2015/16

AMSI Vacation Research Scholarships

AMSI
AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

Australian Government
Department of Education and Training

AMSI Vacation Research Scholarships Report

2015-16

01

Introduction

Each year AMSI's Vacation Research Scholarship Program funds undergraduate students from across Australia to complete a six-week research project over the summer break. The scholarships are awarded on a competitive basis for projects in the mathematical sciences.

In 2015/16, 50 students were selected from 76 applicants to become AMSI Vacation Research Scholars and complete their research project.

Vacation scholars experience life as a researcher – completing actual research projects under the supervision of academics at their home university – giving them a taste of what it's like. The program aims to inspire students to continue with further research in the future, and for some the Vacation Research Scholarship project leads to their first academic publication.

At the end of summer, scholars come together to present their findings to peers and supervisors at the Big Day In Conference, which gives them invaluable professional development experience in communication and networking skills, and a unique opportunity to meet like-minded scholars.

This year's Big Day In was hosted by AMSI from 9-11 February at International House, at the University of Melbourne.

"The best thing about being an AMSI scholar was not just the chance to speak to like-minded students about maths research in a casual setting, but also hearing different perspectives on maths in the wider setting of careers, creativity and life in general"

Alexander Stokes, **The University of Sydney**

Research Projects

02

University	Student	Project Title
Federation University Australia	Debra Briggs	Comprehensive Catalogue Of Polyhedra
La Trobe University	Maxwell Cairns	New Interval Estimators For The Ratio Of Quantiles From Two Independent Populations
	Alex Ligthart-Smith	A Comparison Of Longitudinal Data Models That Include Time-Varying Covariates
	Elisa Tancredi	Factors Affecting Success In Mathematics At La Trobe University
Monash University	Joshua Cameron	The Role Of Concurrent Relationships In Disease Spread
	Kevin Duxbury	Reaction-Diffusion Model For Human Oocyte Symmetry Breaking
	Jamieson Kaiser	The Spread Of Dynamic Processes On Random Graphs With Spatial Structure
	Rhiannon Kirby	Spatial Interactions Of Infected Mosquito Populations
	Haris Sahovic	What Do We Need To Know To Respond To The Next Emerging Disease?
Queensland University of Technology	James Bubear	Skolem Sequences And Graphs
	Luke Ginn	Mathematical Modelling Of Battery Electrodes
	Nicholas Johnson	The G′/G-Expansion Method For Nonlinear Differential Equations
	Emma Johnston	Fractional Reaction-Diffusion Models For Anisotropic, Heterogeneous Media
	Amy Stringfellow	Droplet Pearling
	Lachlan Tyrrell	Evolving Bubbles In A Hele-Shaw Cell
RMIT University	Sarah Gazelle	The Von Bertalanffy Population Model Applied In Tumour Growth Modelling
	Peter Wreford	Analysis Of Vector Dissimilarity Measures To Build Gene Networks From Chickpea Expression Data
The Australian National University	An Ran Chen	Random Planar Graphs
	Xiangyuanchai Guo	Models For Selection Effects
	Maxim Jeffs	The Donaldson-Floer-Fukaya Category In Yang-Mills Theory
	Anna Vaughan	Introduction To String Theory
	Yinli Wang	Modelling Surface Water Flow In The Lower Campaspe Catchment

