and infusion services. The model aims to maximise the number of priority-weighted new chemotherapy and infusion patients incorporated into the system by optimising the route and schedule for a single nurse, considering the cyclical nature of infusion treatments with an extended planning horizon. A novel matheuristic approach, the Temporal Decomposition and Filtering based Matheuristic (TDFM), is introduced to address this large-scale problem. Computational experiments on practical-sized problems demonstrate that the proposed solution approach, combined with commercially available solvers, is able to achieve high-quality solutions within a useful timeframe.

Keywords: routing and scheduling, OR in health services, chemotherapy infusions, periodic treatments

(Tuesday 11:30am, NLBA-105)

Ksenia Sofronova (UNSW Sydney)
Optimal sequential strategies in insurance

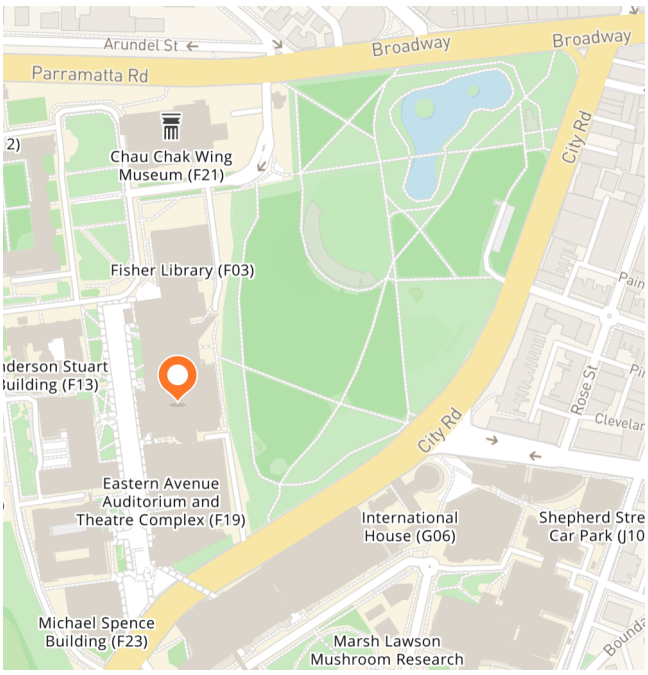
In many applications, data is sequentially observed over time, and it is necessary to make decisions based on already obtained information while future observations are not seen yet. From a mathematical point of view, a decision-maker obtains a sequence of random variables and must decide when to stop with no recall allowed, that is, once a random variable is rejected, it cannot be chosen later. The decision to stop depends only on information already obtained and does not depend on future observations. The aim is to find an optimal sequential strategy that maximizes an expected reward. In this talk, we consider insurance products where a policyholder has the option to insure some of its annual losses within a finite time horizon. (Wednesday 1:30pm, NLBA-105)

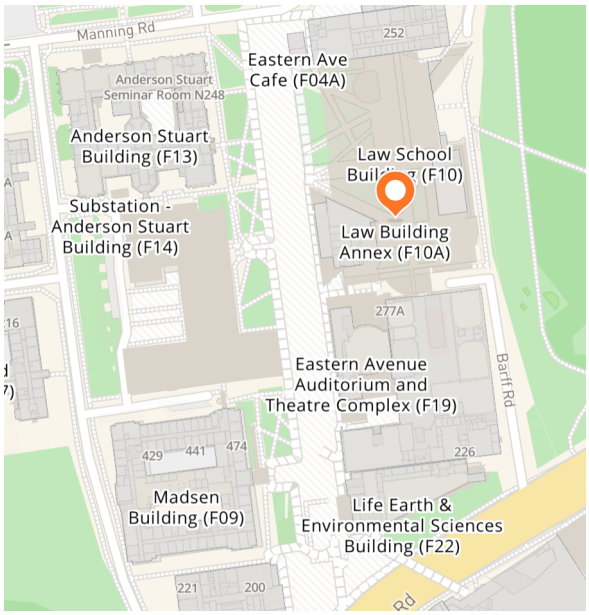
Natalie Thamwattana (Newcastle)
Incorporating heterogeneity in a continuum approach for modelling nanostructures

A continuum approach based on the Lennard-Jones potential has been shown to provide a good estimation for the interaction energy between regular-shaped homogeneous nanostructures comprising the same type of atoms. However, this method may not be accurate for heterogeneous molecules, which comprise more than one chemical elements. In this talk, a traditional method is discussed where we approximate a heterogeneous structure by assuming multiple surfaces. While this approach works well for small sized structures, calculations become intensive for large sized molecules as many sums from multiple surface interactions are involved. To address this issue, we discuss our recent model that approximates a heterogeneous structure with a single surface or volume, where the attractive and repulsive constants in the Lennard-Jones potential are replaced by functions, which depend on the parameterisation of the surface (or volume). We comment that this technique is suitable for regular-shaped nanostructures where their heterogeneity can be modelled by surface (or volume) parameterisation. Proof of concept is demonstrated for coronene, methane and DNA structures. (Wednesday 2:30pm, NLBA-105)

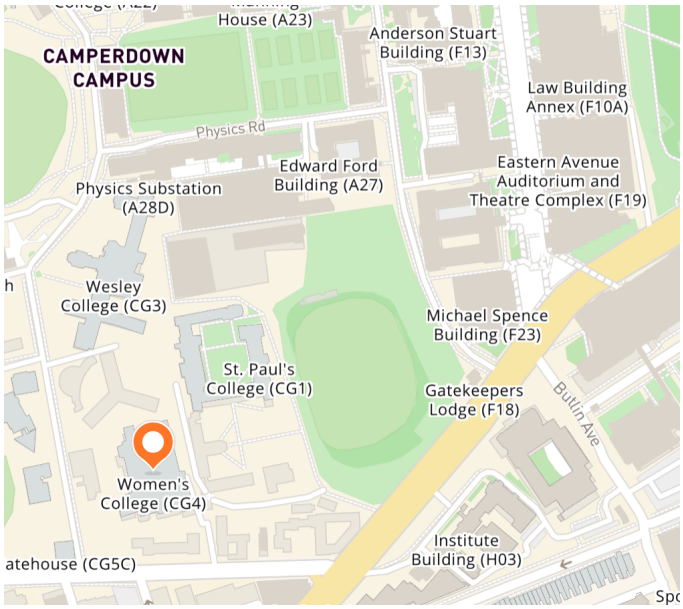
Speaker Index

Maps





New Law Building Annexe (F10): all talks and breaks



Women's College, for the Welcome Reception

WIMSIG Conference 2024 – Schedule Outline

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<tr><td>9:30 – 10:00</td><td></td><td rowspan="2">Plenary Talk
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<tr><td>10:30 – 11:00</td><td></td><td>Morning Tea</td><td>Morning Tea</td></tr>
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