University	Student	Project Title
The University of Adelaide	Russell Edson	Cartilage Biomechanics: Multi-Scale Modelling, Analysis And Scientific Computing
	Michael Hallam	Internal Hom-Objects In The Category Of Topological Spaces
	Daniel Kon	A Statistical Model For Missing Data In Proteomics Studies Of Gastric Cancer
	Angus Lewis	Approximating Heavy-Tailed Distributions Using Infinite Phase-Type
	John McCarthy	Lorentzian Surfaces
	Matthew Ryan	Knots And Sticks
The University of Melbourne	Shane Henry	Forecasting Fire Bugs
	Joseph Johnson	Numerical Solution Of The Boltzmann Equation For Rarefied Gas Flows
	Todd Neve	Partition Function Zeros And The Ising Model In A Field
	Timothy O'Sullivan	Molecular Dynamics
	William Stewart Albert Zhang	Benchmarking A Novel Electromagnetic Scattering Method
The University of Newcastle	Timothy Tillman	Unicellularity Of Shift Operators
	Morris Vysma	Chaos Encrypted Communication Channels
The University of Queensland	Alexander Baker	The Geometry Of Homogeneous Spaces
	Anna Kervison	The Ricci Curvature Of Rotationally Symmetric Metrics
	Ainsley Pullen	Indecomposables Of Quiver Representations In The Category Of Finitely Generated Abelian Groups
	Aiden Suter	Calculus Of Formal Distributions And Vertex Operator Algebras
The University of Sydney	Padraic Gidney	Spectral Dynamics Of Periodic Wavetrains In Reaction Diffusion Equations
	Eric Hester	Studies Of Dead Water In Stratified Fluids
	Alexander Stokes	Symmetry Analysis Of Pole Distribution Of Special Solutions Of The Continuous/Discrete Painleve Equations
	Steve Xu	Acceleration Of Stochastic Approximation Parameter Search In Adaptive Monte Carlo Simulation
	Abdul Zreika	The Space Of Closed Essential Normal Surfaces In Knot Complements
The University of Western Australia	Dimitrio Sidi	Rhino Conservation Problem

University	Student	Project Title
University of South Australia	Xuemei Liu	Study Of Duality Schemes With Sequential Lagrangian Updates
University of Technology Sydney	Andy Chu Logan Haami	Modelling Of Absorbing Thin Film Optical Materials In The Presence Of Highly Conductive Gratings
University of Wollongong	Penelope Drastik	Zappa-Szep Products Of Compact Quantum Groups

Student project reports can be viewed on the AMSI website: www.vrs.amsi.org.au/projects

Student blog posts are posted throughout the year on the AMSI Vacation Research Scholarship website: www.vrs.amsi.org.au/vrs-blog

"Working on a real project was an invaluable experience. Exploring topics that may or may not have ever been addressed before, and being required to find my own way to tackle the problem, brought a strong sense of connection to mathematics and ownership of my own work. As a result I learnt a lot more in the time I had, than I ever have from typical undergraduate coursework."

Morris Vsyma, **The University of Newcastle**

03 Supervisors

AMSI would like to express its appreciation to all Vacation Research Scholarship supervisors who gave their time and expertise to the scholars and their projects. This contribution is integral to the success of the program.

University	Supervisor
Federation University Australia	David Yost
La Trobe University	Luke Prendergast
	David Farchione
	Katherine Seaton
Monash University	Hans De Sterck
	Jennifer Flegg
	Manoj Ghambir
	Simon Clarke
	Joel Miller
Queensland University of Technology	Joanne Hall
	Troy Farrell
	Matthew Simpson
	Tim Moroney
	Scott McCue
	Chris Green
RMIT University	John Shepherd
	Stephen Davis
The Australian National University	Anthony Licata
	Alan Welsh
	Bryan Wang
	Peter Bouwknegt
	Barry Croke
	Tony Roberts
The University of Adelaide	Sarthok Sircar
	Finnur Larusson
	Patty Solomon
	Giang Nguyen
	Thomas Leistner
	Michael Murray
	Joshua Ross
	Nick Reed

University	Supervisor
The University of Melbourne	Peter Taylor
	Nicholas Read
	Iwan Jensen
	John Sader
	Naida Lacevic
	Derek Chan
	Qiang Sun
The University of Newcastle	George Willis
	Bjorn Ruffer
	Ben Babao
The University of Queensland	Artem Pulemotov
	Clement Maria
	Jorgen Rasmussen
The University of Sydney	Robert Marangell
	Geoff Vasil
	Nalini Joshi
	Ray Kawai
	Stephan Tillmann
The University of Western Australia	Neville Fowkes
University of South Australia	Regina Burachik
University of Technology Sydney	Matthew Arnold
	Christopher Poulton
	Dave Robertson
	Nathan Brownlowe

"The Vacation Research Scholarship was an excellent way to develop a strong working relationship with my supervisor, who offered great insight and advice about a career in mathematics. "

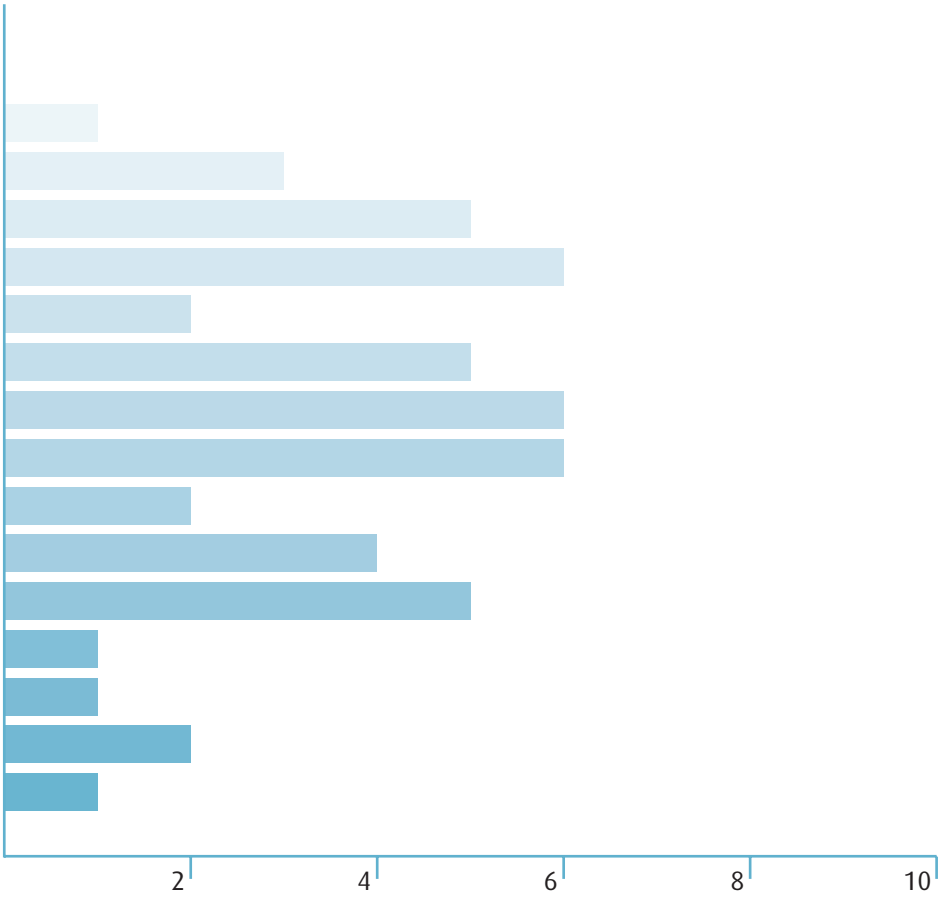
Jamieson Kaiser, **Monash University**

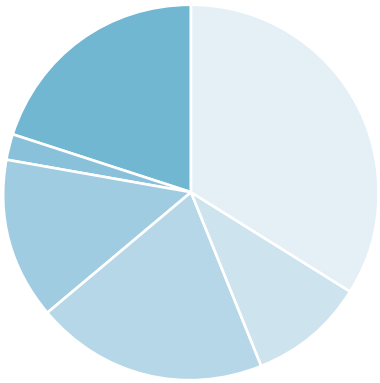
Participation Statistics

04

Breakdown by University

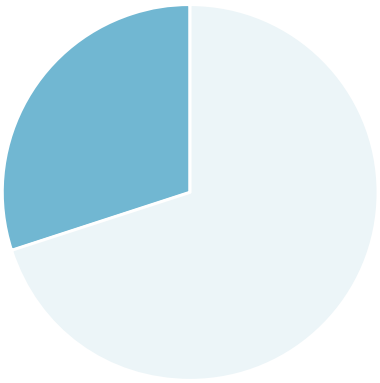
Federation University Australia	1
La Trobe University	3
Monash University	5
Queensland University Technology	6
RMIT University	2
The Australian National University	5
The University of Adelaide	6
The University of Melbourne	6
The University of Newcastle	2
The University of Queensland	4
The University of Sydney	5
The University of Western Australia	1
University of South Australia	1
University of Technology Sydney	2
University of Wollongong	1
Total	**50**





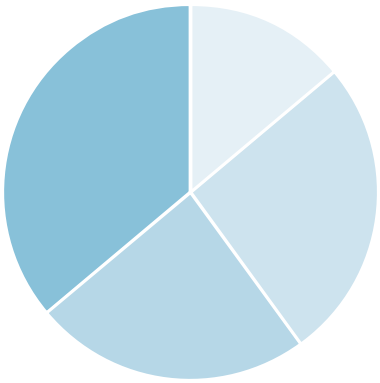
Breakdown by State

VIC	34%
ACT	10%
NSW	20%
SA	14%
WA	2%
QLD	20%



Breakdown by Gender

Male	70%
Female	30%



Breakdown by SES Status

Low	14%
Medium	26%
High	24%
Undisclosed	36%

At AMSI's Big Day In, scholars have the opportunity to present their research findings to their fellow scholars and supervisors in a conference setting.

Big Day In 2016 got off to a fast paced start with the first dodge-ball icebreaker tournament. Scholars were allocated to random teams, in an aid to 'break the ice'. All came along and got involved, excelling their competitive streak, as well as showing team-working skills.

AMSI's Research and Higher Education Program Manager, Simi Henderson opened the 2016 Big Day In with a warm welcome to students and supervisors from all across Australia.

Elena Tartagila took the students on a journey of valour and discovery as she talked about life as a PhD student at The University of Melbourne, while Dr Federico Frascoli brought the opening to a close with an inspirational talk, covering the ideas and values that made him choose a career in research and academia.

Over the two days, scholars delivered high quality presentations about their research projects, prompting questions and debates amongst the audience. As well as formally finding out about each others research, they had plenty of time for networking with other like-minded individuals, during dinner and break times.

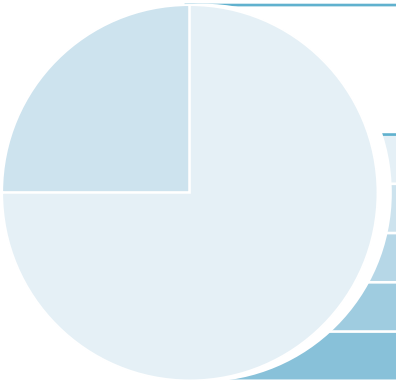
Best Student Presentations

Congratulations to:

Xiangyuanchai Guo, **Australian National University**

Padraic Gidney, **The University of Sydney**

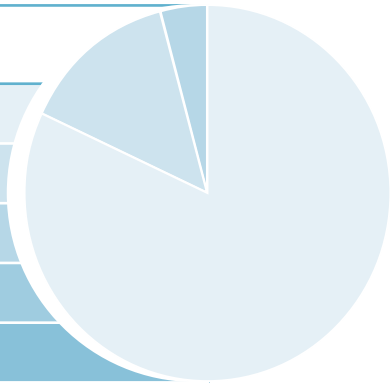
who both won the book prizes for best student presentations.



The scholarship VRS provides a useful introduction to research

STRONGLY AGREE
AGREE
NEUTRAL
DISAGREE
STRONGLY DISAGREE

I would recommend the program to others



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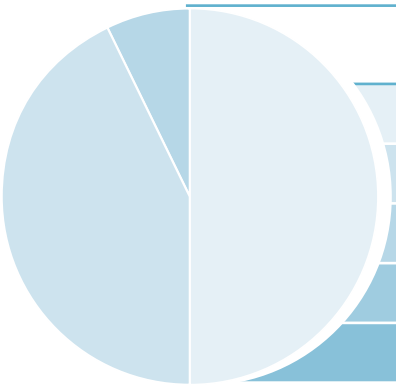

Overall, the Big Day In was well organised

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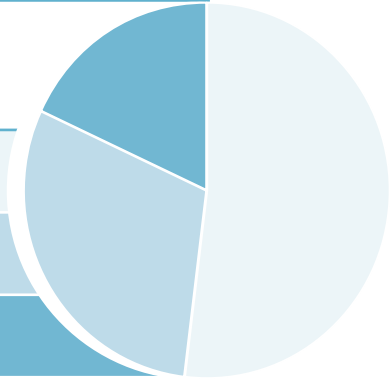
After the Vacation Research Scholarship, what level education do you expect to complete?



HONOURS
MASTERS
PHD

STATISTICS OF SPORT!

Australia is a sporting nation and Norah Finn is a sports fanatic. When she realised sports and the mathematical sciences could mix, she had to get in for a try—Norah spent her summer on the job with our paralympians.

Discovering that her love of numbers was as strong as her love of sports happened in Year 12: "I had a fantastic teacher in Year 12 who was extremely passionate about mathematics. She motivated me to work hard and I realised how much I enjoyed the challenge of mathematics."

Norah attended AMSI's 2015 Summer School at the University of Newcastle. She says residential schools offer fantastic opportunities to be immersed in mathematics and statistics. "We bonded like a sports team; made good friends; and were able to teach and learn from each other."

Summer 2014/15 was pretty hectic; not only did Norah attend SS, but she was also awarded a Vacation Research Scholarship. Over six weeks Norah worked with our wheelchair rugby team and members of the Australian Paralympic Committee to investigate workload training. The research aimed to determine how players perform in competition in comparison to when they train. At the time, the plan was to continue this as an honours project at RMIT throughout 2015.

"I didn't come to any major conclusions in my report. I have, however, set myself up very well for my honours year by getting a majority of the groundwork and coding done. I also have a well-defined set of goals."

Things didn't quite go as planned. Norah's honours project is now on Bayesian spatial analysis for the evaluation of breast cancer detection methods. Statistics provides a mathematical way of describing occurrences in life and can act as a predictive tool to maximise quality of life. "My new research topic is very different to sports statistics! But has always been a path I considered taking. It's great to have gained training in stats research in both fields.

"The most time-consuming task of my VRS project was the creation of the code window. There weren't many mathematical calculations but, creating the links between opening and closing different code buttons was a laborious logical problem! Also, ensuring all codes were labelled coherently and consistently was very tricky – it's one of those things that until you've attempted it yourself you cannot understand how complex it is!"

> *"Doing both SS and VRS, at the same time, taught me how to handle high intensity projects while still working to my full potential."*

Once all this was sorted Norah started sifting through the enormous data set to collect several descriptive statistics, which were dependent upon other variables. Her main forms of analysis were fairly standard hypothesis tests and chi-square tests. "I attempted more complex procedures, but the short time frame of the VRS meant I was only able to code two games, and so, I didn't have a big enough sample size."

Norah confesses that while her curiosities lie in sports statistics, on a day-to-day basis, statistics are crucial. "Stats can help answer questions about where to build a new school or hospital or what the pros and cons are of building a train line, as opposed to a road. Stats is used in many aspects of finance, can assess the performance of new drugs, model the spread of viruses and help uncover ways to contain outbreaks. Or, you can use it to see exactly how your sporting team is performing."

Even though there was no break between finishing her undergraduate degree and officially starting honours, the work was gratifying.

"Doing SS and VRS, at the same time, taught me how to handle high intensity projects while still working to my full potential."

It isn't just the programs Norah believes are of value; she reckons AMSI's work hits it for six too. "The institute encourages and promotes the study of mathematics in society, which is important in a society where the importance of studying mathematics receives not even a fraction of the air-time given to the importance of studying subjects such as English, law and medicine."

Norah definitely recommends both events: "They offer great complimentary opportunities. SS allows you to study with a new group of students, with fantastic lecturers from across Australia and the world, studying subjects that may not be available at your home institution. And the VRS allows you to experience life as a researcher; you gain a feel for what honours will be like. VRS also exposes you to presenting your research to your peers with similar interests – an opportunity not readily available to an undergraduate."

Norah Finn's enthusiasm and expertise will see her shepherding her way past other statisticians to a sporting club, or beating all the other researchers to the scrubs in a medical research facility... very soon. ■

Norah Finn is one of AMSI's favourite ambassadors, tackling both a VRS project and graduate school over summer. She is now applying her statistical skills at RMIT University to breast cancer detection methods.

Photography: Australian Paralympic Committee

A Mathematical Voyage

By Rhiannon Kirby, **Monash University**

Mathematics is a beautiful manifestation of man's desire to understand the physical world he is bound by, an attempt to pave pathways between human perception and the objective exterior. These pathways weave through abstractions, exploring rational thought and logic within the mind, and reconnect with empirical knowledge via experimentation. Through mathematics we discover a universal communicative tool, capable of capturing notions that prove difficult to describe using everyday terminology, and by overcoming the barriers of unique discourse found in different fields of research, we enable interdisciplinary collaboration. Mathematics also embodies the human imposition of structure on all that confronts, to catalogue and control, to seek meaning and definition in the blank, but, few beautiful human phenomena exist without such dichotomy.

Throughout primary school, and a large part of my secondary schooling, mathematics presented itself merely as a weekly schedule of classes to attend, and a symbolic challenge. Endless questions waited numbly in black text, on their white stage, labelled 1a, 3f, 7g. They came with rules of engagement, and a warranty of being useful 'later', but without context, without images. The practice that 'made perfect' was the practice of conceptual amnesia, and a growing herd of spherical cows went unnoticed as crucial assumptions were disregarded. Beyond comparing the relative size of chocolate pieces, scheduling routines, or halving a cake recipe, mathematics was but a small curiosity in my formative years. Maths, for me, needed motivation.

To the teacher that showed me maths was ubiquitous in application, and, dare I say, enjoyable, I thank you for opening a portal. I was sceptical, but my mathematical voyage had begun.

During my three years of undergraduate studies at university, I have been privileged with exploring ideas in classical and quantum physics, thermodynamics, and fluid flows, paralleled by the development of an applied mathematical toolkit. It is this thrilling simultaneity in learning and immediate application that has allowed me sufficient freedom to appreciate the profound relevance of mathematics itself, and to see the sheer charm in math-for-math's-sake. Through reconciliation of abstraction with physical theory, I have discovered underlying beauty in the formation and analysis of mathematical models. I am delighting in using maths to model natural processes, in learning how to implement routines computationally, and gaining further insight into the world around me.

During the summer of 2015/16 I was offered the opportunity to play with new mathematical ideas through an AMSI Vacation Research Scholarship. In a short several weeks, I visited realms of dynamical systems and elementary bifurcation theory, in the context of population ecology, with diversions off to interacting chemical systems, patterns on leopard tails, stripes on fish, and spots on (rectangular) cows. It is precisely this diversity in mathematical modelling that I find truly captivating.

My research focused on a simple continuous model of two competing populations of mosquitoes. In a model of competition, it is particularly important to determine if the system may support a coexistent or lone population, and to consider the long-term fate of the system, which may be sensitive to the initial population conditions. Natural systems also fluctuate in space and time, and so it is vital to consider whether long-term fates are stable to small changes. In this project, we observe that instability can give rise to a plethora of complex and intricate patterning behaviour for the mosquito populations, and this behaviour is heavily dependent on the physical parameters chosen to describe the system.

As a newcomer to the incredible world of mathematics, I look forward to another year of discovery and connection ahead.

Bringing Real Life to the Art of Mathematics

There is a traditional view that arts and sciences are adversaries, that you can be one or the other but not both. For Alexander Stokes, however, the two go hand in hand with mathematics his canvas. The University of Sydney and Vacation Research Scholarship student is currently completing dual Bachelors in mathematics and the arts, including courses in electroacoustic and computer music at the Sydney Conservatorium of Music.

With his earliest memories of maths linked to his now arts major, Japanese Studies, this enmeshing of arts and maths is nothing new.

"I began my formal education, including mathematics, in Japan. The language's mathematical and modular structure opened different ways of organising and sequencing ideas," Alexander recalls.

These early years fuelled a fascination with Japan that ultimately led him to mathematics and the discovery of its creative potential. Supervised by the University of Sydney's Professor Nalini Joshi AO, his Vacation Research Scholarship project focused on Integrable Systems and the algebraic and geometric properties that explain their strangely ordered behaviour.

"The more we can find out about the hidden structure behind such systems, the easier it will be for scientists to identify when they are dealing with one, such as in models of electrodiffusion or rogue open ocean waves," he explains.

As unpredictable as they are, dangerous, rogue, freak, episodic or killer, waves create perilous conditions for ocean traffic. Understanding how to identify when and how these may occur in modelling offers improved capacity to predict conditions and increase safety for large vessels such as cruise liners.

Alexander Stokes, **The University of Sydney**

It is this capacity to reformulate the scientific through insights and observation of the physical using the language, logic and rigour of maths that attracts Alexander to applied mathematics.

"We observe physical things then translate what we see into a model written in the language of mathematics. Applied mathematicians develop and analyse the problem and our observations to form conclusions about the system's initial state and evolution. There's a beautiful mathematical structure behind what we do and how."

For Alexander, the scholarship was a chance to taste the realities of this type of observation and research in a real-world context that requires problem solving, creativity and cross-discipline collaboration.

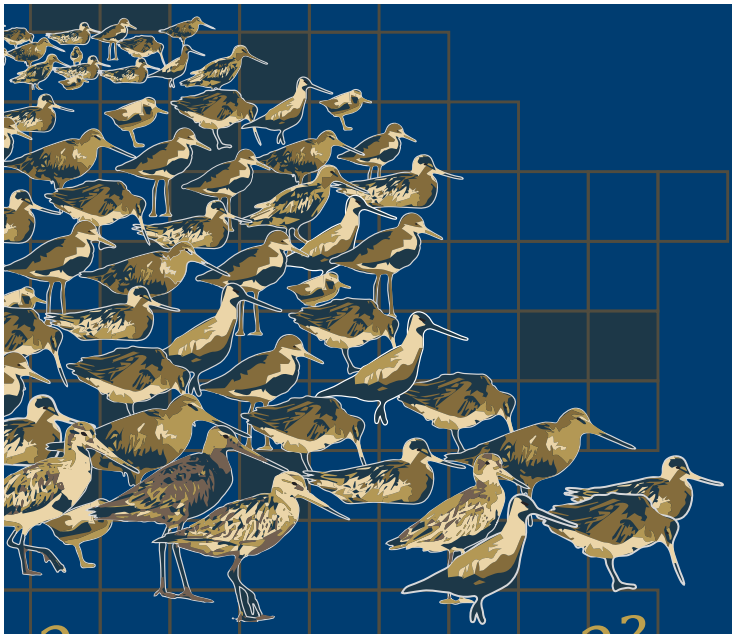
"Far from the stereotype of solitary scribbling and light bulb moments, this experience highlighted the critical need to be able to communicate your ideas and see what you do in wider perspectives both within and beyond your discipline," he reveals.

This is what makes the program such a powerful experience for mathematical sciences students.

"This is a fantastic program, not only does it provide a career development experience beneficial to future research and industry engagement, but it fosters essential ties and communication between the mathematical and general communities," says Alexander.

He also believes the Vacation Research Scholarship plays an important role in bridging the arts-science divide and opening creative engagement with maths to future generations of Australians.

"I don't think these worlds will always be so separate, and I think AMSI is doing a lot to accelerate that change to the benefit of academia and industry."



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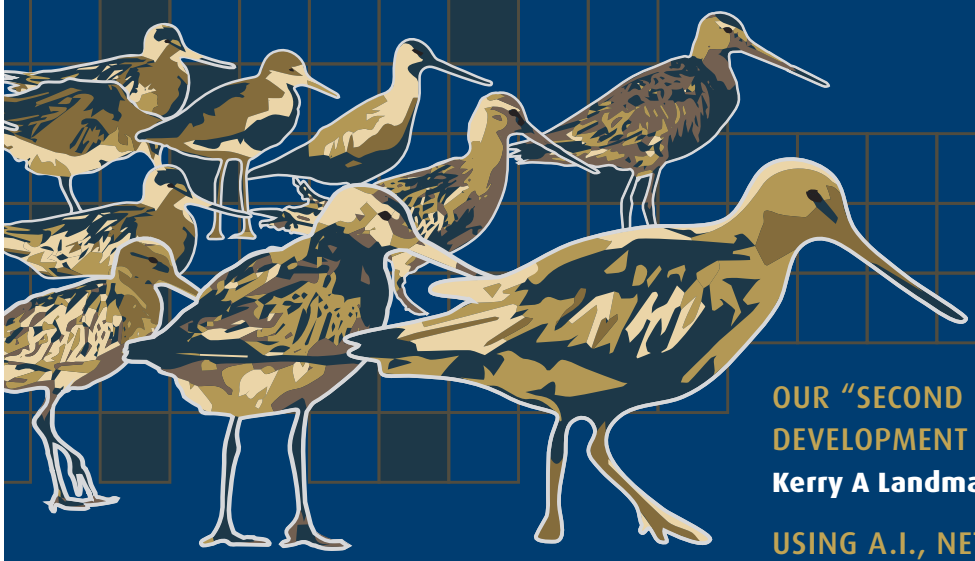

AMSI WINTER SCHOOL 16

ON BIOLOGICAL & ENVIRONMENTAL MODELLING

4-15 JULY | THE UNIVERSITY OF QUEENSLAND

In the twenty-first century, modelling is a crucial research tool for studying complex phenomena and processes.

Our impressive line-up of speakers will build your knowledge of models, algorithms, theoretical analysis tools and topical applications, from molecular biology through to ecosystems analysis.

FULL TRAVEL GRANTS AVAILABLE!

OUR "SECOND BRAIN": MODELLING ITS DEVELOPMENT & DISEASE

Kerry A Landman, The University of Melbourne

USING A.I., NETWORKS THEORY & BUTCHERS PAPERS TO CONSERVE SPECIES

Eve McDonald-Madden, The University of Queensland

THE MATHEMATICAL MODELLING OF CHEMOTAXIS

Graeme Pettet, Queensland University of Technology

MATHEMATICAL APPROACHES TO CONSERVATION BIOLOGY

Hugh Possingham, The University of Queensland

THE DYNAMICS OF CALCIUM: THE INTERACTION OF MODELLING & EXPERIMENTS

James Sneyd, The University of Auckland

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AMSI 16 BIOINFO SUMMER

28 NOV - 2 DEC

THE UNIVERSITY OF ADELAIDE

AMSI BIOINFOSUMMER introduces bioinformatics to students, researchers & professionals working in mathematics, statistics, IT, medical sciences, biological & chemical engineering

INTERNATIONAL SPEAKERS:

ORLY ALTER The University of Utah
SIMON ANDERS Institute for Molecular Medicine Finland
MINGYAO LI University of Pennsylvania
STEPHEN TURNER Pacific Biosciences
XIA YANG University of California, Los Angeles

THEMES:

INTRODUCTION TO BIOINFORMATICS
ANALYSIS OF HIGH DIMENSIONAL DATA
RNA SEQ EXPERIMENTAL DESIGN & ANALYSIS
USING LONG READ SEQUENCING FOR WHOLE GENOME ASSEMBLY
CODING FOR BIOINFORMATICS

IMAGE: OVERLAPS BETWEEN KNOWN BIOLOGICAL PROCESSES BY VILLE-PETTERI MÄKINEN, SAHMRI

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AMSI RESEARCH

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AMSI SUMMER SCHOOL 17

IN THE MATHEMATICAL SCIENCES

9 JAN – 3 FEB 2017

THE UNIVERSITY OF SYDNEY

CATEGORY THEORY & COMPUTER SCIENCE
Richard Garner & Dominic Verity, Macquarie University

COMPUTATIONAL BAYESIAN STATISTICS
Scott Sisson, The University of New South Wales

COMPUTATIONAL MATHEMATICS
Markus Hegland, The Australian National University

GEOMETRIC GROUP THEORY
Lawrence Reeves, The University of Melbourne
& Anne Thomas, The University of Sydney

HARMONIC ANALYSIS
Pierre Portal, The Australian National University

MATHEMATICAL BIOLOGY
Mary Myerscough, The University of Sydney

MATHS & STATS OF BIG DATA
Kerrie Mengersen, Queensland University of Technology

OPTIMISATION
Michelle Dunbar, The University of Sydney

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AMSI RESEARCH

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THE UNIVERSITY OF SYDNEY
Australian Government Department of Education and Training
Aust MS AUSTRALIAN MATHEMATICAL SOCIETY
ANZIAM
bhpbilliton Foundation

AMSI VACATION RESEARCH SCHOLARSHIPS

2016/17

APPLY FOR AN AMSI RESEARCH SCHOLARSHIP

Australian Government
Department of Education and Training

AMSI AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

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Australian Mathematical Sciences Institute

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